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Review article

Environmental, health, wellbeing, social and equity effects of urban green space interventions: A meta-narrative evidence synthesis

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ABSTRACT

Background: As populations become increasingly urbanised, the preservation of urban green space (UGS) becomes paramount. UGS is not just dedicated recreational space such as public parks, but other types of informal green space are important, for example, street trees and roof gardens. Despite the potential from cross-sectional evidence, we know little about how to design new, or improve or promote existing UGS for health, wellbeing, social and environmental benefits, or known influencing factors such as physical activity.
Objectives: To perform a meta-narrative review of the evidence regarding the health, wellbeing, social, environmental and equity effects, or known influencing factors of these outcomes, of UGS interventions.
Data sources: Eight electronic databases were searched ((Medline, PsycINFO, Web of Science (Science and Social Science Citation Indices), PADDI (Planning Architecture Design Database Ireland), Zetoc, Scopus, Greenfiles, SIGLE (System for Information on Grey Literature in Europe)), and reference lists of included studies and relevant reviews were hand searched for further relevant studies.
Study eligibility criteria, participants, and interventions: Eligibility criteria included: (i) evaluation of an UGS intervention; and (ii) health, wellbeing, social or environmental outcome(s), or known influencing factors of these outcomes, measured. Interventions involving any age group were included. Interventions must have involved: (a) physical change to green space in an urban-context including improvements to existing UGS or development of new UGS, or (b) combination of physical change to UGS supplemented by a specific UGS awareness, marketing or promotion programme to encourage use of UGS.
Study appraisal and synthesis methods: Following a meta-narrative approach, evidence was synthesised by main intervention approach, including: (i) park-based; (ii) greenways/trails; (iii) urban greening; (iv) large green built projects for environmental purposes. Outcomes such as economic (e.g. cost effectiveness and cost–benefit analyses), adverse effects and unintended consequences were also extracted. Evidence was synthesised following the RAMESES guidelines and publication standards, the PROGRESS-plus tool was used to explore equity impact, and risk of bias/study quality was assessed. The findings from the evidence review were presented at an expert panel

Abbreviations: AC, Anne Cleary; BMI, body mass index; CC, Claire Cleland; cRCTs, cluster randomized control trials; DIY, 'Do It Yourself'; IEEP, Institute for European Environmental Policy; MET, metabolic equivalent of task; NICE, The National Institute for Health and Care Excellence; NSW, New South Wales; PADDI, Planning Architecture Design Database Ireland; $PM_{2.5}$, particulate matter of < 2.5 μm diameter; PROGRESS-plus, Place of residence, Race/ethnicity, Occupation, Gender/sex, Religion, Education, Socioeconomic status, Social capital; RCTs, randomized control trials; RH, Ruth Hunter; SES, socio-economic status; SIGLE, System for Information on Grey Literature in Europe; SuDS, sustainable drainage systems; UGS, urban green space; UK, United Kingdom; UN, United Nations; USA, United States of America; WHO, World Health Organization

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representing various disciplines in a workshop and these discussions framed the findings of the review and provide recommendations that are relevant to policy, practice and research.

Results: Of the 6997 studies identified, 38 were included. There was strong evidence to support park-based (7/7 studies) and greenway/trail (3/3 studies) interventions employing a dual-approach (i.e. a physical change to the UGS and promotion/marketing programmes) particularly for park use and physical activity; strong evidence for the greening of vacant lots (4/4 studies) for health, wellbeing (e.g. reduction in stress) and social (e.g. reduction in crime, increased perceptions of safety) outcomes; strong evidence for the provision of urban street trees (3/4 studies) and green built interventions for storm water management (6/7 studies) for environmental outcomes (e.g. increased biodiversity, reduction in illegal dumping). Park-based or greenway/trail interventions that did not employ a dual-approach were largely ineffective (7/12 studies showed no significant intervention effect). Overall, the included studies have inherent biases owing to the largely non-randomized study designs employed. There was too little evidence to draw firm conclusions regarding the impact of UGS interventions on a range of equity indicators.

Limitations; conclusions and implications of key findings: UGS has an important role to play in creating a culture of health and wellbeing. Results from this study provide supportive evidence regarding the use of certain UGS interventions for health, social and environmental benefits. These findings should be interpreted in light of the heterogeneous nature of the evidence base, including diverging methods, target populations, settings and outcomes. We could draw little conclusions regarding the equity impact of UGS interventions. However, the true potential of UGS has not been realised as studies have typically under-evaluated UGS interventions by not taking account of the multifunctional nature of UGS. The findings have implications for policymakers, practitioners and researchers. For example, for policymakers the trajectory of evidence is generally towards a positive association between UGS and health, wellbeing, social and environmental outcomes, but any intervention must ensure that negative consequences of gentrification and unequal access are minimised.

1. Introduction

Globally, around two in three people are predicted to live in urban areas by 2050 (Revi et al., 2014). However, these levels of urbanisation are projected to increase social and health inequalities, with corresponding negative impacts on physical and mental health, wellbeing and social cohesion (Giles-Corti et al., 2016). Though health and wellbeing have complex social determinants, a central hypothesis is that benefits to health and wellbeing can be achieved through increasing physical activity and social interaction at the neighbourhood scale and by enhancing people's ability to participate in society. This may be achieved by improving the mobility and social networks of the population through designing better social and physical infrastructure, including increasing and enhancing the provision of urban green space (UGS) (WHO Regional Office for Europe, 2016 2017a, 2017b). Urban green space includes dedicated recreational space such as public parks, and other types of green space and vegetation, for example, street trees and green roofs. Therefore, provision and preservation of UGS in a rapidly urbanising global context is important for a range of health, wellbeing and social outcomes.

However, provision of adequate UGS is challenging due to housing, retail and commercial developments and transport infrastructure all competing for limited space. Furthermore, increasing storm water flows and pollution loads created by impervious surfaces from roofs, driveways, and sidewalks can create considerable environmental and health challenges, such as flooding, water pollution and high air temperature, as well as threatening the condition of existing green space. Nonetheless, there are opportunities to redesign UGS in order to improve liveability and sustainability, and an urgent need to address issues of loss and deterioration of UGS where populations are growing and the urban footprint expanding. Maintaining (and in many cases increasing) green space quantity and quality in the face of increasing urbanisation is therefore a pressing global challenge, recognised in the *UN Sustainable Development Goals* (n.d.).

Research examining the public health benefits of access to green space is extensive and persuasive (Kuo, 2015; Gascon et al., 2016; Twohig-Bennett and Jones, 2018). Physical, psychological, social, economic and environmental benefits are evidenced, although some reviews still report mixed findings and often low-quality evidence (Bedimo-Rung et al., 2005; Bowler et al., 2010a, 2010b; Lee and Maheswaran, 2010; Lachowycz and Jones, 2011; Bragg and Atkins, 2016; Husk et al., 2016; Song et al., 2016; Twohig-Bennett and Jones, 2018). For example, in the most recent systematic review and meta-analyses by Twohig-Bennett and Jones (2018) including 143 studies, there was statistically significant support for exposure to green space and health outcomes such as decreased heart rate (−2.57; 95% CI -4.30, −0.83), decreased risk of type II diabetes (0.72; 95% CI 0.61, 0.85), and all-cause mortality (0.69; 95% CI 0.55, 0.87). However, the conclusions must be interpreted with caution due to high levels of heterogeneity for some meta-analyses and a proportion of studies of poor quality. However, such benefits are not necessarily equitable across all in society. Some research suggests that the provision of UGS is associated with widening health and social inequalities (Cole et al., 2017), whereas other research suggests particular benefits for our most deprived populations (Mitchell and Popham, 2008; Maas et al., 2009a, 2009b; Mitchell et al., 2015; Twohig-Bennett and Jones, 2018). However, many of these arguments are based on observational evidence, and the impact of UGS interventions on equity is limited (Twohig-Bennett and Jones, 2018).

Many policymakers are advocating changes in the physical environment, including the provision of UGS, to support healthy populations (WHO Regional Office for Europe, 2006; Benton et al., 2016; Sallis et al., 2016; NICE, 2018; WHO Regional Office for Europe, 2018). However, despite a substantial body of cross-sectional evidence and the attention given to the importance of physical environments (WHO Regional Office for Europe, 2006; Sallis et al., 2016; NICE, 2018), the evidence for the effectiveness of creating supportive physical environments through intervention research, particularly UGS, is inconsistent and of modest quality (Hunter et al., 2015; Benton et al., 2016). In some places, UGS receive significant investment for delivery and management, particularly from local authorities and through new development. In others, constrained or reduced budgets for managing UGS limit opportunities for growth and improvement. Therefore, in the context of rapid urbanisation and limited public spending, there is a need to determine how to optimally intervene to provide adequate exposure to UGS for all of society to realise the evidenced health, wellbeing, social and environmental benefits.

Using UGS as an intervention for multiple health, social and environmental benefits offers many advantages. Unlike individual-level health promotion approaches, developing a supportive environment has the potential to achieve a greater reach by facilitating, population-wide improvements in health, and long-term effects. Consideration of wider social and environmental benefits alongside health promotes the 'multi-functionality' of UGS interventions with impacts in multiple domains, demonstrating value more comprehensively. Maes et al. (2015) and WHO Regional Office for Europe (2006) encouraged local authorities to increase and improve the provision of UGS and most cities now have green space, open space or green infrastructure strategies. However, there is little information about how to intervene to ensure adequate provision of, and exposure to, UGS that results in the greatest and most cost-effective benefits. A recent review by Hunter et al. (2015) suggested that there was promising evidence for UGS interventions that combined a change to the physical green space with a promotion/marketing programme for increasing park usage and physical activity levels. However, this review solely focused on physical activity behaviour, so there is a need to conduct a review to extend the current evidence base of UGS interventions for other health, social and environmental benefits in order to evidence the holistic nature of UGS interventions and make recommendations regarding future approaches. This is particularly important given the emphasis on multifunctional UGS – there is a need to demonstrate the range of impacts from similar interventions to make the case for investment and the consideration of single benefits can hamper this endeavour. Further, outcomes of health, wellbeing, social and environment are not independent but rather interact in a complex system. For example, the provision of urban street trees may impact positively on mental wellbeing and biodiversity measures yet increase air pollution levels due to reduced air circulation from canopy cover (Jin et al., 2014). Also, provision of lighting in UGS may increases perceptions of safety and increase usage of the space yet reduce biodiversity due to light pollution causing birds to migrate from the area. By focusing on a range of outcomes, this review will help us better understand the multifunctional nature of UGS. Therefore, the aims of this study were three-fold: 1) to review and synthesise the evidence on the environmental, health, wellbeing, social and equity effects of UGS interventions; 2) to discuss the findings at an expert review panel; 3) to develop recommendations on UGS interventions to policymakers, practitioners and researchers.

2. Methods

This work is based on a WHO report on UGS interventions (WHO Regional Office for Europe, 2017a). The purpose of this study is to describe the meta-narrative process used to incorporate the findings from the expert review panel and the development of recommendations for policymakers, practitioners and researchers from the evidence synthesis.

2.1. Review process and meta-narrative review rationale

Initially, a systematic review process was followed according to the PRISMA guidelines (Liberati et al., 2009). However, the varied nature of the literature in terms of the methods, target populations, settings and outcome measures meant that the systematic review process (and a meta-analysis) was quickly found to be inappropriate and would limit the conclusions drawn from the review. For this reason, a systematic review using a meta-narrative method, following the RAMESES guidelines (Wong et al., 2013), was adopted. This methodology enabled the differing conceptualisations, methodologies, outcomes and analyses to be synthesised (Wong et al., 2013).

2.2. Meta-narrative review principles

In this review process, the six guiding principles of the meta-narrative method were followed, namely: pragmatism, pluralism, historicity, contestation, reflexivity and peer review (Greenhalgh et al., 2005).

During the current review process, the six guiding principles of the meta-narrative method as first described by Greenhalgh et al., 2005 and presented by Wong et al., 2013 were followed and are presented below:

1) pragmatism: the review was guided by what the authors felt was the most useful information for the intended audience of urban green space researchers, practitioners and policymakers;
2) pluralism: the topic in question (i.e. environmental, health, wellbeing, social and equity effects of UGS interventions) were reviewed, taking into consideration multiple perspectives and viewpoints from a range of disciplines including urban planning, public health, built environment;
3) historicity: the literature was reviewed over a significant period of time in order to determine how the tradition was shaped (i.e. no date restriction was placed on the database searches, resulting in studies spanning a 14 year period from 2002 to 2016);
4) contestation: conflicting findings were considered in order to determine how the effectiveness of UGS interventions was viewed by UGS researchers, policymakers and practitioners;
5) reflexivity: when performing the review, each of the members of the review team took time to reflect on the findings, individually and as part of the review team;
6) peer review: findings were shown to an independent audience (WHO expert panel – see Section 2.8) and the feedback utilised to inform recommendations for researchers, policymakers and practitioners.

2.3. Scoping the literature

First, a scoping review of the literature was conducted through searches of academic and grey literature. Each member of the multidisciplinary research team had input into the literature review and provided documents for inclusion (Greenhalgh et al., 2005; Wong et al., 2013). This enabled the principle of pragmatism (principle one) and pluralism (principle two) to be implemented within the current review. The literature were searched iteratively, which further allowed different research disciplines and perspectives to be considered in the process and to take into consideration the forth guiding principle of the meta-narrative, contestation.

