International Journal of Hygiene and Environmental Health 220 (2017) 1207–1221

Contents lists available at ScienceDirect

International Journal of Hygiene and Environmental Health

journal homepage: www.elsevier.com/locate/ijheh

Review

Outdoor blue spaces, human health and well-being: A systematic review of quantitative studies

Mireia Gascon[a,b,c,*], Wilma Zijlema[a,b,c], Cristina Vert[a,b,c], Mathew P. White[d], Mark J. Nieuwenhuijsen[a,b,c]

[a] ISGlobal, Barcelona Ctr. Int. Health Res. (CRESIB), Hospital Clínic – Universitat de Barcelona, Barcelona, Spain
[b] Universitat Pompeu Fabra (UPF), Barcelona, Spain
[c] CIBER Epidemiología y Salud Pública (CIBERESP), Barcelona, Spain
[d] European Centre for Environment & Human Health, University of Exeter Medical School, Truro, UK

ARTICLE INFO

Keywords:
Outdoor
Blue spaces
Health
Well-being

ABSTRACT

Background: A growing number of quantitative studies have investigated the potential benefits of outdoor blue spaces (lakes, rivers, sea, etc) and human health, but there is not yet a systematic review synthesizing this evidence.

Objectives: To systematically review the current quantitative evidence on human health and well-being benefits of outdoor blue spaces.

Methods: Following PRISMA guidelines for reporting systematic reviews and meta-analysis, observational and experimental quantitative studies focusing on both residential and non-residential outdoor blue space exposure were searched using specific keywords.

Results: In total 35 studies were included in the current systematic review, most of them being classified as of "good quality" (N = 22). The balance of evidence suggested a positive association between greater exposure to outdoor blue spaces and both benefits to mental health and well-being (N = 12 studies) and levels of physical activity (N = 13 studies). The evidence of an association between outdoor blue space exposure and general health (N = 6 studies), obesity (N = 8 studies) and cardiovascular (N = 4 studies) and related outcomes was less consistent.

Conclusions: Although encouraging, there remains relatively few studies and a large degree of heterogeneity in terms of study design, exposure metrics and outcome measures, making synthesis difficult. Further research is needed using longitudinal research and natural experiments, preferably across a broader range of countries, to better understand the causal associations between blue spaces, health and wellbeing.

1. Introduction

A growing body of literature suggests that natural outdoor environments might help reduce stress, promote physical activity and social relationships and potentially improve human health and well-being (Dadvand et al., 2016; Hartig et al., 2014; Nieuwenhuijsen et al., 2017; Pasanen et al., 2014; Völker and Kistemann, 2011). Furthermore, the presence of natural environments in urban settings, particularly green spaces (trees, grass, forests, parks, etc), has been associated with a reduction of the levels of air pollution and noise, as well as extreme temperatures in cities, which can lead to a reduction of the impacts of these environmental factors on our health (Burkart et al., 2016; Hartig et al., 2014; Shanahan et al., 2015; Wolf and Robbins, 2015). In a world with rapid urbanization and pressure on space (United Nations Department of Economic and Social Affairs, 2014), evidence of such health benefits of natural environments are of high relevance for healthcare professionals, urban planners and policymakers, who can help translate available evidence into salutogenic interventions and policies (i.e. ones that support and promote health and well-being).

Most of the studies in this field to date have focused on the health benefits of green spaces, including several systematic and non-systematic reviews (e.g. Dzhambov et al., 2014; Dzhambov and Dimitrova, 2014; Gascon et al., 2016, 2015; Kabisch et al., 2015; Lee and Maheswaran, 2011; Nieuwenhuijsen et al., 2017; WHO, 2016). However, fewer studies have focused on the health impacts of outdoor blue spaces, defined in the European Commission funded project BlueHealth (https://bluehealth2020.eu/) as "outdoor environments – either natural or manmade – that prominently feature water and are accessible to

* Corresponding author at: Parc de Recerca Biomèdica de Barcelona (PRBB) – ISGlobal (CREAL), Doctor Aiguader, 88 | 08003 Barcelona, Catalonia, Spain.
E-mail address: mireia.gascon@isglobal.org (M. Gascon).

http://dx.doi.org/10.1016/j.ijheh.2017.08.004
Received 28 April 2017; Received in revised form 9 August 2017; Accepted 10 August 2017
1438-4639/

Table 1
Main characteristics and results of the studies on general health.

Author (year, country)	Study design	Age of the study population	N	Blue space exposure	Tool to estimate blue space exposure	Outcome measured	Tools to measure outcome	Main results
De Vries et al., 2003, The Netherlands	Cross-sectional	All ages	10197	Fresh and salt water surface	Land-use map% BS in 1 km & 3 km buffers from the residence	Perceived general health (less than good)	Questionnaire[a]	β = -0.008 (SD = 0.005) (for 3 km buffer)
						Number of symptoms experienced in the last 14 days	Questionnaire (43 symptoms)[a]	β = -0.016 (SD = 0.007; significant association) (for 3 km buffer)
Triguero-Mas et al., 2015, Spain	Cross-sectional	34–64 years	8793	Inland and non-inland BS	BS presence in 100 m, 300 m, 500 m and 1 km buffers from the residence (land-cover)	Perceived general health (poor)	SF-36	OR (95%CI) = 0.82 (0.65, 1.05) for 300 m buffer
Wheeler et al., 2012, UK	Ecological Cross-sectional	Not specified	32482 CAUs	Coast	GIS to measure distance between population-weighted centroid and the coast (> 50 km, 20–50 km, 5–20 km, 1–5 km, < 1 km)	Self-reported good health in the last 12 m	Questionnaire[a]	β (95%CI) for distance < 1 km vs > 50 km = 1.13 (0.99, 1.27) in urban settings, 1.19 (0.79, 1.59) in town settings and −0.09 (-0.69, 0.51) in rural settings
Wheeler et al., 2015, UK	Ecological Cross-sectional	Not specified	31672 CAUs	Salt water, freshwater, coastal	Land-cover map to measure% of BS within each population-weighted centroid	Self-reported good health	Questionnaire[a]	β (95%CI) = 0.074 (0.032, 0.117) for saltwater, 0.000 (-0.010, 0.010 for freshwater and 0.019 (0.010, 0.027) for coastal water
				Freshwater ecological quality	Indicator of the Environment agency for England and Wales map			β (95%CI) = −0.095 (-0.153, −0.037)
White et al., 2013a, UK	Longitudinal	Adults > 25 years	Between 12360 and 15471[b]	Coast	Distance between population-weighted centroid and the coast (< 5 km, 5–50 km (reference category), > 50 km)	General health (good)	Questionnaire[a]	β (SE; *p-value < 0.05) = 0.039 (0.018)* for < 5 km and −0.005 (0.018) for > 50 km
Ying et al., 2015, China	Cross-sectional	Adults 46–80 years	1100	River	GIS to define 500 m buffer distance to the river	Health status (worst to best)	Questionnaire[a]	Coefficient (*p*-value) = −0.016 (0.679)

BS: blue space; CAU level: Census Area Unit level; GIS: geographic information system; SF-36: Short form health survey (36 items).
[a]Not validated questionnaire or not clarified.
[b]In total there were between 90084 and 136756 observations included in the analysis.
[c]In total there were between 56574 and 87573 observations included in the analysis.

Table 2
Main characteristics and results of the studies on mental health and well-being.

Author (year, country)	Study design	Age of the study population	N	Blue space exposure	Tool to estimate blue space exposure	Outcome measured	Tools to measure outcome	Main results
Alcock et al., 2015, UK	Longitudinal (18 years follow-up)	Adults (rural areas)	2020[a]	Saltwater, freshwater, coastal	Land-cover map to determine% at CAU	Mental health	GHQ-12	β (SE; *p-value < 0.05) = 0.3398 (0.7027) for saltwater, −0.289 (0.0693) for freshwater, 0.298 (0.0818) for coastal between-individuals −2.4219 (1.1305*) for saltwater, 0.4700 (0.3545) for freshwater and 0.8380 (0.3318*) for coastal within-individuals
Amoly et al., 2014, Spain	Cross-sectional	Children 7–10 years	2111	Annual beach attendance (time spent)	Questionnaire	Emotional & behavioural problems	SDQ ADHD/DSM-IV	Percent change (95% CI) for an IQR increase in annual beach attendance (32 days) = −3.9 (−7.2, −0.4) for SDQ, 1.1 (0.0, 2.2) for pro-social behavior and −0.1 (−6.7, 6.9) for ADHD
Brerenton et al., 2008, Ireland	Cross-sectional	Adults > 18 years	1467	Proximity to coast and beach	Land-use map based on GIS information to determine proximity to coast (< 2 km, 2–5 km, > 5 km) and to beach (< 5 km, 5–10, > 10 km)	Well-being/life satisfaction	Questionnaire[b]	β (SE; *p-value < 0.05) = 0.8351 (4.32*) for < 2 km from the coast and 0.2271 (1.51) for 2–5 km from the coast −0.1607 (0.73) for < 5 km from the beach and −0.0923 (0.42) for 5–10 km from the beach
De Vries et al., 2003, The Netherlands	Cross-sectional	All ages	10197	Fresh and salt water surface	Land-use map% BS in 1 km & 3 km buffers from the residence	Minor psychiatric morbidity	GHQ	β = -0.004 (SD = 0.005) (for 3 km buffer)
Huynh et al., 2013, Canada	Cross-sectional	Children 11–16 years	17249	Water bodies (oceans, lakes, rivers, streams)	Land-use map based on GIS information. Water bodies (%) in 5 km buffer from the schools (N = 371)	(Positive) emotional well-being	Cantril's ladder	RR (95%CI) = 1.02 (0.97, 1.07) for Q2 of BS exposure, 1.06 (1.01, 1.11) for Q3 and 1.04 (0.99, 1.09) for Q4[c]
MacKerron et al., 2013, UK	Longitudinal	Adults	21947[d]	Marine and coastal margins and freshwater, wetlands and flood plains	Smartphone application with GPS location linked to land cover map	Happiness	Smartphone application with questionnaire[b]	β (SE, *p < 0.05) = 6.02 (0.68*) for marina and coastal margins and 1.80 (0.63*) for freshwater, wetlands and flood plains
Nutsford et al., 2016, New Zealand	Cross-sectional	Adolescents and adults > 15 years	442	Oceanic and freshwater blue spaces	VVI of BS created based on 4 land-cover maps and for a buffer of 15 km using residential meshblocks	Psychological distress	K10	β (95%CI) = −0.28 (-0.41, −0.15) (increase of 10% of BS visibility, 0.28% reduction of psychological stress)
Rogerson et al., 2016, UK	Pre/post observational study	Adult park runners	331	Beach, riverside, grass and heritage routes	Each participant run along one of the routes (they were recruited at the start of the route)	Self-esteem	RSE (pre/post running at each location)	There were no differences pre- and post-run between the different locations (p > 0.05)
						Perceived stress	PSS (pre/post running at each location)	There were no differences pre- and post-run between the different locations (p > 0.05)
						Mood	POMS (pre/post running at each location)	There were no differences pre- and post-run between the different locations (p > 0.05)
Triguero-Mas et al., 2015, Spain	Cross-sectional	34–64 years	8793	Inland and non-inland BS	BS presence in 100m, 300m, 500 m and 1 km buffers from the residence (land-cover)	Perceived mental health (poor)	GHQ-12	OR (95%CI) = 1.13 (0.86, 1.49) for 300 m buffer
						Perceived depression or anxiety (yes/no)	Questionnaire[b]	OR (95%CI) = 1.13 (0.90, 1.41) for 300 m buffer
						Visits to mental health specialists (yes/no)	Questionnaire[b]	OR (95%CI) = 1.30 (0.92, 1.84) for 300 m buffer
						Medication intake (yes/no)	Questionnaire[b]	OR (95%CI) = 0.85 (0.61, 1.17)

(continued on next page)

Table 2 *(continued)*

Author (year, country)	Study design	Age of the study population	N	Blue space exposure	Tool to estimate blue space exposure	Outcome measured	Tools to measure outcome	Main results
								tranquilizers, 0.84 (0.59, 1.19) for antidepressants and 0.95 (0.69, 1.31) for sleeping medication for a 300 m buffer
White et al., 2013a, UK	Longitudinal	Adults > 25 years	Between 12360 and 15471[e]	Coast	Distance between population-weighted centroid and the coast (< 5 km, 5–50 km (reference category), > 50 km)	Mental health	GHQ-12	β (SE; *p-value < 0.05) = 0.147 (0.065)* for < 5 km and −0.121 (0.064) for > 50 km
						Well-being (life satisfaction)	Questionnaire[b]	β (SE; *p-value < 0.05) = 0.044 (0.034) for < 5 km and 0.049 (0.034) for > 50 km
White et al., 2013b, UK	Longitudinal	Adults	Between 10168 and 12818[f]	Freshwater	Land-cover map to determine% of freshwater at CAU	Mental health	GHQ-12	β (SE) = −0.0007 (0.0028) (*p*-value > 0.05)
						Well-being (life satisfaction)	Questionnaire[b]	β (SE) = 0.0018 (0.0014) (*p*-value > 0.05)
White et al., 2013c, UK	Cross-sectional	Adolescents and adults > 16 years	4255	Coast, beach, river, lake, canal	Questionnaire to ask for the time spent in these BS	Recalled restoration	Questionnaire[b]	β (SE; *p-value < 0.05) = 0.13 (0.07) for river/lake/canal, 0.21 (0.07)* for beach, 0.19 (0.08)* for coast (other than beach)

ADHD/DSM-IV: Diagnostic and Statistical Manual of Mental Disorders, Fourth Edition; BS: blue space; CAU level: Census area unit level; GHQ-(12): General Health Questionnaire-(12 items); GIS: geographic information system; IQR: Interquartile range; K10: Kessler Psychological Distress Scale (10 items); POMS: Profile of Mood States; PSS: Perceived Stress Scale; RSE: Rosenberg Self-esteem Scale; SDQ: Strengths and Difficulties Questionnaire; VVI: Vertical Visibility Index.

[a] With 12697 observations included in the analysis.
[b] Not validated questionnaire or not clarified if the questionnaire is validated.
[c] Results are similar in a sensitive analysis including only those living within the 5 km buffer.
[d] With 1138481 observations included in the analysis.
[e] In total there were between 90084 and 136756 observations included in the analysis.
[f] In total there were between 56574 and 87573 observations included in the analysis.

Table 3
Main characteristics and results of the studies on physical activity.