2.4. Search processes

Eight electronic databases were searched ((Medline, PsycINFO, Web of Science (Science and Social Science Citation Indices), PADDI (Planning Architecture Design Database Ireland), Zetoc, Scopus, Greenfiles, SIGLE (System for Information on Grey Literature in Europe)). The references lists from the resulting literature were examined by hand to identify additional studies using the 'forward and backward' citation tracking method. Keywords related to 'urban green space', 'intervention types' and 'study design' were used (Appendix A). To ensure a comprehensive search of the literature was performed and historicity (principle three of the six guiding principles of the meta-narrative method) was considered, no restrictions were placed on year of publication.

2.5. Selection and appraisal of documents

Three researchers (RH, CC and AC) with expertise in different disciplines (namely, public health, urban planning and built environment) independently screened titles, abstracts, and full texts for eligibility. This multidisciplinary approach ensured pluralism (principle two), with any disagreements regarding inclusion of studies being resolved through consensus. Percentage agreement and Cohen's Kappa were calculated for title/abstract and full text screening.

Studies were included if they met the following criteria:

(i). *Population:* No restrictions were placed on included studies by socio-demographic characteristics including age, gender, Socio-economic Position (SEP).

(ii).

Intervention: An UGS intervention to affect environmental conditions, promote/encourage health and wellbeing or tackle inequalities that involved: (a) physical change to green space in an urban-context including improvements to existing UGS or development of new UGS, or (b) a dual approach with both a physical change to UGS and a specific UGS awareness, marketing or promotion programme to encourage use of UGS. Interventions that solely involved an awareness or promotion program with no change to the physical environment were excluded. Appendix B provides further details.

(iii). *Outcomes:* The study must have included a measure related to a health, wellbeing, social or environmental outcome, or a known influencing factors of these outcomes (e.g. physical activity). Relevant environmental outcomes included measures of water quality and quantity, noise pollution, ambient temperature, temperature of buildings, air quality and biodiversity measures (e.g. abundance and diversity of bird species). Health outcomes included measures such as physiological changes (e.g. aerobic fitness, body mass index (BMI), blood pressure), number and types of injuries, and disease reduction in, for example, cardiovascular disease, cancers and diabetes. Factors known to influence health, such as physical activity and green space usage, were included. Wellbeing outcomes included mental health (e.g. levels of depression, stress, anxiety), and general wellbeing (e.g. levels of happiness, measures of mental wellbeing). Social outcomes such as social capital (or specific constructs of this multifactorial concept), social cohesion, perceptions of safety and the number of crimes were considered for inclusion.

(iv). *Study design:* Studies involving a control/comparator group or pre/post design or other relevant design that allowed identification of intervention impacts were included. For example, cluster randomized controlled trials (cRCTs), randomized controlled trials (RCTs), quasi-experimental designs that used a control group or population or exposure for comparison, interrupted time-series, and prospective controlled cohort studies were considered for inclusion.

(v). *English language and full text available:* Only those studies available in English language were included due to resource restrictions for translation. The full text version of articles must have been accessible to be included.

2.6. Data extraction

Key characteristics and outcomes of the studies were extracted and tabulated using a pre-piloted form by RH and cross-checked by CC. These characteristics included study design, country, population, description of intervention and control/comparator group, outcome measures, duration of follow-up and summary of study findings. Economic outcomes (e.g. cost effectiveness and cost-benefit analyses), adverse effects and unintended consequences were also extracted.

2.7. Analysis and synthesis

The methodological heterogeneity of the included studies meant that pooling data after extraction for meta-analyses was not appropriate. However, during the analysis and synthesis stage of the current meta-narrative method it was determined following analysis of the identified data, discussions within the research team and by comparing and contrasting how each member had conceptualised their study under the theme of 'urban green space interventions' that the best approach would be to synthesise the data across four differing meta-narratives. The four meta-narratives that were identified by the research team were categorised by the main intervention approach (see i-iv below). The research team felt that the intervention approach would not only provide the best method to synthesis the meta-narratives for review but by doing so, this would provide the most useful information for practitioners and policymakers. This is in keeping with the pragmatism principle of the meta-narrative approach. Intervention approaches included:

(i). Park-based: involved change to the physical environment of the park only, or employed a dual-approach combining a change to the physical environment with programming or marketing events in order to promote use of the park;

(ii). Greenways/trails: involved change to the physical environment, such as development of new greenways and walking/cycling trails, or the modification of existing greenways and trails, for example, through the addition of signage; or employed a dual-approach (as described in (i));

(iii). Urban greening: involved aesthetic-based interventions such as greening of vacant lots (typically involving removing rubbish, planting trees), provision of street trees;

(iv). Green built interventions, such as rain gardens, green roofs, primarily for environmental purposes such as storm water management or cooling urban/suburban areas.

Initially, both the analysis and synthesis stages were conducted by RH and CC, however, the other review co-authors provided their input based on their multi-disciplinary knowledge and experience in order to comment on, and to provide their input into the four chosen meta-narratives. Subsequently, the results for each study were presented under the four differing meta-narratives enabling interpretation of the findings and to provide insights of the effectiveness of each of the four intervention approaches. This provided the opportunity for the review team to ensure reflexivity (principle five), by taking time to reflect on the findings, individually and as part of the team. Studies were indicated as having a positive intervention effect if they showed a statistically significant positive effect in favour of the intervention at the $p < 0.05$ level.

The PROGRESS-plus tool was used to examine the equity effects of UGS interventions (O'Neill et al., 2014). This tool summarises a number of evidence-based determinants of health, including place of residence, race or ethnicity, occupation, gender, religion, education, social capital, socioeconomic status (SES), plus age, disability and sexual orientation. Appendix C details the working definitions of each of these factors. Studies were classified based on how they analysed PROGRESS-Plus factors including differential intervention effects, subgroup analyses, interaction analyses and demographic descriptors (see Appendix C for further information).

Risk of bias and study quality was assessed using a tool by Twohig-Bennett and Jones (2018) (see Appendix E), that has previously been adapted for interventions (Ogilvie et al., 2007; Hanson and Jones, 2015). No study was excluded due to a low quality score. Assessments of quality were initially made by the first reviewer (RH) and then all studies were cross-checked by either AC or CC for discrepancies. In line with the review by Twohig-Bennett and Jones (2018), a study scoring ≥ 9 was considered high quality.

2.8. Expert panel workshop

As part of the meta-narrative review method the sixth guiding principle is 'peer review'. The findings of the review were presented to an independent/external audience that provided feedback and further in-depth insights into the findings; allowing the reviewers to utilise the responses in a way that guided further reflection and interpretation of the review findings.

For that reason, the findings from the evidence review were presented to 28 experts from 12 countries (UK, Germany, The Netherlands, Norway, France, Spain, Sweden, US, Portugal, Australia, Italy, Estonia) representing research, policy and practice in a workshop (organised by MB). These peer-review discussions were used to frame and reflect upon the findings of the review and in addition, to provide recommendations

Table 1
Summary characteristics of park-based interventions.

	Study descriptor					Results		
Reference	Study design	Urban area	Population	Intervention	Control	Outcome	Follow-up (months)	Outcome measures
Interventions employing a dual-approach (i.e. a physical change to the physical environment and promotion/marketing programme) (n = 7)								
NSW Department of Health, 2002	Quasi-experiment: controlled, pre-post design	Urban area; Western Sydney, Australia	Residents aged 25–65 years living in Lachlan Macquarie ward (intervention group) and Caroline Chisholm ward (control group)	3 types of interventions in 3 parks: promoting PA and park use (via advertisements, walking maps), park modifications (signage, greening, improved paths, new playground) and the establishment of walking groups	2 parks similar in demographic profile of residents, climate, geography, surrounding features, proximity to major centres, transport and other services	+ve: Intervention group more likely to have walked in the 2 weeks prior to follow-up than control. Sig group by gender interaction indicated intervention males were 2.8 times more likely to walk than were males in the control ward	Baseline and at follow-up 12 months later	Telephone survey, direct observation and infra-red counter estimation: PA participation rates, proportion of people adequately active and use of local parks
Tester and Baker, 2009	Quasi-experiment: controlled, pre-post design	Urban area; San Francisco, California, USA	Resource poor neighbourhoods; primarily Latino, African-American and Asian; median household income $34–56,000	Major renovations to 2 parks: lighting, fencing, artificial turf, landscaping, picnic benches, goal posts, walkways	One control park which had similar socioeconomic and racial/ethnic demographics of nearby residents and its features	+ve: Sig increases of > 4-fold magnitude among children and adults of both genders at the intervention park playfields, but not in the control park; Sig park use in non-play fields	May-Jun 2006 and follow up in summer 2007	SOPARC 8 times per day during observation period
Cohen et al., 2013	RCT: parks randomized to 3 study arms (17 parks per study arm)	Urban area; Los Angeles, California, USA	Parks users and residents living within 1 mile radius of park	2 intervention groups: 1) Park Director only; 2) Park Advisory Board-Park Director Involved in all aspects of research and in using baseline results to design park-specific interventions to increase park use and PA; Park Directors received 5 training sessions from a marketing consultant. Each park received $4000 to spend on signage; promotional incentives; outreach and support for group activities	17 control parks: Parks randomized based on park size, number of facilities and programmes offered by the park and socio-demographic characteristics of the population within 1-mile radius	+ve: In both intervention parks, PA increased, generating an estimated average of 600 more visits/week/park, and 1830 more MET-hours of PA/week/park	Baseline (Apr 2008-Mar 2010) and in same season at follow-up (Apr 2010-Apr 2012)	SOPARC (4 times per day over 7 days) Primary outcome: change in number of park users and change in the level of park-based PA (MET-hours) Survey of random sample of residents living within 1 mile of park
Ward Thompson et al., 2013	Quasi-experiment: controlled, pre-post design	Urban and suburban areas; Glasgow, Scotland, United Kingdom	n = 215 high socioeconomic deprivation (within top 15%) and with woods/green space within 500 m of the community	Regeneration project: construction of improved footpaths; clearing rubbish and signs of vandalism; signage and entrance gateways; silvicultural work to improve appearance and safety of trees and vegetation (improve views and visibility); publicity and group activities to encourage knowledge of woodlands and opportunities for use	No environmental intervention within the green space	+ve: Quality of life sig increased in both neighbourhoods (more in intervention) over time and a sig difference in quality of the physical environment between sites in 2006 but not 2009. Sig differences in perceptions of safety ($p < 0.05$) in the intervention site over time, compared with no sig change in the control	Baseline (Nov 2006); follow up a minimum of 12 months post intervention (Nov 2009)	Questionnaire to assess differences in perceptions and behaviour relating to local neighbourhood, environment and woodlands. Environmental assessment to record environmental quality and change
King et al., 2015		Urban area; Denver, Colorado, USA	Residents of transitional housing (homeless and	Transformation of 2-acres of undeveloped green	No control	+ve: Sig increase in total number of people observed		SOPARC – 4 one-hour non-continuous observations

(continued on next page)

Table 1 (*continued*)

	Study descriptor					Results		
Reference	Study design	Urban area	Population	Intervention	Control	Outcome	Follow-up (months)	Outcome measures
	Quasi-experiment: pre-post design		refugees from Burma, Somalia, Afghanistan, Iraq, and Nepal)	space into a recreational park and community garden. The new park had clearly defined recreational spaces including a multipurpose playing field; playground equipment; basketball court; benches, a large community garden; a walking path alongside a creek		using the park post-intervention ($p = 0.004$); increase in proportion of users engaging in moderate ($p = 0.007$) or vigorous PA ($p = 0.04$). Post-intervention average monthly visitors sig increased ($p = 0.002$)	June–October 2010 and again June–October 2012	per day, on 4 days per month including at least 1 weekend day including non-park zones (i.e., adjacent streets, alleys and parking lots) and park zones
Cranney et al., 2016	Quasi-experiment: pre-post time series design	Suburban area; Eastern Sydney, Australia	Beachside suburb comprising relatively high socioeconomic status neighbourhoods, with some pockets of disadvantaged suburbs	Outdoor gym installed (60,000 Aus $), targeted marketing and promotional strategies to engage older adults and hosting exercise sessions by a professional. Park is 16.08 ha, picnic shelters, barbecues, drinking fountains, toilets and change facilities, a skate park and children's playground	No control	+ve: Small but sig increase in senior park users engaging in MVPA at follow-up (1.6 to 5.1%; $p < 0.001$); sig increases from baseline to follow-up in the outdoor gym area for MVPA (6 to 40%; $p < 0.001$); and seniors' use (1.4 to 6%; $p < 0.001$)	9 data collection periods: 3 at baseline, 3 immediately post-installation and 3 12 months follow up	SOPARC 4 days (2 weekdays and 2 weekend days) during the first week of each data collection period; 4 data collection shifts each day Interviews with park users > 18 years (demographics, PA, park use, outdoor gym use (post-installation)). Environmental audit at baseline and follow-up
Slater et al., 2016	Quasi-experimental: prospective, controlled, longitudinal design	Urban area; Chicago, Illinois, USA	Predominantly African American and Latino neighbourhoods; household income range US$12,333- US$121,541	Park renovations and community engagement (39 intervention parks) Renovations involved replacing old playground equipment and ground surfacing. Mean park size 3.86 square acres (range 0.09–40.48)	No renovations performed (39 matched control parks) in first instance but then by spring 2014 9 control parks were exposed to the intervention and renovated and were classified as intervention parks at follow up. Parks were matched on size, proximity, neighbourhood socioeconomic status, and race/ethnicity	+ve: Sig increases between baseline and 12-month follow-up for park utilization and the number of people engaged in MVPA; increase in park utilization over time in intervention parks compared with control	Baseline (Jul-Oct 2013) and follow up (Jul-Oct 2014)	SOPARC: At baseline 1 weekday and 1 weekend day; At follow up 2 weekdays and 1 weekend day; 4 scans per day Park incivilities; neighbourhood safety, weather, distance and park size
Interventions not employing a dual-approach (e.g. change to the physical environment only) ($n = 9$)								
Cohen et al., 2009a	Quasi-experiment: controlled, pre-post design	Urban area; Los Angeles, California, USA	Predominantly Latino and African-American and low-income neighbourhoods (mean 31% of households in poverty)	5 parks underwent major improvements including new/improved gyms, picnic areas, walking paths, playgrounds, watering and landscaping (cost: > $1 m each) Parks ranged from 3.4 to 16 acres (mean 8 acres) and served an average of 67,000 people within a 1-mile radius. Parks	Each intervention park had a matched control park ($n = 5$) of similar size, features, amenities and served a similar population that did not undergo any improvements	-ve: Overall park use and PA declined in both intervention and control parks	Baseline (Dec 2003-Nov 2004); follow-up (Apr 2006-Mar 2008) Follow up measures were initiated at least 3 months after construction (range 3–14 months post construction)	SOPARC: 4 time points over 7 days Intercept surveys Interviews with residents within 1–2 miles from each park: use of park and PA levels