Author (year, country)	Study design	Age of the study population	N	Blue space exposure	Tool to estimate blue space exposure	Outcome measured	Tools to measure outcome	Main results
Ball et al., 2007, Australia	Cross-sectional	Women18-65 years	1282	Coastal neighbourhood	Living (yes/no) in a coastal (bayside) suburb defined with GIS and Open Space 2002	Walking for leisure-time and transport	IPAQ (long version)	OR (95%CI) = 1.46 (1.02, 1.90) for leisure-time walking and 2.74 (2.20, 3.28) for transport walking
Bauman et al., 1999, Australia	Cross-sectional	Adults	16178	Coast	Use of the postal code to define coastal residence vs inland residence	Physical activity	Questionnaire (to measure energy expenditure)	OR (95%CI) = 0.77 (0.69, 0.87) for being sedentary, 1.27 (1.18, 1.37) for being adequately active, 1.38 (1.25, 1.52) for having a high level of activity
Edwards et al., 2014, Australia	Cross-sectional	Rural adolescents 12–15 years	1304	Beach	Distance from the residence to the closest beach using network analysis ($\leq$ 800 m and $>$ 800 m)	Use of beach for PA	Questionnaire[a]	OR (95%CI) of using the beach for PA in those living $>$ 800 m = 0.84 (0.51, 1.30) in winter and 0.68 (0.50, 0.93) in summer
					Use of beach for PA (yes/no)	Physical activity	APARQ (MetMins/ week values obtained)	OR of meeting PA guidelines if beach use reported = 1.45 (*p*-value = 0.01) during winter and 3.6 (95%CI = 1.9, 4.7) in summer
Elliot et al., 2015, UK	Cross-sectional	Adults > 16 years	71603	Seaside resort or other coast visits	Questionnaire asking for visits to seaside resorts or towns, or other coast sites in the last week	Physical activity	Questionnaire[a] (duration of the visit multiplied by METs associated to the activity performed during the visit)	β (95%CI) = 0.03 (0.02, 0.04) for seaside visits and 0.02 (0.01, 0.04) for other coast visits using urban greenspace visits as reference. If only walkers included then numbers are: 0.07 (0.05, 0.08) and 0.10 (0.07, 0.12), respectively
Gilmer et al., 2003, USA	Cross-sectional	Youth 11–14 years (children of parents with premature heart disease)	113	Coastal region	Geographic regions based on school location within the state of North Carolina	Physical activity	Youth Health Survey	Mean (SD) of levels of PA between regions: coastal 229 (3.68), piedmont 237 (3.31), mountains 252 (2.99). Differences were significant ($p < 0.05$) between coastal and the other two regions
Humpel et al., 2004a, Australia	Cross-sectional	Adults > 40 years	399	Costal geographical locations	Based on postal code	Neighbourhood walking	Questionnaire	Men: OR (95%CI) = 1.69 (0.69, 4.18) Women: 3.32 (1.51, 7.29)
						Exercise walking	Questionnaire	Men: 1.72 (0.70, 4.19) Women: 1.40 (0.62, 3.18)
						Pleasure walking	Questionnaire	Men: 1.59 (0.64, 3.95) Women: 1.65 (0.72, 3.82)
						Walking for commuting	Questionnaire	Men: 0.94 (0.40, 2.19) Women: 1.83 (0.87, 3.85)
Humpel et al., 2004b, Australia	Cross-sectional	Adults 18–71 years	800	Costal geographical locations	Based on postal code	Total walking	IPAQ	Men: OR (95%CI) = 1.01 (0.64, 1.59) Women: 1.00 (0.63, 1.58)
						Total physical activity	IPAQ	Men: 1.12 (0.70, 1.76) Women: 0.99 (0.63, 1.57)
						Neighbourhood walking	Questionnaire[a]	Men: 1.66 (1.04, 2.67) Women: 0.99 (0.62, 1.58)
Karusisi et al., 2012, France	Cross-sectional	Adults 30–79 years	7290[b]	Water (fresh)	Geographic unit was used to calculate% of area covered with water in a buffer of 1 km from the residence	Jogging behavior in the previous week (yes/no)	Questionnaire[a]	RR (95%CI) of jogging = 1.15 (1.03, 1.36)
Perchoux et al., 2015, France	Cross-sectional	Adults 30–79 years	4365	Lakes or waterways	Land-use maps to determine presence of lakes/waterways for different areas and buffers (residential − 1 km, work − 1 km, recreational − 500 m…)	(Not reporting) recreational walking time within and outside their neighbourhood in the previous week	Questionnaire[a]	OR (95%CI) = 0.84 (0.71, 0.99) for residential BS, 0.83 (0.70, 0.98) for residential + recreational BS, 0.96 (0.78, 1.18) for all BS
White et al., 2014, UK	Cross-sectional	Adults	183755	Coast	Land-cover map to determine residential distance to the coast (< 1 km, 1–5 km, 5–20 km, > 20 km)	Leisure and travel-related physical activity	Questionnaire[a]	OR (95%CI) for 5 days of 30 min of PA or more/week = 1.08 (1.03, 1.14) for distance < 1 km vs > 20 km, when adjusted for coastal visits = 0.93 (0.89, 0.98)
Wilson et al.,	Cross-	Adults 40–65 years	10286	Coastal visits River	Questionnaire MapInfo GIS	Time spent walking for	Questionnaire	OR (95%CI) = 1.62 (1.55, 1.69) OR (95%CI) of

(continued on next page)

Table 3 (*continued*)

Author (year, country)	Study design	Age of the study population	N	Blue space exposure	Tool to estimate blue space exposure	Outcome measured	Tools to measure outcome	Main results
2011, Australia	sectional			or coast	(quintiles) to define network distance from the residence to the river or the coast	recreation, exercise or to go to places in the last week		walking ≥ 300 min = 2.06 (1.41, 3.02) for those on Q1 (least distance) vs those on Q5 (greatest distance)
Witten et al., 2008, New Zealand	Cross-sectional	Adolescents and adults > 15 years	Between 11233 and 12425	Beach	GIS and land information New Zealand to obtain travel time to access the nearest beach and define access to (from the neighbourhood)	Sedentary behavior (< 30 min of PA in the past week)	Questionnaire[a]	OR (95%CI) for those living further from the beach (> 31.8 min walking) = 1.04 (0.81, 1.33)
						Meet the recommended level of PA (at least 2.5 h on five or more days in the preceding week)	Questionnaire[a]	OR (95%CI) for those living further from the beach = 0.88 (0.76, 1.03)
Ying et al., 2015, China	Cross-sectional	Adults 46–80 years	1100	River	GIS to define 500 m buffer distance to the river	PA	Pedometer	Coefficient (*p*-value) = −0.112 (0.231)

APARQ: Adolescent Physical Activity Recall Questionnaire; BMI: body mass index; BS: blue space; IPAQ: International Physical Activity Questionnaire; PA: physical activity.

[a] Not validated questionnaire or not clarified if the questionnaire is validated.

[b] The final number of subjects included in the analysis is not clear.

humans either proximally (being in, on, or near water) or distally/virtually (being able to see, hear or otherwise sense water)" (Grellier et al., 2017). Despite a rich and growing body of multi-faceted, qualitative and narrative work that is shedding important light on people's interactions with blue space environments, including their perceptions of potential health benefits (Foley and Kistemann, 2015; Völker and Kistemann, 2011), we know less about the quantitative, primarily epidemiological data that seeks to address questions such as "Is living near or having better access to blue space environments associated with positive health and well-being outcomes?". Although one systematic review, focusing on mortality, did seek to explore the relationship with blue space, in addition to more commonly researched green space, no studies were found at that time to have considered this association (Gascon et al., 2016). However, we know of far more studies that have looked at blue space and morbidity and well-being outcomes although as yet no systematic review of this literature has been conducted. The aim of the current paper was to fill this gap. Moreover, given that it has been hypothesized that any of the potential benefits to health and well-being from exposure to outdoor blue space may follow pathways similar to those identified for green space including stress reduction, increased physical activity, promotion of positive social contacts, increased place attachment and the reduction of extreme temperatures may also play a role for outdoor blue spaces (Grellier et al., 2017), the current review will explore this potential pathways as well.

2. Materials and methods

2.1. Search strategy and selection criteria

We followed the PRISMA statement guidelines for reporting systematic reviews and meta-analyses (Moher et al., 2010). The bibliographic search was conducted using MEDLINE (National Library of Medicine) and SCOPUS search engines and keywords related to outdoor blue spaces (*blue space, river*, *lake, sea, beach, fountains, riparian, oceans, coastal, marine*) combined with keywords related to health and well-being (*mood disorder*; *depressive disorder*; *depression*; *anxiety disorder*; *anxiety*; *obsessive-compulsive disorder*; *stress*; *mental health*; *mental hygiene*; *mental disorders*; *emotional well-being*; *psychological well-being*; *social well-being*; *well-being*; *cognitive function*; *health*; *cardiovascular diseases*; *heart diseases*; *blood pressure*; *hypertension*; *obesity*; *overweigh*; *weight*; *body mass index*; *BMI*) as well as keywords related to the potential mechanisms accounting for this association (*physical activity*; *social capital*; *social contacts*; *social support*). The search was limited to the English language and studies in humans and the last search was conducted on July 1st 2016. All studies published prior to that date and that followed the inclusion criteria were included in the systematic review. In order to have a potentially global overview; the country where the study had been conducted was not an inclusion criterion. Two authors (MG and WZ) independently identified and conducted the first screening of the articles based on the information available in the title and abstract by using the Rayyan tool (Elmagarmid et al. 2014); an online tool that provides procedural support in the selection of articles for systematic reviews. After this first screening stage; based on titles and abstracts; both authors independently read each article to decide whether or not these were eligible for inclusion. After this process; authors compared the final list of papers included by each of them and where disagreements or doubts were encountered the final decision was resolved by discussion between the two independent researchers. We also checked the references of the relevant articles and other sources to find additional articles following the inclusion criteria.