(*continued on next page*)

Table 1 (*continued*)

	Study descriptor					Results		
Reference	Study design	Urban area	Population	Intervention	Control	Outcome	Follow-up (months)	Outcome measures
				contained multipurpose fields; playgrounds; gymnastics areas; and picnic and lawn areas				
Cohen et al., 2009b	Quasi-experiment: controlled, pre-post design	Urban area; Los Angeles, California, USA	Youths and seniors living within 2 mile radius of parks; 10.5% households in poverty; 21% residents aged > 60 years; 17.5% Hispanic	2 parks (48–67 acres) underwent renovations: (1) improvements to skate park surfaces only (cost $3.5 m) (2) improvements to entrance, courtyard areas and gymnasium of senior centre (cost $3.3 m)	Control skate park and control senior centre that did not have any improvements were chosen based on matching neighbourhood characteristics (demographics and economic distribution) and physical features (size and type of facilities)	+ve: 510% increase in skate park use compared to 77% in comparison skate park; substantially fewer users of senior centre	Baseline and follow-up 1–3 months following opening of renovated areas	SOPARC: 4 timepoints over 7 days Face to face interviews with park users and residents (age 18+) living within a 2-mile radius of park; perception of safety; park proximity
Quigg et al., 2011	Quasi-experiment: controlled, pre–post design	Urban area; Dunedin, New Zealand	*n* = 156 Children aged 5–10 years from the local community	Upgrade 2 community playgrounds: 1) playground had 10 new components installed, including play equipment, seating, additional safety surfacing, and waste facilities; 2) playground had 2 new play equipment pieces installed	Broadly similar community. Factors included: school decile, a socioeconomic indicator; size of school roll; number of primary schools in area; local authority's assigned and published play value of existing playgrounds; transportation routes; population characteristics; household income; household vehicle characteristics; potential control community location—physical separation from intervention community	-ve: No statistically sig difference in total daily PA compared with control	Oct-Dec 2007 and follow up was completed Oct–Dec 2008 (Spring in the Southern Hemisphere)	Actigraph accelerometer (primary outcome: mean total daily PA); BMI; questionnaire (child, family structure and neighbourhood scale)
Cohen et al., 2012	Quasi-experiment: controlled, pre-post design	Urban area; Los Angeles, California, USA	Residents within 1 mile radius of intervention parks (mean 29% of households in poverty, 59% Latino population)	12 parks involving installation of Family Fitness zones (outdoor gyms), 8 pieces of equipment at each park (average cost $45,000 for each park) Mean park size 14.4 acres (range, 1–29 acres); served an average of 40,964 individuals within 1-mile radius	10 matched control parks that did not install Family Fitness zones Mean park size 12.4 acres (range 0.5–46 acres); served an average of 33,226 individuals in a 1-mile radius	-ve: Non-sig increase in park usage (11% in intervention parks compared to control parks)	Baseline (winter of 2008–2009); 1st follow-up 1 year later during winter 2009–2010; 2nd follow-up a few months thereafter (Spring 2010)	SOPARC 3 times per day for 4 days Intercept survey: use of park, use of fitness equipment, perceptions of park, distance travelled to park
Veitch et al., 2012	Quasi-experiment: controlled, pre-post design	Urban area; Victoria, Australia	Most disadvantaged decile in state of Victoria	1 park (size 25,200 m^2): involving establishment of a fenced leash-free area for dogs (12,800m^2); an all-abilities playground; a 365 m walking track; BBQ area; landscaping; fencing to prevent motor vehicle access to the park	1 matched control park (size 10,000m^2) located in same neighbourhood as intervention park and having similar features at baseline	+ve: Sig. increase from pre to post-improvement in number of park users for intervention park (T1 = 235, T3 = 985) and number of people walking (T1 = 155, T3 = 369) and being vigorously active (T1 = 38, T3 = 257)	Baseline (Aug-Sept 2009), immediately following park improvement (Mar-Apr 2010) and 12 months after baseline (Aug-Sept 2010)	SOPARC: 7 times each day on 9 days (over 4 weeks)
Bohn-Goldhaum et al., 2013	Quasi-experiment: controlled, pre-post design	Urban area; Sydney, Australia	2–12 year olds and their parents or care givers; low socioeconomic neighbourhood	1 park underwent renovations: new children's play equipment, upgrading paths, adding new	Control park of a similar size and type which did not undergo any improvements	-ve: No sig. Difference between parks for usage or the number of children engaging in MVPA at	Baseline (May 2007) and follow up 9 months after the upgrade (May 2009)	SOPARC: 3 timepoints over 14 days Intercept surveys with park

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Table 1 (*continued*)

	Study descriptor					Results		
Reference	Study design	Urban area	Population	Intervention	Control	Outcome	Follow-up (months)	Outcome measures
				greenery, lighting and facilities (e.g., park furniture), green space was created by opening the adjacent sports field to public use		follow up. In the intervention park the number of girls engaging in MVPA significantly decreased (p = 0.04) between baseline and follow up		users who were accompanied with a child under 13 years (demographics, park usage & PA behaviour)
Cohen et al., 2014	Quasi-experiment: post data only	Urban areas; Los Angeles, California, USA	Residents living within 0.5 mile radius of parks 30–41% household poverty; minority populations (70–80% Latino, 3–17% African-American, 0–16% Asian)	Creation of 3 pocket parks (0.15–0.32 acres) from vacant lots and undesirable urban parcels; playground equipment and benches installed, walking path developed around the perimeter, all fenced and enclosed by lockable gates (average cost $1 m funded by local non-profit groups)	15 playground areas in neighbourhood parks (15–50 times larger than pocket parks) matched to each pocket park by % of households in poverty	-ve: Pocket parks were used as frequently or more often than playground areas in neighbourhood parks. However, they were vacant during the majority of observations	Baseline (Jul-Aug 2006) and follow-up (Jul-Aug 2008) and comparison parks in 2008–2009	SOPARC: 4 times per day over 7 days Surveyed park users and residents about park use Random sample of household addresses (n = 392 pre; n = 432 post) within 0.25 miles of pocket park and another between 0.25 and 0.5 miles of the park was selected, field staff went door to door to conduct the surveys (adults 18 + yrs)
Peschardt and Stigsdotter, 2014	Natural experiment: pre-post design	Urban area; Copenhagen, Denmark	52% male; 88% Danish; 21% < 10 years education; 10% > 65 years	A pocket park (932m^2) in a dense urban area was redesigned to increase seating areas and walking trails	No control	-ve: No sig change in number of park users but demographics of park users changed slightly with more men, people aged 15–29 and more educated people using the park	Baseline (Apr-Oct 2011) and after redesign (May-Aug 2012)	Questionnaires (before n = 48, after n = 45) and interviews (after n = 6) with park users collecting data on park use (reasons for visiting and frequency) and perceptions of redesign
Droomers et al., 2015; Gubbels et al., 2016;	Quasi-experiment: controlled, pre-post design	Urban areas; 24 most deprived neighbourhoods, Netherlands	Adolescents (12–15 years) and adults in severely deprived neighbourhoods Droomers et al. (2015): 48132 local residents Gubbels et al. (2016): n = 401 Adolescents (12–15 years) and n = 454 adults	Dutch District Approach (5 million euros): new public parks replacing vacant land (n = 9), refurbishing existing parks (n = 9), n = 6 improving paths, drainage, landscaping, planting flower bulbs in front yards; constructing wall gardens; greening streets, developing a greenway	Various control areas similar with regard to living circumstances, physical and social neighbourhood characteristics and safety	-ve: Droomers et al. (2015): Intervention areas did not show an increase in PA and general health compared to the different groups of control areas for adults Gubbels: Leisure time walking (decrease 89.2 mins per week) and cycling (decrease 62.7 min per week) significantly decreased and depressive symptoms significantly increased in adolescents	Repeated cross-sectional data collected 2004–2011 as part of the Dutch National Health Interview Survey and other publicly available data	Droomers et al. (2015): PA (SQUASH questionnaire); single item self-reported general health Gubbels et al. (2016): perceived greenery (NEWS); PA (SQUASH); depressive symptoms (CES-D); perceptions of greenery improvement and use

BMI = Body mass index; CES-D: Centre for Epidemiologic Studies Depression Scale; MET = Metabolic Equivalent of Task (a physiological measure expressing the energy cost of physical activities and is defined as the ratio of metabolic rate during a specific physical activity to a reference metabolic rate); MVPA = Moderate-vigorous physical activity; NEWS: Neighbourhood Environment Walkability Survey; PA = physical activity; RCT = Randomized Control Trial; SOPARC = Systems for Observing Play and Recreation in Communities; SQUASH: The Short Questionnaire to Assess Health; USA = United States of America; +ve = positive intervention effect (statistically significant); −ve = no intervention effect.

Table 2
Summary characteristics of greenway and trial interventions.

	Study descriptor					Results		
Reference	Study design	Country	Population	Intervention	Control	Outcome	Follow-up (months)	Outcome measures
Interventions employing a dual-approach (i.e. involving a physical change to greenway/trail and promotion/marketing programme) (n = 3)								
Fitzhugh et al., 2010	Quasi-experiment: controlled, pre-post design	Urban area; Tennessee, USA	Children, adolescents and adults in neighbourhood (10.9% elderly (aged ≥65 years); 17.7% ethnic minority; 32.2% living in poverty)	Retrofit of an urban greenway (2.9 miles long; 8-ft wide) to enhance connectivity of pedestrian infrastructure with nearby retail establishments and schools (cost: $2.1 m)	2 control neighbourhoods with similar socioeconomic dimensions	+ve: Pre and post intervention changes between experimental and control neighbourhoods were sig different for total PA ($p = 0.001$); walking ($p = 0.001$) and cycling ($p = 0.038$). There was no sig change over time for active transport to school	Baseline (Mar 2005) and follow-up (Mar 2007) 14 months after construction was completed	Pedestrian count surveys at school and neighbourhood areas (2 h on 2 days) for 1-week at baseline and follow-up
Brand et al., 2014; Sahlqvist et al., 2013; Bird et al., 2014; Goodman et al., 2014	Quasi-experimental, longitudinal design	Urban and Suburban areas; Cardiff (Wales), Kenilworth and Southampton (England), United Kingdom	n = 1796 adults living within 5 km of the core Connect2 infrastructure	Building or improvement of walking and cycling routes across the United Kingdom including a traffic-free bridge over Cardiff Bay; a traffic-free bridge over a busy trunk road; an informal riverside footpath turned into a boardwalk	Pre-specified intervention exposure to the interventions sites with less exposed people living farther away and acting as a comparison group for the more exposed people living closer to intervention sites	+ve: Proximity to Connect2 infrastructure associated with greater use of Connect2 infrastructure; 32% reported using Connect2 infrastructure at 1 year and 38% at 2 years; at 2 years, those nearer the intervention displayed sig increased walking and cycling (15.3 mins/week/km) and total PA (12.5 mins/week/km)	Baseline surveys (Apr 2010); 1 and 2 year follow-up surveys (Apr 2011; Apr 2012)	Baseline survey: demographic, socioeconomic and health characteristics Follow-up surveys: use of Connect2 project, walking or cycling on Connect2 infrastructure for recreation, health, or fitness; past-week walking and cycling for transport; past week recreational PA using adapted short version of IPAQ
Clark et al., 2014	Quasi-experiment: controlled, pre-post design	Urban area; Southern Nevada, USA	2 of the trails (commuter trails) were in lower SES neighbourhoods	6 intervention trails: after a marketing campaign promoting PA and trail use (2012), signage was added/altered including: distance markings, way-finding signs, trail maps, trail names, and icons for acceptable uses	Comparison trails matched on length, trail environment, amenities, and neighbourhood demographics as closely as possible Mean length of trails 3.96 miles (range 0.9–8.7 miles); 70% were lit; 70% had landscaping	+ve: Sig increases for both control and intervention, pre–post for trail usage per day; 31% increase for the control trails and 35% for the intervention trails ($p < 0.01$); non-sig difference between the intervention and control group ($p = 0.32$)	Baseline (Fall 2011), mid-intervention (Spring 2012), post-intervention (Fall 2012)	Infrared sensors on each trail access point (hourly totals)
Interventions not employing a dual-approach (e.g. a marketing programme with no change to the physical environment) (n = 3)								
Evenson et al., 2005	Quasi-experimental: pre-post design	Urban area; North Carolina, USA	Adults aged > 18 years living within 2 miles of the trail; approx. 66% females; 33% non-Hispanic black	A railway was converted to a multiuse trail Trail 2.8 miles (of 23 mile trail; trail passed by 2 schools, shopping areas, apartment buildings and neighbourhoods)	No control	-ve: Those who had never used the trail had sig declines in median time spent in MVPA, vigorous PA and bicycling for transport. Those who had used the trail also had sig declines in median time spent in vigorous PA	Baseline (Jul 2000-Apr 2001) and follow up (Nov 2002)	Telephone survey: BRFSS (leisure activity, walking and bicycling, MVPA); transportation activity; trail use; trail and neighbourhood characteristics; neighbourhood safety; general health; BMI
Burbidge and Goulias, 2009	Quasi-experiment:	Suburban area; Utah, USA	*N* = 290 households/796 individuals residing near the new trail	Construction of a trail (2-way multiuse trail separated from existing roads and sidewalks)	No control	-ve: Negative sig effect on PA and walking between baseline and follow-up;	Baseline survey (Oct 2007); 3 activity diaries (Feb 2007 prior to	Household Survey (demographics, lifestyle and travel preferences); 3