2.2. Study eligibility criteria and quality of the studies

The selection criteria were as follows: a) the article needed to be an original research article, b) all type of study designs were included (ecological, prospective, cross-sectional, case-control, and intervention

Table 4
Main characteristics and results of the studies on cardiovascular related outcomes and obesity.

Author (year, country)	Study design	Age of the study population	N	Blue space exposure	Tool to estimate blue space exposure	Outcome measured	Tools to measure outcome	Main results
Bergovec et al., 2008, Croatia	Cross-sectional	Adults 23–102 years (coronary heart disease patients)	3054	Coastal hospitals (vs continental)	Based on residence on a coastal region (not explained how it is defined)	Hypertension[a]	Physical measurements	OR (95%CI) = 0.73 (0.59, 0.89)
						Cholesterol and triglycerides		0.90 (0.68, 1.20) for total cholesterol, 0.74 (0.60, 0.92) for decreased HDL, 1.01 (0.81, 0.943) for triglycerides
						Diabetes		1.86 (0.69, 1.06)
Halonen et al., 2014, Finalnd	Longitudinal (8 years of follow-up)	Adults (urban areas)	25317 (15621 nonmovers and 9696 movers)	Lake, river, sea	Land-cover map to determine residential distance to each blue space (< 250 m to > 750m)	BMI (normal weight, overweight and obesity)	Self-reported height and weight	No associations and no patterns were observed between distance to blue spaces and BMI, neither among non-movers nor among movers. The only statistically significant association observed was for overweight vs normal weight in distance 500–750 m vs < 250 m in non-movers [OR (95%CI) = 1.24 (1.01, 1.52)]
Kern et al., 2009, Croatia	Cross-sectional	Adults	Not reported	Coastal region (vs continental)	Based on administrative divisions of the regions of the country (Adriatic sea)	Cardiovascular risk burden (CVRB)[b]	Not clearly reported	Prevalence of high CVRB in the coastal region = 46.3% (95%CI 40.9, 51.8) for men and 43.9% (41.4, 46.4) for women, and in the northern region = 53.1 (46.7, 59.6) and 54.2 (49.5, 58.9; $p < 0.05$), respectively
Modesti et al., 2013, Yemen	Cross-sectional	Adults 15–69 years	10242	Coast	Based on administrative divisions of the regions of the country	Hypertension	Physical measurements & self-reported use of antihypertensive drugs at time of interview	OR (95%CI) = 1.53 (1.25, 1.84) compared to participants living in the capital of the country
						Diabetes		0.88 (0.65, 1.20)
						Abdominal obesity		0.88 (0.72, 1.08)
Qin et al., 2013, China	Cross-sectional	Hypertensive adults 45–75 years	17656	Coastal county (vs inland)	Based on administrative divisions (two counties)	Overweight and obesity (BMI based)	Physical measurements	OR (95%CI) = 1.10 (1.02, 1.18) for those living inland vs coastal
						Abdominal obesity (waist circumference based)		OR (95%) = 1.53 (1.43, 1.64) for those living inland vs coastal
Turek et al., 2001, Croatia	Cross-sectional	Adults	5840	Coast	Based on residence in a coastal region	Hypertension[a]	Physical measurements	Difference with a *p*-value < 0.001 (coastal Rijeka = 20.6% and Split = 29.2% prevalence vs non-coastal Osijek 23.8% and Zagreb 30.9% prevalence)
						Cholesterol, triglycerides and lipoprotein		"No major differences between regions"
						BMI		"No major differences between regions"
Witten et al., 2008, New Zealand	Cross-sectional	Adolescents and adults > 15 years	Between 11233 and 12425	Beach	GIS and land information New Zealand to obtain travel time to access the nearest beach and define access to (from the neighbourhood)	BMI	Questionnaire[c]	β (95%CI) for those living further from the beach = 0.13 (0.07, 0.18)
Wood et al., 2016, UK	Ecological Cross-sectional	Children 10–11 years	1475617	Coast	Euclidean distance between population-weighted centroid and the coast	BMI > 95th percentile	Physical measurements	β (95%CI) for those living nearer (< 1 km) vs further (> 20 km) = −0.684 (-1.141, −0.227)
Ying et al., 2015, China	Cross-sectional	Adults 46–80 years	1100	River	GIS to define 500 m buffer distance to the river	BMI	Physical measurements	Coefficient (*p*-value) = 0.040 (0.16)

(continued on next page)

Table 4 (*continued*)

Author (year, country)	Study design	Age of the study population	N	Blue space exposure	Tool to estimate blue space exposure	Outcome measured	Tools to measure outcome	Main results
Zhang et al., 2014, China	Cross-sectional	Children 7–18 years	42296	Coastal districts (vs inland)	Based on administrative divisions (sixteen districts)	Overweight/obesity Abdominal obesity (waist circumference based)	Physical measurements	Coefficient (*p*-value) = 0.144 (0.022) Prevalence in boys = coastal (17.71%) and inland (14.97%), p < 0.01 Prevalence in girls = coastal (7.91%) and (6.72%), p < 0.01

BMI: body mass index.

[a] They also measure plasma fibrinogen levels.

[b] CVRB: variable created based on several cardiovascular related outcomes or determinants (cardiovascular related incidents, weight status, blood pressure, smoking status, physical activity levels, alcohol consumption, nutrion).

[c] Not validated questionnaire or not clarified if the questionnaire is validated.

studies), c) the article used quantitative data to report analysis of health and well-being, social or physical activity outcomes in relation to outdoor blue space exposure, d) outdoor blue space exposure was included as a separate variable within the analysis and results were reported specifically for outdoor blue space, even if this was not the primary aim of the study.

We extracted the following data: author, year of publication, country, study design, study population, sample size, exposure assessment, outcome assessment, confounding factors, and other relevant information including information on potential biases (Tables 1–4 and Supplemental material Table A). The data extraction work was conducted by the two authors independently, as well as the evaluation of their quality and classification of the evidence. Agreement was reached via consensus. Study quality evaluation was based on an adapted version of the criteria used in previous reviews in the green space field (Gascon et al., 2016, 2015). Further information on how the quality scores were given is provided in Table B of the Supplemental material. The following quality scores (%) were derived as follows (Supplemental material Table C): *excellent quality* (score ≥81%), *good quality* (between 61 and 80%), *fair quality* (between 41 and 60%), *poor quality* (between 21 and 40%) and *very poor quality* (≤20%). These quality scores facilitated establishing the degree of evidence for causal relationships (while recognizing that many of these studies are not designed to test causality directly) between outdoor blue spaces and the outcomes evaluated. The definitions of the degree of evidence for causal relationships used in the current systematic review are an adaptation of the International Agency for Research on Cancer (IARC) definition to define evidence of a causal relationship for cancer (IARC, 2006): *sufficient* – a positive relationship has been observed between the exposure and outcome in most of the studies, including good quality studies, in which chance, bias and confounding could be ruled out with reasonable confidence; *limited* – several good quality, independent, studies report a statistically significant association, but chance, bias or confounding cannot be rule out and therefore evidence is not yet conclusive enough; *inadequate* – if statistically significant associations are reported in one or more studies, but insufficient quality, insufficient number of studies, lack of consistency, and/or lack of statistical power preclude a conclusion regarding the presence or absence of a causal relationship; *evidence for lack of association* – several good quality studies are consistent in showing no causal relationship. We separately evaluated the evidence according to the different outcomes assessed in the studies included.