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Table 2 (*continued*)

	Study descriptor					Results		
Reference	Study design	Country	Population	Intervention	Control	Outcome	Follow-up (months)	Outcome measures
	longitudinal design			for both transportation and recreation. The trail created a 2.5 mile loop connecting two currently existing sidewalks		18–64 years olds sig increased number of PA bouts between baseline and follow-up ($p = 0.024$)	construction; Oct 2007 immediately after construction; Feb 2008 5 months after construction)	activity diaries (activity type, timing, duration, interpersonal interactions, travel and travel distance)
West and Shores, 2011	Quasi-experiment: controlled, pre-post design	Urban area; North Carolina, USA	$n = 597$ residents living within 0.5 mile radius of greenway	5 miles of greenway developed and added to existing greenway along a river	$n = 591$ randomly selected households living 0.5–1 mile radius from greenway	-ve: No sig difference between intervention and control group	Baseline and follow-up (conducted 11 months after the opening of the greenway)	Household survey included self-report question of PA levels

BMI = Body mass index; BRFSS = Behavioral Risk Factor Surveillance System; IPAQ = International Physical Activity Questionnaire; mins = minutes; MVPA = Moderate-vigorous physical activity; PA = physical activity; SOPARC = Systems for Observing Play and Recreation in Communities; USA = United States of America; +ve = positive intervention effect (statistically significant); −ve = no intervention effect.

that are relevant to policymakers and practitioners.

3. Results

Initially, 6997 studies were identified through the database search, 224 full-text articles screened, and 38 studies included in the evidence review (Appendix D). Percentage agreement between researchers (89.2%) and inter-rater agreement for title/abstract and full-text screening (Cohen's Kappa = 0.81) was good.

Physical UGS interventions are often complex and multi-faceted with four intervention approaches emerging from the review, namely: 1) Park-based; 2) Greenways/trails; 3) Greening; and 4) Green built features. Tables 1–4 present a summary of the key characteristics and findings of the studies for each intervention approach. Of the 38 studies, sixteen were park-based interventions, six involved the development or improvement of urban greenways or walking/cycling trails, eight focussed on urban greening, and seven involved built green features (e.g. rain gardens, green roofs) for storm water management with a further study examining the effects of green roofs for cooling a sub-urban area. No studies investigating green wall-based interventions met the pre-defined eligibility criteria.

The majority of the studies were natural experiments employing a quasi-experiment, controlled pre-post design ($n = 21$), uncontrolled pre-post design ($n = 6$) or controlled post-design ($n = 8$). Studies were mainly implemented in high-income countries including the United States of America (USA) ($n = 22$), Australia ($n = 4$), and the United Kingdom (UK) ($n = 3$). Due to the limited number of follow-up periods, it was not possible to provide a rigorous assessment of the longer-term effectiveness of UGS interventions much beyond 12 months. Of the limited number of studies that did include follow-up periods beyond 12 months, there was a trend towards positive benefits (e.g. Goodman et al., 2014 showed positive outcomes at 2 years).

3.1. Evidence synthesis

Overall, 68% (26/38) of studies found a significant positive intervention effect to support the provision of UGS interventions for health, wellbeing, social and environmental effects. Quality appraisal (described in 3.1.5) indicated that studies were generally of moderate to good quality, although half of the studies scored ≤7 out of 11.

3.1.1. Park-based interventions (Table 1)

All studies of park-based interventions (7/7 studies) that used a dual approach (i.e. physical change to UGS and promotion/marketing programmes) showed a significant intervention effect. These findings were particularly evident for health benefits delivered through increasing park use and physical activity behaviour.

Five of these seven studies showed a significantly positive post-intervention effect for increasing park usage and physical activity following: major improvements to the playing fields of public parks (Tester and Baker, 2009); provision of signage (Cohen et al., 2013); development of a new recreational park and community garden from undeveloped existing green space (King et al., 2015); replacement of old playground equipment and ground surfacing (Slater et al., 2016); and installation of an outdoor gym (Cranney et al., 2016). A further study showed a positive intervention effect for increasing physical activity following provision of signage (NSW Department of Health, 2002). The final study reported positive effects for increasing park usage, quality of life and the perception of safety following improved footpaths and clearing of rubbish and vandalism (Ward Thompson et al., 2013). Promotional programmes/events included training and skills development for park staff (Tester and Baker, 2009), publicity and organization of group activities to encourage use (Ward Thompson et al., 2013), and extensive community engagement activities to encourage and promote park usage (Slater et al., 2016), advertisements, walking maps, and the establishment of walking groups (NSW

Table 3
Summary characteristics of urban greening interventions.

	Study descriptor					Results		
Reference	Study design	Country	Population	Intervention	Control	Outcome	Follow-up (months)	Outcome measures
Greening of vacant lots (n = 4)								
Branas et al., 2011	Quasi-experiment: difference-in-difference design	Urban area; Philadelphia, Pennsylvania, USA	Cohort of 50,000 Philadelphians from household survey	Greening of vacant urban sites (n = 4436); (> 725,000 m^2) from 1999 to 2008 involving removing trash and debris, grading the land, planting grass and trees, installing low wooden fences around perimeter	Matched control vacant lots (n = 13,300) randomly selected and matched to intervention lots at 3:1 ratio	+ ve: Greening associated with reductions in gun assaults ($p < 0.001$), vandalism ($p < 0.001$), residents reported less stress and more exercise ($p < 0.01$)	Household Health Survey (every 2 years to a new cohort of 50,000 Philadelphians) using waves 1998–2008	Self-report questions of PA levels, stress, and number of crimes/arrests
Garvin et al., 2013	Pilot RCT: difference-in-difference analytical approach	Urban area; Philadelphia, Pennsylvania, USA	People living in the approx. 2 blocks surrounding the randomly selected vacant lots; 97% African-American; median income $15,417-$17, 743	Greening of vacant lots included removing debris, grading the land and adding topsoil, planting grass and trees, building a wooden fence	No greening intervention (4500–5500 square feet of vacant lots identified as intervention of control sites; 50 index sites in total)	+ ve: Non-sig decrease in the number of total crimes and gun assaults around greened vacant lots compared with control; people around the intervention lots reported feeling sig safer after greening compared with control lots ($p < 0.01$)	Baseline (n = 29 resident interviews) and 3-month (n = 21 resident interviews) follow-up	Police reported-crime: within half mile buffer of vacant lots for 3.5 months before and 3.5 months after the intervention; self-reported neighbourhood disorder (physical and social)
Anderson et al., 2014	Quasi-experimental, controlled (post data only)	Urban area; Cape Town, South Africa	Spectrum of socioeconomic neighbourhoods, ranging from middle to lower income areas	Civic-led greening interventions implemented via 3 sites	3 control sites: one vacant lot and two conservation sites	+ ve: biodiversity in the greening intervention sites was higher than the vacant lot and comparable to the conservation sites	No baseline monitoring; monitoring completed post-project completion	Flora and fauna biotic measures
South et al., 2015	Quasi-experimental, controlled, pre and post	Urban area; Philadelphia, Pennsylvania, USA	n = 12 participants completed pre- and post-intervention walks; all were African-American, 8 male; majority had household income < S15, 000	Randomly selected cluster of vacant lots received standard greening treatment involving cleaning and removing debris, planting grass and trees, and installing a low wooden post-and-rail fence	Randomly selected cluster of vacant lots did not receive the greening treatment	+ ve: difference-in-difference estimates between greened and non-greened vacant lots was sig lower for heart rate ($p < 0.001$) for the greened site; being in view of a greened vacant lot decreased heart rate sig more than a non-greened vacant lot	Baseline 3 months pre intervention; follow-up 3 months post intervention	During each walk the participants' heart rate was continuously measured
Provision of trees in urban streets (n = 4)								
Strohbach et al., 2013	Quasi-experimental, controlled (post data only)	Urban area; Boston, Massachusetts, USA	Low SES areas; 617,594 inhabitants; tree canopy covers 29% of the city area	12 community driven greening projects in low SES areas including creation of a small park (424 m^2),tree plantings in an existing park (4377 m^2) and tree plantings at residential houses (859 m^2)	Randomly selected urban sites	+ ve: sig difference between greening projects and random urban sites (p = 0.049); most greening projects had more species than the random urban sites in their vicinity	No baseline data, bird counts during early and late June 2010 and 2011	Abundance and diversity of bird species
Jin et al., 2014	Quasi-experimental, controlled (post data only)	Urban area; Shanghai, China	Area of 6340.5 km^2, 23.5 million population	Street trees 6 streets (length 205-223 m; width 15.2–17.5 m) were treated with different pruning intensities (strong, weak and null) which would result in different canopy	Each of the sampling streets were paired with nearby street segment controls which had similar features but contained no trees (2	-ve: Increased street tree canopy was positively associated with $PM_{2.5}$ concentrations owing to reduced air circulation	No baseline data, monitoring once every four months (i.e. every season)	$PM_{2.5}$ data

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Table 3 (*continued*)

Reference	Study descriptor: Study design	Country	Population	Intervention	Control	Results: Outcome	Follow-up (months)	Outcome measures
				coverage across the four seasons	streets: length 160-165 m; width 15.5-17 m)			
Ward Thompson et al., 2014	Quasi-experiment: controlled, pre-post design	Urban areas; England, Scotland and Wales, United Kingdom	Mean age 75 years; 44% male; 22.5% non-white British	*n* = 56 residents pre and n = 29 post intervention 'DIY Streets': 9 intervention streets located in urban areas in United Kingdom. Streets were made safer, more attractive and traffic calming measures were added	Each intervention street was paired with a comparison street that had no intervention *n* = 40 residents pre and *n* = 32 post intervention	+ve: sig positive perceptions of intervention streets post-intervention ($p = 0.04$); longitudinal participants perceived they were sig more active post-intervention ($p = 0.04$) than the control group	Baseline (May-Sept 2008); and 2 years later between 3 and 6 months post-intervention	Surveys (cross-sectional with a longitudinal subset) including measures of general health, quality of life, activity levels, frequency, type and location of activity
Joo and Kwon, 2015	Quasi-experimental, controlled (post data only)	Urban area; Suwon, South Korea	City population 1.2 m	City council installed street greenery (e.g. planter boxes) at 74 sites located in low-rise residential areas	74 non-street greenery sites in low-rise residential areas which are vulnerable to illegal dumping of household garbage	+ve: Illegal dumping of household garbage occurred at 55.4% of sites with installed greenery compared to 91.9% of sites without greenery installed ($p < 0.001$)	No baseline data, one off site visits prior to weekly collection of illegal dumping	Presence of garbage-filled bags generated from the individual household at monitoring sites

NEWS = Neighbourhood Environment Walkability Survey; PM = Particulate Matter; SES = Socioeconomic status; SQUASH = Short Questionnaire to Assess Health; USA = United States of America; +ve = positive intervention effect (statistically significant); −ve = no intervention effect.

Department of Health, 2002). In one study, the social activities were particularly focussed on engaging older adults through hosting exercise sessions and targeted marketing and promotional strategies (Cranney et al., 2016). One study included a broad range of soft measures including $4000 to spend on park programs which included signage (e.g., banners, walking path signs), promotional incentives (e.g., water bottles, park-branded key chains, individually targeted e-mails), and outreach activities (e.g., hiring community engagement officers, buying activity materials) (Cohen et al., 2013).

In contrast, where park-based interventions only involved a physical change to the green space 22% (2/9 studies) of studies showed a significant intervention effect for increases in physical activity, park usage and perceptions of safety. These two studies involved improvements to a skate park and green space surrounding a centre for older adults (Cohen et al., 2009b) and major improvements to a park involving a fenced dog area, playground, walking track, landscaping and fencing (Veitch et al., 2012).