3. Results

We identified 2438 articles in MEDLINE and 2380 articles in SCOPUS and 33 through other sources. After screening the title and the abstracts and checking for duplicates, 91 articles were chosen for full-text evaluation, of which 35 articles were finally included in the systematic review as these fulfilled the inclusion criteria (Fig. 1).

Out of the 35 studies included, 29 had a cross-sectional design, of which three were ecological. Five studies were longitudinal and another had a pre-/post-observational study design. The quality of 35 the studies was mainly good (N = 22), but one study received a score of excellent quality, six studies were rated as fair and the remaining six studies received a score of poor quality (no study was rated as very poor; Supplemental material Table C).

All studies, except four, were conducted in high-income countries: twenty-one in Europe, including the United Kingdom (n = 11), Croatia (N = 3), Spain (N = 2), France (N = 2), The Netherlands (N = 1), Finland (N = 1), Ireland (N = 1). The other studies were conducted in Australia (N = 6), China (N = 3), New Zealand (N = 2), Canada (N = 1), the USA (N = 1) and Yemen (N = 1). Additionally, most studies included in this review were published in the last five years (N = 24).

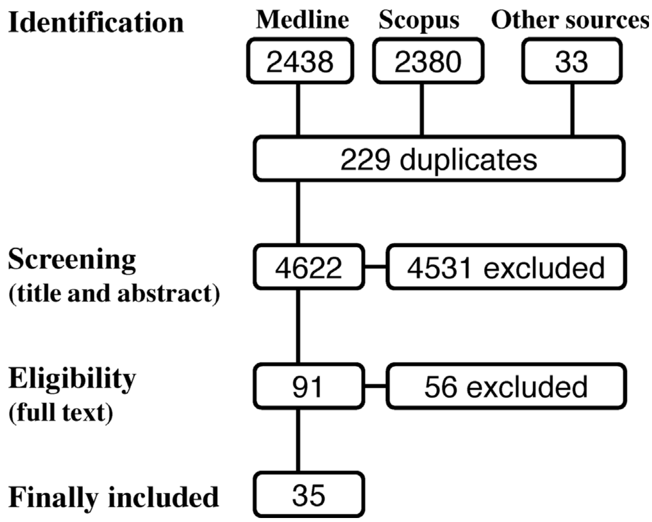

Fig. 1. Selection procedure of the articles.

3.1. Outdoor blue space exposure assessment

Regarding outdoor blue space exposure assessment we evaluated different aspects: outdoor blue space type (whether the outdoor blue space was inland – rivers, lakes, ponds, streams, rivulets, wetlands, fresh waters − or non-inland – including coast, beach, and salt waters), the environment of assessment (residential, school, leisure, etc.) and the method used to evaluate exposure to outdoor blue spaces (Fig. 2). For all three aspects there was a high heterogeneity among studies.

3.2. Inland, non-inland outdoor blue space

Most studies only focused on salt water and/or the coast (N = 20), while others combined fresh and salt water surfaces or inland and non-inland outdoor blue spaces in the analysis (N = 11). Only four were limited to only freshwater (Tables 1–4).

3.3. Outdoor blue space environment of assessment

Most studies (N = 28) focused on outdoor blue space exposure around individuals' residential area. Exceptions included three studies evaluating the use of outdoor blue spaces in general (Amoly et al., 2014; Elliott et al., 2015; White et al., 2013c), a study evaluating running routes (Rogerson et al., 2016), a study that focused on exposure to water bodies (e.g. oceans, lakes, rivers, streams) 5 km around schools (in addition to home residence (Huynh et al., 2013), a study that used school location as a proxy for home location (Gilmer et al., 2003), and a time-series study evaluating the real-time use of different spaces, including outdoor blue spaces (MacKerron and Mourato, 2013).

3.4. Method of evaluation

Six studies used land-cover or land-use maps and GIS techniques to define the percentage of outdoor blue spaces surface within a defined area (e.g. buffer or census area unit) (Alcock et al., 2015; de Vries et al., 2003; Huynh et al., 2013; Karusisi et al., 2012; Wheeler et al., 2015; White et al., 2013a). Two further studies used the land-cover and land-use maps to define the presence/absence of blue space water environments within a particular buffer (Perchoux et al., 2015; Triguero-Mas et al., 2015). Another common approach, also using land-cover and land-use maps and GIS-techniques, was measuring the distance between the residence, neighbourhood or school of the participants and the edge of outdoor blue space of interest (e.g. coastline); some studies evaluated linear distance (; Halonen et al., 2014; Wheeler et al., 2012; White et al., 2014, 2013b; Wood et al., 2016; Ying et al., 2015) and others network distance (Edwards et al., 2014; Wilson et al., 2011) or travelling time (Witten et al., 2008). GIS-techniques and land-cover maps were also used to define whether the study subjects lived in a coastal neighborhood (Ball et al., 2007). Three studies defined coastal vs. inland residence based on the postal code (Bauman et al., 1999; Humpel et al., 2004a, 2004b), whereas seven other studies defined exposure to coast based on whether the region of the country or the state had coast or not (Bergovec et al., 2008; Gilmer et al., 2003; Kern et al., 2009; Modesti et al., 2013; Qin et al., 2013; Turek et al., 2001; Zhang et al., 2014). The three studies that used questionnaires as the tool to define outdoor blue space exposure assessed the time spent in blue spaces (Amoly et al., 2014; Elliott et al., 2015; White et al., 2013c), whereas MacKerron and Mourato evaluated real-time exposure to outdoor blue spaces based on a smartphone application with geolocation linked to a land-cover map (MacKerron and Mourato, 2013). Nutsford et al. created an index, named Vertical Visibility Index (VVI), which takes into account different aspects of the built environment to define visibility of outdoor blue spaces (or any other type of natural space) from the residence of the participants, in this case within a buffer of 15 km (Nutsford et al., 2016). Rogerson et al. evaluated exposure to outdoor blue spaces by recruiting runners using the routes that included the beach or the river, and who were therefore considered to be exposed (Rogerson et al., 2016). Finally, Wheeler et al. also factored in freshwater quality, as well as quantity, using an index created by the Environmental Agency for England and Wales (Wheeler et al., 2015).

3.5. Outcomes

3.5.1. General health

General health was evaluated in six studies (Table 1) (de Vries et al., 2003; Triguero-Mas et al., 2015; Wheeler et al., 2015, 2012; White et al., 2013b; Ying et al., 2015). In four of these studies information on perceived general health and well-being was self-reported by the participants and was based on one single question (which is supposed to have a strong association with more complex dimensions of physical and psychological health) (de Vries et al., 2003; Wheeler et al., 2015, 2012; White et al., 2013b). The study by de Vries et al. additionally asked for the number of symptoms experienced in the last 14 days (a maximum of 43 health symptoms, including e.g. headaches, fatigue, cough) (de Vries et al., 2003). A study conducted in Spain used the Short Form health survey (SF-36) to define perceived general health (Triguero-Mas et al., 2015), whereas a study of the Chinese population asked the question "How do you feel about your health status?" (Ying et al., 2015) (Table 1).