Seven studies showed no significant positive impact on physical activity, park usage or general health for UGS interventions involving change to the physical environment only (Cohen et al., 2009a; Quigg et al., 2011; Cohen et al., 2012; Bohn-Goldhaum et al., 2013; Cohen et al., 2014; Peschardt and Stigsdotter, 2014; Droomers et al., 2015; Gubbels et al., 2016). Indeed, one study found that park use and physical activity decreased in parks following major improvements that included new/improved outdoor gyms, picnic areas, walking paths, playgrounds, watering and landscaping (Cohen et al., 2009a). There was no evidence to support the provision of pocket parks for increased usage and physical activity (Cohen et al., 2014; Peschardt and Stigsdotter, 2014). Further, the URBAN 40 study reported no impact on physical activity and general health following a suite of park-based and greening interventions (costing EUR 5 million) in 24 severely deprived neighbourhoods in the Netherlands compared to control areas (Droomers et al., 2015). In a subset of these neighbourhoods, an additional cohort study also found no significant health-related improvements in the same individuals before and after the interventions with two exceptions (Gubbels et al., 2016). Here, the greening interventions were associated with a small decline in leisure time cycling in adolescents, and improvements in perceived greenery were related to a decrease in depressive symptoms in adults. The interventions were wide ranging and included new public parks, wall gardens, street planting and a greenway, as well as improvements to paths, drainage, planting and maintenance in existing parks. Quigg et al. (2011) also reported no change in physical activity levels in children aged 5 to 10 years following the installation of new play equipment and seating in a park. Finally, Cohen et al. (2012) found that although park usage increased by 11% compared to control parks following the installation of outdoor gyms in 12 parks, this was not statistically significant.

3.1.2. Greenways and trails (Table 2)

All studies of greenways and trails (3/3 studies) that employed a dual approach (i.e. combined a change to the physical environment of a greenway or trail with promotion/marketing programmes) showed a significant intervention effect.

Two studies reported a significant positive intervention effect on total physical activity, walking and cycling (Fitzhugh et al., 2010; Sahlqvist et al., 2013; Brand et al., 2014; Goodman et al., 2014). One investigated the impact of an urban greenway trail designed to enhance connectivity of pedestrian infrastructure with nearby retail establishments and schools and showed significant changes between the intervention and control neighbourhoods (Fitzhugh et al., 2010). Similarly, a large multisite natural experiment in the UK (*n* = 1796 participants) found that proximity to new walking and cycling routes was strongly associated with greater use; 32% and 38% of the study population reported using the new infrastructure at one and two year follow-ups respectively (Sahlqvist et al., 2013; Brand et al., 2014; Goodman et al., 2014). Proximity was also associated with a comparable increase in

Table 4
Summary characteristics of green built interventions for storm water management and urban cooling.

	Study descriptor				Results		
Reference	Study design	Country	Intervention	Control	Outcome	Follow-up (months)	Outcome measures
Green built interventions for storm water management (n = 7)							
van Seters et al., 2009	Quasi-experiment, controlled (post data only)	Urban area; Toronto, Canada	A 241 m^2 green roof vegetated with wildflowers installed on a multi-story, university building	A 131 m^2 shingled, modified bitumen roof	+ve: the green roof retained 63% more rainfall than the conventional roof over the 18 month monitoring period	No baseline data, green roof installed in 2002; monitoring from May 2003-Aug 2005	Precipitation, flow, water quality, soil moisture, relative humidity, air temperature, and the temperature of the growing medium as well as water quality parameters (total suspended solids, alkalinity, phosphorus and nitrogen compounds, metals, bacteria)
Carpenter and Kaluvakolanu, 2011	Quasi-experiment, controlled (post data only)	Urban area; Michigan, USA	Extensive green roof of 10.16 cm depth applied to the roof of a building on a university campus; a green roof section of 325.2 m^2 and 929 m^2 were monitored	2 control sites; a stone-ballasted roof with an area of 84.7 m^2 and an asphalt roof with an area of 153m^2	+ve: sig higher total solids concentration ($p = 0.045$) for the green roof than the asphalt roof; lower total phosphate concentrations for the green roof (non-sig); green roof retained 68% of rainfall volume and reduced peak discharge by an average of 89%	No baseline data; 6 month follow-up post-installation (Apr 2008-Sep 2008)	Rainfall, runoff retention, peak discharge attenuation, and water-quality parameters including total phosphate, nitrate and total solids
Mayer et al., 2012	Before-after-control-intervention (BACI) experimental design	Suburban area; Ohio, USA	Retro-fit storm water management: Installation of 83 rain gardens and 176 rain barrels onto > 30% of the 350 eligible residential properties through an incentivised auction (2007–2008)	No control	+ve: intervention had an overall small but sig effect of decreasing storm water quantity at the sub watershed scale	3 years before and after treatment implementation	Monitored hydrologic and ecological variables: discharge (spring 2011); water quality (monthly base-flow and opportunistic storm-flow sampling spring 2010); aquatic biota (stream macroinvertebrate and periphyton sampling every 6 weeks, Apr-Oct 2010); dissolved oxygen, water temperature, and photosynthetically active radiation; air-water gas exchange rate (from 2007)
Fassman et al., 2012	Quasi-experiment, controlled (post data only)	Urban area; Auckland, New Zealand	A 500 m^2 extensive green roof installed on a council civic centre	An adjacent bitumen roof on a building that was one story higher	+ve: 57% retention of rain water in comparison to control	No baseline data; post installation monitoring for 8 months (Aug 2010–Mar 2011)	Rainfall and runoff water quality parameters including Total Suspended Solids, Total Dissolved Solids, Nitrate and Nitrite Nitrogen, Total Kjeldahl Nitrogen, Soluble Reactive Phosphorus and Total Phosphorus, dissolved and total Zinc, dissolved and total Copper
Shuster and Rhea, 2013; Roy et al., 2014	Before–after–control–intervention (BACI) experimental design	Suburban area; Ohio, USA	Retro-fit storm water management: Installation of 81 rain gardens and 165 rain barrels onto 30% of properties through an incentivised auction (2007–2008) at 4 experimental subcatchments	Two control subcatchments	-ve: No sig difference between control and experimental sites with regards to stream water quality, periphyton, and macroinvertebrate metrics +ve: Small sig decrease in runoff volume in treatment subcatchments	Sites were sampled 5 times per year from 2003 through 2010 (3 years before and after treatment implementation)	Monthly baseflow water quality, and seasonal (5× per year) physical habitat, periphyton assemblages, and macroinvertebrate assemblages in the streams

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Table 4 (*continued*)

	Study descriptor				Results		
Reference	Study design	Country	Intervention	Control	Outcome	Follow-up (months)	Outcome measures
Kondo et al., 2015	Quasi-experiment: difference-in-difference design	Urban areas; Philadelphia, Pennsylvania, USA	Installation of green storm water infrastructure at 52 sites: 152 tree trenches, 46 infiltration or storage trenches, 43 rain gardens, 29 pervious pavement installments, 20 bumpouts, 14 bio-swales, 5 storm water basins, 1 wetland, and 12 other	Matched control sites where no construction took place	+ve: Sig reductions in narcotics possession (18%–27% less) ($p < 0.01$), ($p < 0.01$) at varying distances from treatment sites; sig reductions in narcotics manufacture and burglaries; non-sig reductions in homicides, assaults, thefts, public drunkenness, stress levels, blood pressure and cholesterol	Before (2000) and up to 4 years after installation (2012)	GPS coordinates for 14 classes of crimes, self-reported blood cholesterol, blood pressure, and stress data via household survey
Jarden et al., 2016	Before–after–control–intervention (BACI) experimental design	Suburban area; Ohio, USA	Installation of 91 rain gardens, street-connected bio-retention cells and rain barrels at 2 treatment streets. Rain gardens (< 25 m^2) were installed in front yards and backyards; bio-retention cells (~26–44 m^2) were installed between the sidewalk and street	Each treatment street had a matched control street (n = 4) of similar size, drainage area and characteristics	+ve: Reduction in storm water flow at the treatment streets with reductions of up to 33% of peak discharge and 40% of total run-off volume	Baseline (Aug-Nov 2012), Phase 1 follow up (Jun-Nov 2013), Phase 2 follow up (Apr- Oct 2014)	Number, duration and precipitation of storm events, peak discharges, and total runoff generated
Green built interventions for cooling urban/suburban areas (n = 1)							
Peng and Jim, 2015	Quasi-experiment, controlled, pre and post design	Suburban area; Hong Kong, China	A 484 m^2 extensive green roof was retrofitted on a 2-story railway station	Nearby original bare roof control plot with an area of 106 m^2	+ve: green roof displayed cooling effects in spring, summer, and fall, with slight warming effects in winter	Baseline (Jun 2008-May 2009); green roof installed in Jul 2009; follow up (Aug 2009-Sep 2011)	Thermal-performance indicators including temperature at 10 cm and 160 cm level, relative humidity at 10 cm and 160 cm level, and surface temperature at the vegetation surface and concrete tile

BACI = Before-after-control-intervention; GPS = Global Positioning System; USA = United States of America; +ve = positive intervention effect (statistically significant); −ve = no intervention effect.

total physical activity; effect of 12.5 min per week per km closer to the intervention. However, further analyses showed that the intervention was not associated with any reduction in CO_2 emissions (Brand et al., 2014). A study in the USA (Clark et al., 2014) found a significantly positive intervention effect for trail usage following a marketing campaign and addition of signage.

In contrast, all studies (3/3 studies) that only involved a change to the physical environment of the greenway or trail with no promotion or marketing, reported no significant intervention effect on usage or physical activity. These interventions were all in the USA and included a new 2.8 mile (approx. 4.5 km) multiuse trail (Evenson et al., 2005), a 2.5 mile (approx. 4 km) multiuse trail in a loop (Burbidge and Goulias, 2009) and a five miles (approx. 8 km) addition to an existing greenway along a river (West and Shores, 2011).

3.1.3. Urban greening interventions (Table 3)

All studies (4/4 studies) showed a significant intervention effect to support the greening of vacant lots for improved physiological, psychological, safety and biodiversity.

Three studies examined the effect of greening vacant lots in the USA (Branas et al., 2011; Garvin et al., 2013; South et al., 2015) and one in South Africa (Anderson et al., 2014). One study, conducted over 10 years, using a difference-in-difference design found statistically significant reductions in gun assaults and vandalism, while residents reported decreased stress and greater physical activity (Branas et al., 2011). A statistically significant decrease in the number of total crimes and gun assaults, and increased safety compared with control was reported in an RCT (Garvin et al., 2013). The third study found a significant reduction in heart rate in African-Americans exposed to greened compared to non-greened vacant lots (South et al., 2015). Finally, the South African study reported significant improvements in biodiversity in range of greening interventions in three deprived urban areas (Anderson et al., 2014).

The majority of studies (3/4 studies) showed significant impacts on health and environmental outcomes for greening of urban streets. Interventions here were varied as were the measured outcomes. The provision of 'DIY streets', including street planting and traffic calming measures, in urban areas in the UK was associated with increased physical activity and perceptions of the environment (e.g. safer, more attractive) (Ward Thompson et al., 2014). Joo and Kwon (2015) reported reduced levels of illegal dumping of household waste at greened sites ($n = 74$) compared to those without greenery (n = 74) at 55.4% of compared to 91.9% respectively. Strohbach et al. (2013) found a greater number of bird species in 12 community-led tree planting projects in deprived areas compared to random urban sites ($p = 0.049$). In contrast, greater concentrations of $PM_{2.5}$ were associated with increased tree canopy cover due to reduced air circulation in the street canyon (Jin et al., 2014).

3.1.4. Green built interventions for storm water management and cooling urban areas (Table 4)

In summary, there were eight studies identified using this approach – four which investigated the effectiveness of rain gardens (i.e. planted shallow depressions, with freely draining soils that provide temporary storage of rainwater running off of hard surfaces, allowing it to soak slowly into the ground), and four investigating green roofs. Three (out of four) studies found a significant intervention effect to support the provision of rain gardens for managing storm water.

A study in Ohio, USA reported a small but statistically significant decrease in storm water quantity at the sub-watershed scale, following the installation of 83 rain gardens and 176 rain barrels (also knowns as water butts; collect and store water from roofs allowing it to be used instead of potable water, for example, to water plants) on > 30% of the 350 eligible residential properties in a 1.8 km^2 catchment area (Mayer et al., 2012). The invention also had a positive impact on the water quality and aquatic biology of the catchment. A similar intervention in the same area found a small significant decrease in runoff volume in four areas equipped with 81 rain gardens and 165 rain barrels compared to two control areas (Shuster and Rhea, 2013; Roy et al., 2014). In contrast, however, there were no significant impacts on stream water quality, periphyton, and macroinvertebrate metrics at the invention sites compared to the controls. A significant reduction in storm water flow of up to 33% of peak discharge and 40% of total run-off volume was reported following the construction of 91 rain gardens (< 25 m^2), street-connected bio-retention cells (i.e. linear depressions that run alongside roads providing temporary storage for rainwater, allowing it to soak into the soil slowly) (~26–44 m^2) and rain barrels on two streets (Jarden et al., 2016). In this study each intervention street had a matched control street ($n = 4$) of similar size, drainage area and characteristics. A further study examined the impact of SuDS on crime; significant reductions in narcotics possession (18%–27% less), narcotics manufacture and burglaries were reported (Kondo et al., 2015) using a difference-in-difference design where comparator groups were matched to control sites where no intervention took place. There were non-significant reductions in homicides, assaults, thefts and public drunkenness. In addition, there were negative, non-significant effects on stress levels and increased reporting of high blood pressure and cholesterol. The intervention took place on 52 sites in Philadelphia and included 152 tree trenches, 46 infiltration/storage trenches (similar to bio-retention cells), 43 rain gardens, 29 pervious pavements, five stormwater basins, and one wetland.

All studies (3/3 studies) that investigated the provision of green roofs showed a significant intervention effect for managing the adverse impact of storm water, and one further demonstrated a significant intervention effect for urban cooling. A green roof on a building in Toronto, Canada (241 m^2) was reported to retain 63% more rainfall than the conventional (bitumen) roof over an 18-month monitoring period (van Seters et al., 2009). An extensive green roof (325.2 m^2 and 929 m^2) on a university building in Michigan, USA, retained 68% of rainfall volume and reduced peak discharge by an average of 89% compared to a stone-ballasted roof and an asphalt roof (Carpenter and Kaluvakolanu, 2011). The green roof also resulted in a significant increase in the concentration of total solids compared to the asphalt roof. Finally, a green roof (500 m^2) on a council civic centre in Auckland, New Zealand was found to retain 57% of rainwater when compared to the control bitumen roof (Fassman et al., 2012). All of these studies were quasi-experiments which collected post-implementation data only.

Finally, an extensive green roof (484 m^2) retrofitted on a two storey railway station in suburban Hong Kong had a significant cooling effect in spring, summer and fall, and a slight warming effect in winter compared to a bare roof control site (Peng and Jim, 2015).

3.1.5. Risk of bias and study quality

Appendix E presents the results from the risk of bias and study quality assessment for all included studies. Scores ranged from 6 (7 studies) to 11 (5 studies) out of a total of 11 criteria. Further, half of the included studies (19 studies) scored ≤7. Factors relating to randomisation, exposure and representativeness were most commonly missing or not reported in the included studies. In particular, for park-based interventions employing a dual approach, scores ranged 6 (NSW Department of Health, 2002; Ward Thompson et al., 2013) to 11 (Cohen et al., 2013) (mean 8.1). The risk of bias for studies investigating park-based interventions that only involved a change to the physical environment ranged from 6 (Bohn-Goldhaum et al., 2013; Peschardt and Stigsdotter, 2014) to 11 (Droomers et al., 2015) (mean 8.3). Greenways and trails studies, employing both a dual approach and involving a change to the physical environment only, showed similar levels of risk of bias, ranging from 6 (Burbidge and Goulias, 2009; Clark et al., 2014) to 11 (Goodman et al., 2014). The risk of bias findings for greening of vacant lots showed a mean of 9.8 (range 7–11), and mean 7.5 (range 6–9) for provision of street trees. For green built interventions targeting

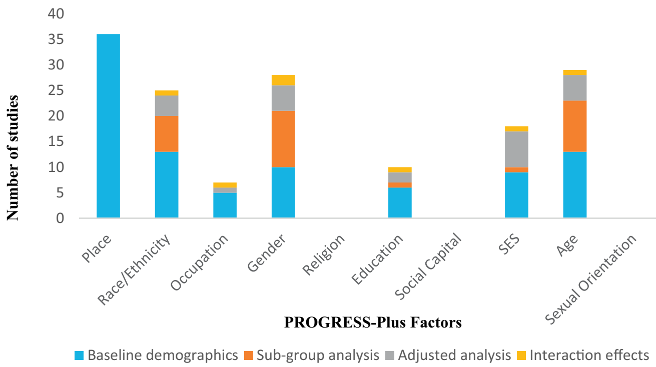

Fig. 1. PROGRESS-Plus reporting in included studies
Note: Studies may report PROGRESS-Plus factors in more than one way. The figure shows that the majority of studies, if they reported any equity indicators, mainly did so using baseline demographics to describe the population sample. A limited number of studies undertook any sub-group analysis, adjusted analysis or interaction analysis which greatly limits our ability to draw any firm conclusions about the impact of UGS interventions on equity factors.

stormwater management and urban cooling, the mean score was 7.3 (range 7–9), and only one study scored above 7 (Kondo et al., 2015).

3.1.6. Impact on equity factors

Overall, there is currently too little evidence to enable us to draw firm conclusions regarding the impact of UGS interventions on a range of equity indicators (Fig. 1). Twenty studies were based in disadvantaged neighbourhoods, and the results were relatively mixed in providing supporting evidence for UGS interventions. For those studies that did show a positive intervention effect in disadvantaged neighbourhoods there is, however, insufficient reported information on whether the community used, or indeed, benefitted from the UGS interventions. Four studies targeted specific age groups; children aged 5–10 years (Quigg et al., 2011), adolescents (Cohen et al., 2009b; Gubbels et al., 2016) and older adults (Ward Thompson et al., 2013). Quigg et al. (2011) found no significant impact on objectively measured physical activity among children for a park-based intervention involving change to only the built environment. Cohen et al. (2009b) showed significant increased use for skate park use in adolescents using a non-dual approach in a park. In contrast, Gubbels et al. (2016) demonstrated a decrease in walking and cycling levels of adolescents using a non-dual approach in parks. Ward Thompson et al. (2013) showed a significant increase in quality of life for older adults in a park-based intervention employing a dual approach. Most studies reported the gender ($n = 17$), age ($n = 21$) and race or ethnicity (n = 21) of participants. Ten studies did not report any information on the PROGRESS-plus indicators (van Seters et al., 2009; Carpenter and Kaluvakolanu, 2011; Mayer et al., 2012; Fassman et al., 2012; Clark et al., 2014; Jin et al., 2014; Roy et al., 2014; Joo and Kwon, 2015; Peng and Jim, 2015; Jarden et al., 2016). However, it should be noted that for some studies, these indicators may not be applicable as the outcomes are environmental (e.g. rainwater management, species number). None of the studies reported powering their analysis of outcomes for these equity variables.

3.1.7. Cost–effectiveness of UGS interventions

Four studies undertook preliminary economic evaluations and found that UGS interventions were relatively cost-effective (Cohen et al., 2012, 2013, 2014; Bird et al., 2014). Studies investigated interventions that ranged from $45,000 (Cohen et al., 2012) to $3.5 million per park (Cohen et al., 2009b), to a total area-wide intervention cost of $6.1 million (Droomers et al., 2015). Cohen et al. (2012, 2013, 2014) based cost-effectiveness on increased physical activity, measured in Metabolic Equivalent of Task (MET)-hours/year. Each MET-hour gained is equivalent to a person engaging in moderate-vigorous physical activity for approximately 15 min, with cost effectiveness judged at whether the cost was less than between $0.50 and $1.00 per MET-hour. Cost effectiveness of the three park-based interventions was reported to be $0.14 to $2.40 per MET (Cohen et al., 2012, 2013, 2014). Preliminary evidence suggests that investment in trails for walking and cycling have significant benefit-cost ratios due to increased walking and cycling attributable to the intervention (Bird et al., 2014). There was no evidence investigating the economic implications of other types of UGS interventions in these studies.

4. Discussion

To our knowledge, this review is the first of its kind to perform a systematic review with a meta-narrative method to explore the effects of UGS interventions on health, wellbeing, social, environmental and equity outcomes.

4.1. Summary of findings

In summary, the overall findings from the current review demonstrated evidence to support the provision of UGS interventions for environmental, health, wellbeing and social effects. As the narratives were categorised by intervention approach it is not possible to present the findings by study design. There was particularly strong evidence for park-based and greenway/trail interventions employing a dual approach (i.e. a physical change to the UGS and promotion/marketing programmes), principally for promoting health and wellbeing through increasing park use and physical activity; greening of vacant lots for health and wellbeing (e.g. reduction in stress) and social benefits (e.g. reduction in crime, increased perceptions of safety); greening of urban streets particularly for environmental benefits (e.g. increased biodiversity, reduced illegal dumping); and SuDS for managing storm water. There was some evidence to support the provision of green roofs for environmental benefits (i.e. urban cooling).

There was little evidence to support the use of park-based interventions that only involved physical change to the UGS (i.e. they did not include programmes to promote the use of the green space), including pocket parks for usage, health and wellbeing benefits. There was no evidence (i.e. an absence of studies) for green walls, allotments/community gardens and urban agriculture-based interventions. Finally, there was a lack of evidence regarding adverse or unintended consequences, the long-term impact, economic benefits or the differential impacts of UGS interventions on various equity indicators.

However, overall it is important to interpret these findings in the context of a relatively sparse evidence base, and methodological limitations highlighted in the Research Recommendations section below.

4.2. Practice, policy and research directions

The findings of this review and discussions among the authors at a WHO expert panel workshop informed meta-narratives for future directions regarding UGS practice, policy and research. These meta-narratives are summarised below and outline specific recommendations for practitioners (including urban planners, urban designers, landscape architects, civil engineers, transport engineers, property developers, public health practitioners), policymakers and researchers regarding UGS interventions.

4.2.1. Practice directions

Findings from this review provide particularly strong evidence for employing dual approaches that provide a change to the physical environment but also include programmes to encourage and promote use of the UGS. Where UGS interventions are being developed, practitioners should ensure that funding is in place to promote the UGS or deliver programmes to encourage its use. Low cost successful strategies such as implementation of signage, promotional events and training park managers to promote use of the parks have been shown to be effective, including in the long-term.

Practitioners and policymakers must also extend their view of UGS beyond the provision and maintenance of public parks. Although public parks are an important resource for public health (Bedimo-Rung et al., 2005), funding for the long-term management and maintenance is seldom prioritised against other spending. This can result in a widening of health inequalities and environmental justice issues, due to a lack of access to UGS and poor maintenance in the most deprived areas. Although, adequate funding for park maintenance should be a priority, this review highlights the effectiveness of other types of UGS interventions in achieving health, wellbeing, social and environmental benefits. These diverse types of UGS interventions, such as greening vacant lots, green roofs and green trails, offer the opportunity to green deprived areas and provide a mix of UGS at the neighbourhood scale. Practitioners and policymakers should consider this mix of interventions in order to ensure equitable, effective and cost efficient delivery of health, social and environmental benefits to all urban residents. However, it should be noted that the issue regarding maintenance also extends to these other types of UGS interventions as well as parks.

The findings of this review, together with those from a WHO expert panel workshop on UGS interventions (see Acknowledgements), have been used to build on the previous recommendations by the WHO Regional Office for Europe (2006) and NICE (2018), Public Health England (2014) and Institute for European Environmental Policy (IEEP) (2016). This provides a broader suite of recommendations to incorporate other health, social and environmental outcomes.

The following factors should be considered when designing UGS interventions:

1. Given the complex social and economic dynamics that occur at scale, the delivery of UGS requires both a multidisciplinary (urban planning, landscape architecture, civil engineering, ecology, environmental science, urban design, public health, health economics, environmental science) and multisector (academic, government, non-governmental organisations, private sector) approach.
2. Not all UGS interventions, or the neighbourhoods in which they are located, are the same, factors such as type of UGS, maintenance requirements and users all affect its desired functions and benefits. Therefore, the context of UGS must be considered from the outset.
3. The design of UGS interventions should incorporate and maximise health, environmental and social benefits based on the context of the area.
4. 'Soft measures' including promotion and marketing of UGS should be included alongside physical or 'hard' interventions, to maximise use and the resulting health and social benefits, this is particularly important in new communities and deprived neighbourhoods.
5. Local communities, and indeed different population subgroups in these communities, use UGS in a variety of ways. Interventions therefore need to consider how the UGS may be used and what the needs of the local community are now and in the future as the population changes.
6. Engage the local community throughout the design process to ensure that their needs are incorporated into the intervention. This will also encourage the community to take ownership for the UGS and its future management and maintenance, which is particularly important given the reductions in budgets for this type of activity.
7. UGS interventions should be planned and designed from the outset to maximise the long-term delivery of benefits. This means 'designing-in' features that specifically focus on long-term health, social and environmental effects, including the provision of 'soft measures' and the long-term management and maintenance plans for the UGS.

4.2.2. Policy directions

Providing, enhancing and protecting UGS presents a significant policy opportunity to improve multiple facets of health, quality of life and the environment. While the evidence summarised here and in other reviews is sometimes mixed, there trajectory is generally towards a positive association between UGS and health, wellbeing, social and environmental outcomes. Policymakers must ensure that any provision or improvement of UGS is done so through an 'equity lens' to ensure that negative consequences of gentrification and unequal access are minimised.

Although the economic impact of such interventions is limited to date, projected cost-effectiveness is likely to be excellent (Dallat et al., 2014) and the few published economic evaluations of UGS interventions are positive. Bird et al. (2014) suggests significant financial savings could be made as a result of increased numbers of people walking and cycling. Similarly, a modelling study suggested that effectiveness estimates as low as a 2% gain in population physical activity levels would be cost-effective (£18, 411/disability-adjusted life year) (Dallat et al., 2014). Although the direct health gains are predicted to be small for any individual, summed over an entire population, they are substantial (e.g. health value of physical activity in natural environments in England has been estimated at £2.2bn/year) (White et al., 2016). The current research provides evidence to support international commitments, such as the Parma Declaration in the WHO European Region and the global Sustainable Development Goals. Although, as noted by Kelly et al. (2017), the relationship between evidence and action, and evidence and policy is not a linear process, and research, policy and practice must work together in a virtuous circle. Researchers must understand and listen to what policymakers and practitioners need.

4.2.3. Research directions

Although, the findings in this review are generally positive there is still a paucity of robust evidence related to UGS interventions, particularly 12 months post intervention. We must now move towards intervention-based research that will help policymakers and practitioners, such as built environment professionals. Research must be co-created and provided in a timely and accessible manner, and this has implications for current publication and funding models. Although many cities are increasing and improving their UGS, funding is seldom available to provide a robust assessment of its impact. This could be improved by ring fencing a proportion of the capital budget for evaluation.