Results for self-reported general health were heterogeneous; two ecological cross-sectional studies reported better perceived general health in relation to outdoor blue spaces (Wheeler et al., 2015, 2012). The first study observed this association among those living in urban areas less than 1 km from the coast compared to those living more than 50 km away, but not among those living in smaller towns or rural areas (Wheeler et al., 2012). The second study observed beneficial effects among those subjects with a higher percentage of salt and coastal water in their census area. However, no associations were observed with freshwater (Wheeler et al., 2015). A longitudinal study also reported better perceived general health among the same individuals when they lived less than 5 km from the coast compared to years when they lived further inland (White et al., 2013b). However, three cross-sectional studies reported no associations between perceived general health and the percentage of fresh or salt water present within a 3 km buffer (de Vries et al., 2003) or access to inland and non-inland outdoor blue spaces in buffers between 100 m and 1 km (Triguero-Mas et al., 2015; Ying et al., 2015). Although the pioneering de Vries (2003) study did not observe associations with perceived general health, it did observe a reduction in the number of symptoms reported by the participants associated with the percentage of fresh and salt water (de Vries et al., 2003). Finally, Wheeler et al. also evaluated whether ecological quality

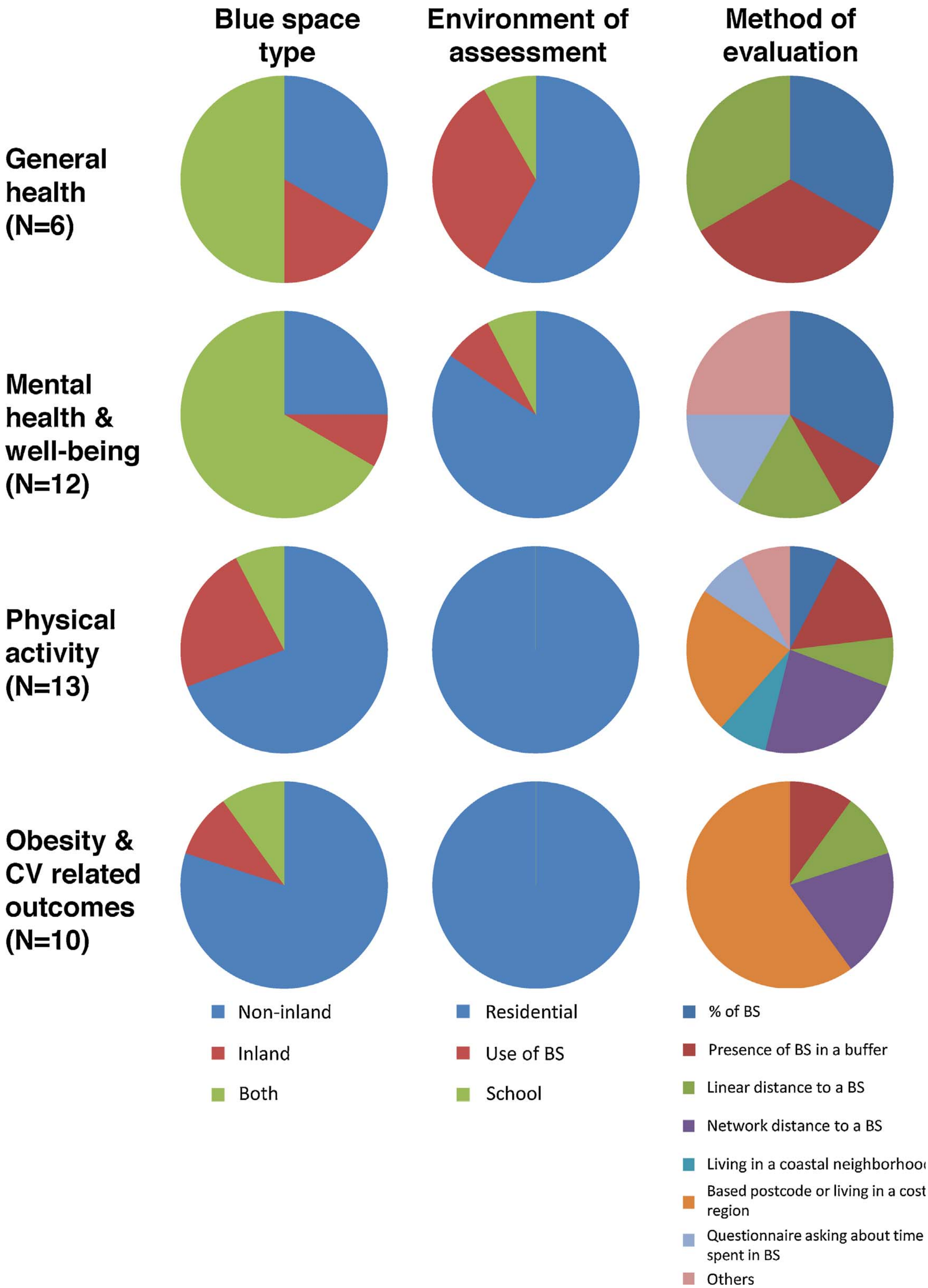

Fig. 2. Summary (%) of the blue space type, environment of assessment and the method of evaluation used in the studies included by each outcome assessed. BS: blue space; CV: cardiovascular.

of freshwater was associated with better perceived general health; however, they observed an inverse association (Wheeler et al., 2015) (Table 1).

Based on the few studies available, the quality of the studies, the heterogeneity in both study design and results obtained (Table 1), we classified the evidence of an association between outdoor blue space exposure and general health as '*inadequate*' to make a firm conclusion for either inland or coastal waters at this time.

3.5.2. *Mental health and well-being*

Mental health and well-being was evaluated in twelve studies (Alcock et al., 2015; Amoly et al., 2014; Brereton et al., 2008; de Vries et al., 2003; Huynh et al., 2013; MacKerron and Mourato, 2013; Nutsford et al., 2016; Rogerson et al., 2016; Triguero-Mas et al., 2015; White et al., 2013b, 2013c, 2013a) (Table 2). Tools to evaluate mental health varied substantially; five studies used the General Health Questionnaire (GHQ) (Alcock et al., 2015; de Vries et al., 2003; Triguero-Mas et al., 2015; White et al., 2013a, 2013b), with remaining studies using a variety of validated questionnaires measuring behavioral and emotional problems, well-being, self-esteem, mood, perceived stress, and psychological distress (Table 2). Six studies used either widely utilized single item measures of well-being e.g. life satisfaction (Brereton et al., 2008; White et al., 2013a, 2013b), happiness (MacKerron and Mourato, 2013) with unknown validity; constructed original scales based on the content of existing surveys e.g. recalled mental restoration (White et al., 2013c) or perceived depression or anxiety, and visits to mental health specialists and medication intake (Triguero-Mas et al., 2015), within untested psychometric properties.

Three of the five studies using the GHQ to evaluate mental health did not observe associations with the percentage of residential fresh or salt water within the area of study (de Vries et al., 2003; White et al., 2013a) or access to inland and non-inland outdoor blue spaces between 100 m and 1 km (Triguero-Mas et al., 2015). Triguero-Mas et al. also failed to find a significant association with perceived depression or anxiety, visits to mental health specialists or medication intake (tranquilizers, antidepressants, sleeping medication) (Triguero-Mas et al., 2015). However, two other studies, both using data from an 18 year longitudinal survey in the UK, reported positive associations; the first study observed that people's mental health was better in years when they lived less than 5 km from the coast, compared to years when they were living further inland (White et al., 2013b). The second study, including residents from rural areas, found that while greater exposure to purely coastal areas was again associated with better GHQ scores (over time), quantities of saltwater (estuaries) was associated with worse GHQ scores (over time) (Alcock et al., 2015).These differences were found for people moving between different areas over time, while cross-sectional analyses did not reveal any significant patterns (similarly to most cross-section findings), suggesting that moving location (to ones with more or less blue space) may affect outcomes, but that people may adapt in the long-term so that these differences wash-out over time. White et al. additionally evaluated life satisfaction as a proxy for well-being, but the authors did not observe associations with residential coastal or freshwater distance (White et al., 2013a, 2013b). A third study including life satisfaction reported that those individuals living < 2 km from the coast were more satisfied with their life than those living > 5 km. No associations were observed with distances between 2 and 5 km and with residential distance from the beach (Brereton et al., 2008). Nutsford et al. reported a reduction of psychological distress with increasing outdoor blue space (oceanic and freshwater) visibility from the home in a buffer of 15 km (Nutsford et al., 2016). Finally, Huyhn et al. used the percentage of water bodies within a 5 km buffer around schools to define exposure to outdoor blue spaces in children aged 11–16 years (Huynh et al., 2013). The study observed that increasing exposure to water bodies increased emotional well-being, even after excluding children living outside the 5 km buffer around the schools (Huynh et al., 2013) (Table 2).

Three studies evaluated the effects of time spent at the beach (Amoly et al., 2014) or any blue space (MacKerron and Mourato, 2013; White et al., 2013c). The first study observed that children (7–10 years) whose parents reported spending more time at the beach during the year had less emotional problems and more pro-social behavior, but no associations were found with Attention Deficit Hyperactivity Disorder (ADHD) symptoms (Amoly et al., 2014). The second study used GPS and a smartphone application for geolocalization, as well as a real-time questionnaire about happiness, which the same individuals completed in many different locations. The results showed that individuals were happier when they reported being in marine and coastal areas, as well as freshwater, wetlands and flood plains than when they were in any other type of urban or rural setting (MacKerron and Mourato, 2013) (Table 2). The third study reported that adolescents and adults spending more time at the beach or the coast had better recalled restoration than urban green spaces (i.e. felt more relaxed/refreshed). However, this association was not statistically significant among those spending more time at inland waters such as rivers, lakes or canals (White et al., 2013c).

Finally, in a pre-/post-observational study, Rogerson et al. did not observe significant differences in self-esteem, perceived stress or mood between runners running along beach or riverside routes compared to those running along other routes called the "grass" and the "heritage" routes before and after the running (Rogerson et al., 2016) (Table 2).

Although some good quality studies reported an association between residential and the use of outdoor blue spaces and mental health and well-being, the number of studies is still limited and there is heterogeneity in study design and results among and within them (Table 2). We therefore feel that, based on the classification criteria defined, the most appropriate classification is '*limited*' for both inland and coastal waters.

3.5.3. Physical activity

Thirteen cross-sectional studies focused on the promotion of physical activity (Ball et al., 2007; Bauman et al., 1999; Edwards et al., 2014; Elliott et al., 2015; Gilmer et al., 2003; Humpel et al., 2004a, 2004b; Karusisi et al., 2012; Perchoux et al., 2015; White et al., 2014; Wilson et al., 2011; Witten et al., 2008; Ying et al., 2015) (Table 3). Six of these studies used non-validated questionnaires, or at least the validation was not reported, whereas the other seven studies used validated tools. Two of these studies used the International Physical Activity Questionnaire (IPAQ) (Ball et al., 2007; Humpel et al., 2004b), another the Youth Health Survey (YHS) (Gilmer et al., 2003), Edwards et al. used the Adolescent Physical Activity Recall Questionnaire (APARQ) (Edwards et al., 2014) and Ying et al. used a pedometer (Ying et al., 2015). Wilson et al. reported previous validation of the questionnaire, but only in a sample of middle-aged women (Wilson et al., 2011), and Bauman et al. also referred to validity and reliability studies for the questionnaire used (Bauman et al., 1999) (Table 3). Additionally, six of the studies defined exposure based on a relatively coarse assessment of proximity to coastal areas (Ball et al., 2007; Bauman et al., 1999; Gilmer et al., 2003; Humpel et al., 2004a, 2004b; Wood et al., 2016), and not on the actual distance between the coastal areas and the address of residence of the participants (Table 3).

The studies using this relatively coarse exposure assessment obtained diverse results; Ball et al. reported increasing leisure-time and transport walking among adult women living in coastal suburbs (Ball et al., 2007). Bauman et al. also reported a higher likelihood of having a less sedentary lifestyle and achieving an adequate weekly energy expenditure or high levels of physical activity among those adults who lived near the coast (Bauman et al., 1999). However, two other studies including adults did not report associations between living in a coastal area and levels of physical activity (Humpel et al., 2004a, 2004b); only two statistically significant associations were observed in these two studies among the several results reported for men and women separately (Table 3). Finally, a study including youth aged 11–14 years with a parental history of premature coronary heart disease reported statistically significantly lower levels of mean physical activity among youth living in coastal areas compared to non-coastal areas (Gilmer et al., 2003).

In a French cross-sectional study involving adults from 30 to 79 years of age the percentage of inland water in a buffer of 1 km from the residence was associated with reporting jogging behavior in the previous week (Karusisi et al., 2012). Some years later a similar methodology was applied, but in this case the exposure was defined as the presence of lakes or waterways in different spaces (residential, recreational, work, groceries, social and services) and buffers (Table 3) and the outcome was the reporting of recreational walking in the previous week (Perchoux et al., 2015). The results showed that subjects with access to residential and/or recreational blue spaces were less likely to not report recreation walking in the previous week. However, when outdoor blue spaces from all types of space were included in the analysis no association was observed (Perchoux et al., 2015) (Table 3). In another study distance from the beach, measured as the driving travel time to access the nearest beach, was not associated with meeting the recommended levels of physical activity (at least 2.5 h on five or more days over the preceding week) in adolescents and adults above 15 years of age (Witten et al., 2008). However, those living between 9.2 and 31.8 min from the beach were more likely to report a sedentary behavior profile (< 30 min of physical activity in the past week) compared to those living less than 9.2 min. No associations were observed among those living further than 31.8 min walking distance to the coast (Witten et al., 2008). A study including adults of 40–65 years of age in Australia reported that living in a shorter network distance to the river or the coast was associated with spending more time walking for recreation (≥ 300 min/week) (Wilson et al., 2011). However, a similar study in China reported no associations between living within 500 m from the river and physical activity measured with a pedometer (Ying et al., 2015). Again in Australia, Edwards et al. observed that rural adolescents reporting the use of the beach for physical activity were more likely to meet physical activity guidelines both in summer and winter, and that those living more than 800 m from the beach were less likely to report using the beach for physical activity than those living less than 800 m (Edwards et al., 2014). Related to visits to blue spaces and levels of physical activity, a study showed that living < 1 km from the coast statistically significantly increased the likelihood of doing 30 min or more of physical activity at least 5 days a week compared to those living more than 20 km from the coast. The study also showed that this association was mediated by the number of coastal visits and that coastal visits were associated to residential distance from the coast (White et al., 2014). Elliott et al. also reported increased levels of physical activity (MET min based on activity and duration of the activity) among those who visited coastal areas (seaside resort and other coastal visits) compared to inland urban and rural green spaces (Elliott et al., 2015).

Despite the heterogeneity in relation to the study design, mainly in exposure and outcome assessment, most of the studies (N = 8/13) were of good quality. Five of these good quality studies reported increasing levels of physical activity with increasing exposure to outdoor blue spaces (Table 3). Nevertheless, despite this relatively consistent association, we classified the evidence for an association as '*limited*' given the methodological heterogeneities between studies. This classification of the evidence was mainly for non-inland waters, as most of the studies evaluated only beach and coastal areas (N = 9/13).

3.5.4. Obesity and cardiovascular related outcomes

Eight studies evaluated obesity related outcomes in relation to blue spaces (Table 4). The only longitudinal study (8 years of follow-up) evaluating the relationship between residential distance to blue spaces (lakes, rivers or sea) and overweight and obesity did not find a significant pattern of associations, either among people who moved home residence over the time or those who did not (Halonen et al., 2014). Two cross-sectional studies comparing adults of coastal and non-coastal areas also failed to find any associations with abdominal obesity (Modesti et al., 2013) or statistically significant differences in BMI between regions (Turek et al., 2001). However, two Chinese studies with a similar study design to those of Modesti et al. and Turek et al. obtained heterogeneous results; Qin et al. reported increased risk of overweight, obesity and abdominal obesity among hypertensive adults aged 45–75 years living inland compared to those living in the coastal county, whereas Zhang et al. reported higher prevalence of abdominal obesity among children (7–18 years) living in coastal districts. Ying et al. found no association between living within 500 m distance from a river and BMI (continuous variable) in adults (40–80 years), but did find increased overweight/obesity (as compared to normal weight participants) in this range. In the cross-sectional study of Witten et al., where the estimated driving time to the nearest beach was used as a proxy for the distance to the beach, the BMI (self-reported) of adolescents and adults was higher among those living further (> 31.8 min) from the beach compared to those living less than 31.8 min (Witten et al., 2008). A second study, of ecological design, observed that children living less than 1 km from the coast in England had a lower BMI than those living further (more than 20 km) (Wood et al., 2016) (Table 4).