Recent reviews have highlighted areas to improve the rigour of UGS interventions (although these reviews did not consider interventions such as SuDS as are included here) and researchers are referred to Hunter et al. (2015) and Benton et al. (2016) for further details regarding methodological issues in conducting research in this area. Future research should address the key gaps identified in the evidence base in particular around intervention types (green walls, allotments/ community gardens, urban agriculture), and issues such as adverse and unintended consequences, the long-term impact, economic benefits or the differential impacts of UGS interventions on various equity indicators. Further, only a small number of studies investigated the impact on health and wellbeing outcomes. Future research should focus on extending the evidence base for these outcomes. While a number of studies assessed physical activity outcomes, a pathway to health and wellbeing, only a few studies directly assessed health and wellbeing outcomes.

Economic evaluations are fundamental to support policymaking and urban planners. Future research must consider the wider economic impact of UGS interventions, including health and societal costs, for example, health care costs, reductions in carbon emissions due to change in travel behaviour, improvements in safety, and reduced crime. Given the limited attention in this area to date, we argue that UGS interventions are largely undervalued as their aggregated benefits on health, society and environment are yet to be investigated. These are essential in making the case for investment in UGS as often decision making is based on the opportunity cost of providing UGS as opposed to other land uses, and in prioritising other areas of public spending.

There is a considerable gap in the theoretical basis to guide intervention approaches, and further, the current intervention approaches largely negate the large and conclusive cross-sectional evidence base. Future studies should include a more complete description of their intervention strategies and logic models that describe the assumed causal pathways by which the intervention effects the outcomes. For example, null findings (especially of physical change only interventions) could be associated with lack of long term follow-up. Such interventions may take several years to have an impact (Goodman et al., 2014) as behaviours take time to settle.

It is well established that complex, public health interventions can sometimes have unintended negative consequences. However, evaluating adverse effects and unintended consequences is a neglected area in UGS interventions. For example, the provision of UGS may lead to gentrification of an area and widen health inequalities (Cole et al., 2017), or increased air pollution due to reduced air circulation from canopy cover (Jin et al., 2014). Future research must take a multifaceted approach to measurement, including health, wellbeing, social and environmental factors. Given the narrow, unidimensional lens of previous interventions, we suggest that research is yet to realise the true potential of UGS. As shown in this review, most studies only measure one/few outcomes (e.g. physical activity, surface water flow, temperature or biodiversity) and therefore do not capture all potential impacts of the UGS intervention. This highlights the importance of having multidisciplinary evaluations as well as design teams. However, based on the results of this review it is unknown whether UGS interventions could impact on all outcomes as this has yet to be investigated. None of the included studies investigated the combined effects of UGS interventions on health, well-being, social, environmental, equity effects and known influencing factors. Hence, it is unknown whether UGS interventions could affect all outcomes together as they interact in a complex system. Indeed, such interactions may have positive or negative consequences. For example, the installation of an outdoor gym or a (paved) greenway trail might increase physical activity but may also decrease the capacity to absorb storm water. This is important to evaluate the true potential of UGS interventions.

Our results show that these studies have some inherent risk of bias due to study designs, which is in line with previous reviews (Hunter et al., 2015; Benton et al., 2016). Methods of randomisation, exposure and representativeness were poorly described but where reported, were appropriate.

Our results show that little is known about equity effects in UGS interventions. The majority of the included studies record information on a number of the PROGRESS-Plus factors. However, very few actually report details of relevant analyses to determine which population subgroups may stand to benefit or be further disadvantaged by UGS interventions. In order to fully understand the equity impacts of UGS interventions, we recommend that subgroup and interaction analyses are conducted in future studies. UGS may be a core resource in tackling health inequalities by moderating the effects of income inequality on disparities in mortality (Mitchell and Popham, 2008).

4.3. Strengths and limitations

This review included a comprehensive search across a range of public health, social sciences and urban planning databases, and shone a multi-dimensional lens on the various possible outcomes of UGS interventions. In an attempt to negate publication bias, we searched for studies in grey literature. However, included studies were mostly from high-income countries, particularly the USA, UK and Australia, which limits the generalisability of the findings, particularly to other countries with distinct urban planning contexts and cultural differences in the design and use of UGS. There was also large heterogeneity across the included studies, including target populations, settings, intervention approaches, study design and outcome measures which has restricted our ability to draw firm conclusions. Given the complex nature of these interventions, it is difficult to disentangle the 'active' components. For example, the fact that the dual approach is the most effective raises questions whether the physical change to the green space is really efficient, or that it is due to the marketing programmes to stimulate physical activity in the green space. Further, UGS interventions for storm water management are all in combination with other "non-green" interventions, like rain barrels and pervious pavements. Therefore, it is hard to separate true effects of "green" interventions from the "non-green" interventions. As the longest follow-up period was maximum two years in the included studies, there is uncertainty regarding the longer term effectiveness of UGS interventions. Further, we did not exclude studies of low quality and therefore conclusions should be interpreted in light of these assessments. Due to the heterogeneous nature of the review, outcome measures and interventions, it was not appropriate to conduct a meta-analysis.

5. Conclusion

In summary, UGS has an important role to play in creating a "culture of health" including the "social health" of our neighbourhoods and communities. Results from this study provide supportive evidence regarding the use of certain UGS interventions for health, social and environmental benefits, in particular park-based and greenway/trail-based interventions employing a dual approach. However, for other UGS interventions the evidence is inconclusive. These findings should be interpreted in light of the heterogeneous nature of the evidence base, including diverging methods, target populations, settings and outcomes. The potential for unintended consequences of UGS interventions, for example increased air pollution due to reduced air circulation by urban street trees, should be noted. None of the studies included in this review considered a holistic approach, measuring health, wellbeing, social and environmental outcomes. We argue that the true potential of UGS has not been realised as studies have typically under-evaluated the intervention. Rather, the findings from the present review highlight the need for researchers to conduct better natural experiments that address issues such as inadequate control sites and poor control of confounding variables, measurement of outcomes, and selection of the reported result as described by Benton et al. (2016), to inform policy and practice, especially in light of the growing policy response in this area.

Urban green space – and urban planning in general – cannot be seen in isolation from other local government priorities such as transport and housing. It must be framed holistically and viewed as a complex system in which the interplay between physical, economic, social and natural ecosystems affects health, behaviours and communities. The growing diversity of our towns and cities is transforming how UGS is required and negotiated for health, wellbeing, social and environmental benefits. In an increasing urbanised world, UGS is competing against the growing need for housing, transport infrastructure etc. Significant UGS investment is made worldwide, and many researchers and policymakers alike have gradually shown increased support to implement cost-efficient and effective UGS interventions to improve population-level health, wellbeing, social and environmental factors. There are very few – if any – other public health interventions that can achieve all of this.

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Declaration of Competing Interest

The authors declare no competing interests.

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References

Anderson, P.M.L., Avlonitis, G., Ernstson, H., 2014. Ecological outcomes of civic and expert-led urban greening projects using indigenous plant species in Cape Town, South Africa. Landsc. Urban Plan. 127, 104–113.
Bedimo-Rung, A.L., Mowen, A.J., Cohen, D.A., 2005. The significance of parks to physical activity and public health: a conceptual model. Am. J. Prev. Med. 82, 159–168.
Benton, J.S., Anderson, J., Hunter, R.F., French, D.P., 2016. The effect of changing the built environment on physical activity: a quantitative review of the risk of bias in natural experiments. Int. J. Behav. Nutr. Phys. Act. 13, 107.
Bird, E., Powell, J., Ogilvie, D., Goodman, A., Rutter, H., 2014. Health economic assessment of walking and cycling interventions in the physical environment: interim findings from the iConnect study. In: South West Public Health Scientific Conference, Weston-Super-Mare, UK, 5th February 2014, Available from: http://eprints.uwe.ac.uk/23015, Accessed date: 31 August 2017.
Bohn-Goldhaum, E., Phongsavan, P., Merom, D., Rogers, K., Kamalesh, V., Bauman, A.E., 2013. Does playground improvement increase physical activity among children? A quasi-experimental study of a natural experiment. J. Environ. Public Health, 109841. https://doi.org/10.1155/2013/109841.
Bowler, D.E., Buyung-Ali, L.M., Knight, T.M., Pullin, A.S., 2010a. A systematic review of evidence for the added benefits to health of exposure to natural environments. BMC Public Health 10, 456.
Bowler, D.E., Buyung-Ali, L., Knight, T.M., Pullin, A.S., 2010b. Urban greening to cool towns and cities: a systematic review of the empirical evidence. Landsc. Urban Plan. 97, 147–155.
Bragg, R., Atkins, G., 2016. A Review of Nature-based Interventions for Mental Health Care. Natural England Commissioned Reports (Number 204).
Branas, C.C., Cheney, R.A., MacDonald, J.M., Tam, V.W., Jackson, T.D., Ten Have, T.R., 2011. A difference-in-differences analysis of health, safety, and greening vacant urban space. Am. J. Epidemiol. 174, 1296–1306.
Brand, C., Goodman, A., Ogilvie, D., 2014. Evaluating the impacts of new walking and cycling infrastructure on carbon dioxide emissions from motorized travel: a controlled longitudinal study. Appl. Energy 128, 284–295.
Burbidge, S.K., Goulias, K.G., 2009. Evaluating the impact of neighborhood trail development on active travel behavior and overall physical activity of suburban residents. J. Transp. Res. Board 2135, 78–86.
Carpenter, D.D., Kaluvakolanu, P., 2011. Effect of roof surface type on storm-water runoff from full-scale roofs in a temperate climate. J. Irrig. Drain. Eng. 137, 161–169.
Clark, S., Bungum, T., Shan, G., Meacham, M., Coker, L., 2014. The effect of a trail use intervention on urban trail use in Southern Nevada. Prev. Med. 67, S17–S20. https://doi.org/10.1016/j.ypmed.2014.04.027.
Cohen, D.A., Golinelli, D., Williamson, S., Sehgal, A., Marsh, T., McKenzie, T.L., 2009a. Effects of park improvements on park use and physical activity: policy and programming implications. Am. J. Prev. Med. 37, 475–480.
Cohen, D.A., Sehgal, A., Williamson, S., Marsh, T., Golinelli, D., McKenzie, T.L., 2009b. New recreational facilities for the young and the old in Los Angeles: policy and programming implications. J. Public Health Policy 30, S248–S263.
Cohen, D.A., Marsh, T., Williamson, S., Golinelli, D., McKenzie, T.L., 2012. Impact and cost-effectiveness of family fitness zones: a natural experiment in urban public parks. Health Place 18, 39–45.
Cohen, D.A., Han, B., Derose, K.P., Williamson, S., Marsh, T., McKenzie, T.L., 2013. Physical activity in parks: a randomized controlled trial using community engagement. Am. J. Prev. Med. 45, 590–597.
Cohen, D.A., Marsh, T., Williamson, S., Han, B., Derose, K.P., Golinelli, D., McKenzie, T.L., 2014. The potential for pocket parks to increase physical activity. Am. J. Health Promot. 28, S19–S26.
Cole, H.V.S., Garcia Lamarca, M., Connolly, J.J.T., Anguelovski, I., 2017. Are green cities healthy and equitable? Unpacking the relationship between health, green space and gentrification. J. Epidemiol. Community Health 71, 1118–1121. https://doi.org/10.1136/jech-2017-209201.
Cranney, L., Phongsavan, P., Kariuki, M., Stride, V., Scott, A., Hua, M., Bauman, A., 2016. Impact of an outdoor gym on park users' physical activity: a natural experiment. Health Place 37, 26–34. https://doi.org/10.1016/j.healthplace.2015.11.002.
Dallat, M.A., Soerjomataram, I., Hunter, R.F., Tully, M.A., Cairns, K.J., Kee, F., 2014. Urban greenways have the potential to increase physical activity levels cost-effectively. Eur. J. Pub. Health 24, 190–195. https://doi.org/10.1093/eurpub/ckt035.
Droomers, M., Jongeneel-Grimen, B., Kramer, D., de Vries, S., Kremers, S., Bruggink, J.W., van Oers, H., Kunst, A.E., Stronks, K., 2015. The impact of intervening in green space in Dutch deprived neighbourhoods on physical activity and general health: results from the quasi-experimental URBAN40 study. J. Epidemiol. Community Health 70, 147–154. https://doi.org/10.1136/jech-2014-205210.
Evenson, K.R., Herring, A.H., Huston, S.L., 2005. Evaluating change in physical activity with the building of a multi-use trail. Am. J. Prev. Med. 28, 177–185.
Fassman, E., Simcock, R., Voyde, E., Yit Sing Hong, Y.S., 2012. 4 living roofs in 3 locations: does configuration affect runoff quality or quantity? In: Storm Water Conference, . https://www.waternz.org.nz/Article?Action=View&Article_id=547.
Fitzhugh, E.C., Bassett, D.R., Evans, M.F., 2010. Urban trails and physical activity: a natural experiment. Am. J. Prev. Med. 39, 259–262.
Garvin, E.C., Cannuscio, C.C., Branas, C.C., 2013. Greening vacant lots to reduce violent crime: a randomised controlled trial. Inj. Prev. 19, 198–203. https://doi.org/10.1136/injuryprev-2012-040439.
Gascon, M., Triguero-Mas, M., Martinez, D., Dadvand, P., Rojas-Rueda, D., Plasència, A., Nieuwenhuijsen, M.J., 2016. Residential green spaces and mortality: a systematic review. Environ. Int. 86, 60–67.
Giles-Corti, B., Vernez-Moudon, A., Reis, R., Turrell, G., Dannenberg, A.L., Badland, H., Foster, S., Lowe, M., Sallis, J.F., Stevenson, M., Owen, N., 2016. City planning and population health: a global challenge. Lancet 388, 2912–2924.
Goodman A, Sahlqvist S, Ogilvie D; iConnect Consortium. New walking and cycling routes and increased physical activity: one- and 2-year findings from the UK iConnect Study. Am. J. Public Health 2014; 104: e38–46. doi:https://doi.org/10.2105/AJPH.2014.302059.
Greenhalgh, T., Robert, G., Macfarlane, F., Bate, P., Kyriakidou, O., Peacock, R., 2005. Storylines of research in diffusion of innovation: a meta-narrative approach to systematic review. Soc. Sci. Med. 61, 417–430.
Gubbels, J.S., Kremers, S.P., Droomers, M., Hoefnagels, C., Stronks, K., Hosman, C., de Vries, S., 2016. The impact of greenery on physical activity and mental health of adolescent and adult residents of deprived neighborhoods: a longitudinal study. Health Place 40, 153–160. https://doi.org/10.1016/j.healthplace.2016.06.002.
Hanson, S., Jones, A., 2015. Is there evidence that walking groups have health benefits? A systematic review and meta-analysis. Br. J. Sports Med. 49, 710–715.
Hunter, R.F., Christian, H., Veitch, J., Astell-Burt, T., Hipp, J.A., Schipperijn, J., 2015. The impact of interventions to promote physical activity in urban green space: a systematic review and recommendations for future research. Soc. Sci. Med. 124, 246–256.
Husk, K., Lovell, R., Cooper, C., Stahl-Timmins, W., Garside, R., 2016. Participation in environmental enhancement and conservation activities for health and well-being in adults: a review of quantitative and qualitative evidence. Cochrane Database Syst. Rev. 5 (CD010351). https://doi.org/10.1002/14651858.CD010351.pub2.
Institute for European Environmental Policy (IEEP), 2016. The Health and Social Benefits of Nature and Biodiversity Protection Stakeholder Workshop 27th & 28th January 2016 Workshop Summary. http://www.ieep.eu/assets/2018/Workshop_Summary_Health_and_Social_Benefits_of_Nature_sent_for_approval.pdf.
Jarden, K.M., Jefferson, A.J., Grieser, J.M., 2016. Assessing the effects of catchment-scale urban green infrastructure retrofits on hydrograph characteristics. Hydrol. Process. 30, 1536–1550. https://doi.org/10.1002/hyp.10736.
Jin, S., Guo, J., Wheeler, S., Kan, L., Che, S., 2014. Evaluation of impacts of trees on PM2.5 dispersion in urban streets. Atmos. Environ. 99, 277e287.
Joo, Y., Kwon, Y., 2015. Urban street greenery as a prevention against illegal dumping of household garbage-a case in Suwon, South Korea. Urban For. Urban Green. 14, 1088–1094.
Kelly, M.P., Atkins, L., Littleford, C., Leng, G., Michie, S., 2017. Evidence-based medicine meets democracy: the role of evidence-based public health guidelines in local government. J. Public Health 1–7. https://doi.org/10.1093/pubmed/fdx002.
King, D.K., Litt, J., Halec, J., Burniece, K.M., Ross, C., 2015. 'The park a tree built': evaluating how a park development project impacted where people play. Urban For. Urban Green. 14, 293–299.
Kondo, M.C., Low, S.C., Henning, J., Branas, C.C., 2015. The impact of green stormwater infrastructure installation on surrounding health and safety. Am. J. Public Health 105, e114–e121. https://doi.org/10.2105/AJPH.2014.302314.
Kuo, F., 2015. How might contact with nature promote human health? Promising mechanisms and a possible central pathway. Front. Psychol. 25, 1093.
Lachowycz, K., Jones, A.P., 2011. Greenspace and obesity: a systematic review of the evidence. Obes. Rev. 12, e183–e189.
Lee, A.C.K., Maheswaran, R., 2010. The health benefits of urban green spaces: a review of the evidence. J. Public Health 33, 212–222.
Liberati, A., Altman, D.G., Tetzlaff, J., Mulrow, C., Gotzsche, P.C., Ioannidis, J.P., Clarke, M., Devereaux, P.J., Kleijnen, J., Moher, D., 2009. The PRISMA statement for reporting systematic reviews and meta-analyses of studies that evaluate health care interventions: explanation and elaboration. J. Clin. Epidemiol. 62, e1–34.
Maas, J., van Dillen, S.M.E., Verheij, R.A., Groenewegen, P.P., 2009a. Social contacts as a possible mechanism behind the relation between green space and health. Health Place 15, 586–595.
Maas, J., Verheij, R.A., de Vries, S., Spreeuwenberg, P., Schellevis, F.G., Groenewegen, P.P., 2009b. Morbidity is related to a green living environment. J. Epidemiol. Community Health 63, 967–973.
Maes, J., Barbosa, A., Baranzelli, C., Zulian, G., Batista, E., Silva, F., Vandecasteele, I., Hiederer, R., Liquete, C., Paracchini, M.L., Mubareka, S., Jacobs-Crisioni, C., Castillo, C.P., Lavalle, C., 2015. More green infrastructure is required to maintain ecosystem services under current trends in land-use change in Europe. Landsc. Ecol. 30, 517–534.

Mayer, A., Shuster, W.D., Beaulieu, J., Hopton, M., Rhea, L.K., Thurston, H., Roy, A.H., 2012. Building green infrastructure via citizen participation: a six-year study in the Shepherd Creek (Ohio). Environ. Pract. 14, 57–67 (doi:10.10170S1466046611000494).
Mitchell, R., Popham, F., 2008. Effect of exposure to natural environment on health inequalities: an observational population study. Lancet 372, 1655–1660.
Mitchell, R.J., Richardson, E.A., Shortt, N.K., Pearce, J.R., 2015. Neighborhood environments and socioeconomic inequalities in mental well-being. Am. J. Prev. Med. 49, 80–84.
NICE, 2018. Physical activity and the environment. https://www.nice.org.uk/guidance/ng90.
NSW Department of Health, 2002. The Effect of Park Modifications and Promotion on Physical Activity Participation. Summary Report. vol. vi NSW Health Dept., North Sydney (38 p.: ill., 1).
Ogilvie, D., Foster, C.E., Rothnie, H., Cavill, N., Hamilton, V., Fitzsimons, C.F., Mutrie, N., 2007. Interventions to promote walking: systematic review. BMJ 334, 1204.
O'Neill, J., Tabish, H., Welch, V., Petticrew, M., Pottie, K., Clarke, M., Evans, T., Pardo Pardo, J., Waters, E., White, H., Tugwell, P., 2014. Applying an equity lens to interventions: using PROGRESS ensures consideration of socially stratifying factors to illuminate inequities in health. J. Clin. Epidemiol. 67, 56–64.
Peng, L.L.H., Jim, C.Y., 2015. Seasonal and diurnal thermal performance of a subtropical extensive green roof: the impacts of background weather parameters. Sustainability 7, 11098–11113. https://doi.org/10.3390/su70811098.
Peschardt, K.K., Stigsdotter, U.K., 2014. Evidence for designing health promoting pocket parks. Archnet-IJAR 8, 149–164.
Public Health England, 2014. Local action on health inequalities: improving access to green spaces. In: Health Equity Evidence Review. vol. 8. https://www.gov.uk/government/uploads/system/uploads/attachment_data/file/357411/Review8_Green_spaces_health_inequalities.pdf.
Quigg, R., Reeder, A.I., Gray, A., Holt, A., Waters, D., 2011. The effectiveness of a community playground intervention. J. Urban Health 89, 171–184. https://doi.org/10.1007/s11524-011-9622-1.
Revi, A., Satterthwaite, D.E., Aragón-Durand, F., Corfee-Morlot, J., Kiunsi, R.B.R., Pelling, M. (Eds.), 2014. Climate Change 2014: Impacts, Adaptation, and Vulnerability. Part a: Global and Sectoral Aspects. Contribution of Working Group II to the Fifth Assessment Report of the Intergovernmental Panel of Climate Change. Cambridge University Press, Cambridge, United Kingdom and New York, NY, USA, pp. 535–612.
Roy, A.H., Rhea, L.K., Mayer, A.L., Shuster, W.D., Beaulieu, J.J., Hopton, M.E., Morrison, M.A., Amand, A.S., 2014. How much is enough? Minimal responses of water quality and stream biota to partial retrofit stormwater management in a suburban neighborhood. PLoS One 17, e85011. https://doi.org/10.1371/journal.pone.0085011.
Sahlqvist, S., Goodman, A., Cooper, A.R., Ogilvie, D., iConnect consortium, 2013. Change in active travel and changes in recreational and total physical activity in adults: longitudinal findings from the iConnect study. Int. J. Behav. Nutr. Phys. Act. 10, 28. https://doi.org/10.1186/1479-5868-10-28.
Sallis, J.F., Cerin, E., Conway, T.L., Adams, M.A., Frank, L.D., Pratt, M., Salvo, D., Schipperijn, J., Smith, G., Cain, K.L., Davey, R., Kerr, J., Lai, P.C., Mitáš, J., Reis, R., Sarmiento, O.L., Schofield, G., Troelsen, J., Van Dyck, D., De Bourdeaudhuij, I., Owen, N., 2016. Physical activity in relation to urban environments in 14 cities worldwide: a cross-sectional study. Lancet 387, 2207–2217.
Shuster, W.D., Rhea, L.K., 2013. Catchment-scale hydrologic implications of parcel-level stormwater management (Ohio USA). J. Hydrol. 485, 177–187.
Slater, S., Pugach, O., Lin, W., Bontu, A., 2016. If you build it will they come? Does involving community groups in playground renovations affect park utilization and physical activity? Environ. Behav. 48, 246–265.
Song, C., Ikei, H., Miyazaki, Y., 2016. Physiological effects of nature therapy: a review of the research in Japan. Int. J. Environ. Res. Public Health 13 (E781). https://doi.org/10.3390/ijerph13080781.
South, E.C., Kondo, M.C., Cheney, R.A., Branas, C.C., 2015. Neighborhood blight, stress, and health: a walking trial of urban greening and ambulatory heart rate. Am. J. Public Health 105, 909–913. https://doi.org/10.2105/AJPH.2014.302526.
Strohbach, M.W., Lermana, S.B., Warren, P.S., 2013. Are small greening areas enhancing bird diversity? Insights from community-driven greening projects in Boston. Landsc. Urban Plan. 114, 69–79.
Tester, J., Baker, R., 2009. Making the playfields even: evaluating the impact of an environmental intervention on park use and physical activity. Prev. Med. 48, 316–320.
Twohig-Bennett, C., Jones, A., 2018. The health benefits of the great outdoors: a systematic review and meta-analysis of greenspace exposure and health outcomes. Environ. Res. 166, 628–637. https://doi.org/10.1016/j.envres.2018.06.030.
UN Sustainable Development Goals. http://www.un.org/sustainabledevelopment/sustainable-development-goals/.
van Seters, T., Rocha, L., Smith, D., MacMillan, G., 2009. Evaluation of green roofs for runoff retention, runoff quality, and leachability. Water Qual. Res. J. Can. 44, 33–47.
Veitch, J., Ball, K., Crawford, D., Abbott, G.R., Salmon, J., 2012. Park improvements and park activity: a natural experiment. Am. J. Prev. Med. 42, 616–619.
Ward Thompson, C., Roeb, J., Aspinall, P., 2013. Woodland improvements in deprived urban communities: what impact do they have on people's activities and quality of life? Landsc. Urban Plan. 118, 79–89.
Ward Thompson, C., Curl, A., Aspinall, P., Alves, S., Zuin, A., 2014. Do changes to the local street environment alter behaviour and quality of life of older adults? The 'DIY Streets' intervention. Br. J. Sports Med. 48, 1059–1065. https://doi.org/10.1136/bjsports-2012-091718.
West, S.T., Shores, K.A., 2011. The impacts of building a greenway on proximate residents' physical activity. J. Phys. Act. Health 8, 1092–1097.
White, M.P., Elliott, L.R., Taylor, T., Wheeler, B.W., Spencer, A., Bone, A., Depledge, M.H., Fleming, L.E., 2016. Recreational physical activity in natural environments and implications for health: a population based cross-sectional study in England. Prev. Med. 91, 383–388.
WHO Regional Office for Europe, 2006. Promoting Physical Activity and Active Living in Urban Environments. The Role of Local Governments. The Solid Facts. WHO Regional Office for Europe, Copenhagen.
WHO Regional Office for Europe, 2016. Urban Green Spaces and Health. WHO Regional Office for Europe, Copenhagen, Denmark.
WHO Regional Office for Europe, 2017a. Urban Green Space Interventions and Health. WHO Regional Office for Europe, Copenhagen, Denmark.
WHO Regional Office for Europe, 2017b. Action Brief on Urban Green Spaces. WHO Regional Office for Europe, Copenhagen, Denmark.
WHO Regional Office for Europe, 2018. Global Action Plan on Physical Activity 2018–2030: More Active People for a Healthier World. World Health Organization, Geneva, Switzerland.
Wong, G., Greenhalgh, T., Westhorp, G., Buckingham, J., Pawson, R., 2013. RAMESES publication standards: meta-narrative reviews. BMC Med. 11, 20.