Four cross-sectional studies also evaluated other outcomes related to cardiovascular disease and diabetes (Table 4). All of these studies based exposure on the region of residence of study subjects (coastal and non-coastal areas). Regarding hypertension, one study reported reduced hypertension among adult coronary heart disease patients in hospitals located in coastal areas (Bergovec et al., 2008). However, another study reported increased risk of hypertension among residents of coastal areas (Modesti et al., 2013) and the other study only reported statistically significant differences in hypertension prevalence in four different regions, but no gradient in distance to the coast (Turek et al., 2001). Finally, Kern et al. defined cardiovascular risk burden (CVRB) based on several cardiovascular factors (Table 4). The authors observed differences between regions, reporting higher prevalence of CVRB among those living in the continental regions compared to those living in the coastal region, particularly among women (Table 4) (Kern et al., 2009).

No associations or statistically significant differences were reported in relation to cholesterol and triglyceride levels in the two studies that evaluated the relationship with blue spaces (Bergovec et al., 2008; Turek et al., 2001). Only a reduced risk of decreased high-density lipoproteins (HDL) − they transport fat molecules out of artery walls to the liver − was observed in one of the studies (Bergovec et al., 2008). No associations with blue space proximity and diabetes were observed in the two studies that investigated this association (Bergovec et al., 2008; Modesti et al., 2013) (Table 4).

Given the very limited number of studies examining these outcomes and high heterogeneity in the study design and in the results obtained, we classified the evidence supporting a causal relationship between exposure to blue spaces and cardiovascular disease and diabetes as '*inadequate*'.

4. Discussion

In the present review we evaluated the current quantitative evidence on the relationship between exposure to outdoor blue space environments such as rivers, lakes and the coast, with a range of health and well-being outcomes. The 35 studies that were selected used a wide range of exposures and outcomes. The body of evidence suggested a positive association between exposure to outdoor blue spaces and mental health and well-being and the promotion of physical activity; however the evidence of any direct causation was '*limited*'. The evidence of an association between outdoor blue space and general health was even weaker, as was the evidence with respect to obesity and cardiovascular related outcomes, in part due to the paucity of studies to date. Further, the review found a large degree of heterogeneity across studies in terms of design, exposures, outcomes assessed and measurement tools, preventing any possibility of conducting meta-analysis.

4.1. Study design

Most of the studies included in the review were of cross-sectional design, which are of course unable to rule out reverse causation (e.g. those with better mental health are more likely to move to areas with high residential blue space exposure). Indeed, some of these studies were ecological, a design open to the ecological fallacy, and very few were used longitudinal data. Furthermore, the study evaluating pre-and post- exposure measurement had a number of study design limitations (Rogerson et al., 2016). For instance, study participants were people already running in each of the routes established, and these same people did not run along the other routes (Rogerson et al., 2016). Overall, there is a need for more well-designed longitudinal and intervention studies.

4.2. Outdoor blue spaces exposure assessment and other urban determinants

The present review highlights the high heterogeneity among studies considering outdoor blue spaces exposure assessment. In order to facilitate comparability between studies and meta-analyses, efforts to conduct common approaches are recommended in future. To this end we suggest a number of things which could be considered in the future. First, although the main interest of a particular study was usually one type of outdoor blue space (e.g.% of or distance to seawater), other types of outdoor blue spaces could (perhaps even should) be included in the analysis as well (e.g.% inland water), to simultaneously explore multiple blue spaces, and reduce potential confounding across blue space types and aid comparability across more studies. Also, as green spaces are a significant part of natural environments and are often highly correlated with outdoor blue spaces and the outcomes of interest, green spaces should also be included in the analysis (see Supplemental material Table A for studies in the current review that did do this), to clarify how the two exposures potentially interact or play the largest role. Other characteristics of blue spaces also need greater consideration in future work, e.g. ease of accessibility to a particular outdoor blue space (e.g. presence of busy roads, high slopes, etc) or degree of urbanity. This would provide more accurate information on the actual potential exposure to a particular outdoor blue space. Another important aspect to consider is the inclusion of the actual use (and the type of uses) of outdoor blue spaces in order to more accurately estimate actual exposure. Finally, one aspect that limits the inference of long-term effects of outdoor blue spaces is the fact that some of the studies did not take into account residential history (e.g. most did not report whether or not respondents had been living in their current home for at least 12 months). On a related point, even in the few longitudinal studies it was assumed that blue spaces were constant over time but there may have been important changes in terms of the development of reservoirs, changes in river courses or coastlines which may have altered proximity for access to blue spaces within a given residential area over time. Again, blue space studies should try and capture these longitudinal changes in exposures when possible although we recognize that this is often difficult (Pearce et al., 2016). Additionally, linkage of (historical) residential information to clinical databases or cohort data provide great opportunities for blue health research and environmental epidemiology in general, but researchers and data providers should be aware of potential privacy issues associated with geographic data (Bovenberg et al., 2016). It should also be acknowledged that many studies were using a relatively coarse assessment of coastal proximity (e.g. living in a coastal area or non-coastal area) and there was also considerable heterogeneity in blue space measurement limiting our ability to make direct comparison across studies or conduct meta-analyses. Future research would benefit from more standardized percentage of land cover buffers and/or network distance parameters.

4.3. Outcome assessment

Our literature search resulted in studies focusing on various outcomes: general health, mental health, physical activity, obesity and cardiovascular related outcomes. Many studies included in the present review used non-validated questionnaires, especially studies which focused on physical activity. In this sense, future studies should make use of existing standardized and validated questionnaires, although we recognize that much of this literature is relying on secondary datasets which the authors may not be able to influence in terms of item inclusion. Furthermore, in the case of physical activity, nowadays GIS techniques, apps and smartphones allow researchers to obtain more accurate estimates of both physical activity and exposure through processes of geospatial linkages (Bell et al., 2015; Bort-Roig et al., 2014; Donaire-Gonzalez et al., 2013) or real-time information on different health outcomes, as done by MacKerron et al. (MacKerron and Mourato, 2013). Tools evaluating the use of the outdoor blue spaces and the levels of physical activity conducted around or in these spaces are also an interesting option (McKenzie et al., 2006).

4.4. Mediators

As stated in the introduction, stress, physical activity, social contacts and place attachment, and the reduction of extreme temperatures, are potential pathways of the association between outdoor blue spaces and health and well-being indicators. In the present review only one article attempted to examine mediation (i.e. visit frequency as a function of coastal proximity, White et al., 2014), and thus far more work is needed in order to understand whether certain health determinants could explain the associations observed between outdoor blue spaces and health. Indeed, a recent systematic review on green spaces and mental health highlighted that some of the included studies observed that the health benefits of green spaces could be mediated by some of these variables (Gascon et al., 2015). Including these analyses would help understand the mechanisms of the association between outdoor blue spaces and health.

4.5. Effect modifiers

It is also necessary to identify specific populations that could benefit more from urban planning actions (i.e. neighbourhoods of lower socioeconomic positions, women, children, elderly, etc.), in order to reduce health inequalities (WHO, 2012). In fact, Wheeler et al. conducted such analyses and observed that beneficial effects of outdoor blue spaces were largest in lower socioeconomic areas (Wheeler et al., 2015, 2012) but none of the other studies in this review explored this issue.

4.6. Limitations of this review

Although we believe this is the first systematic review in this area and we endeavored to use standard reviewing and grading protocols, we also recognize several limitations. First, the concept of “blue space” has not been widely used compared to, for instance, green space. In the present review we used search terms based on the keywords and title words used in the articles that we already knew about on the topic. However, at the end, and despite the efforts to find all relevant articles, only 18 of the 35 articles included in the review were found through the traditional online search databases; the rest were obtained through other means such as searching citations of included papers, which may have resulted in some key papers being missed. The causes for not detecting half of the papers through the standard research tools could be that: 1) the blue spaces concept, in contrast with green spaces, is not a common concept; or that 2) some studies were not directly designed to evaluate health impacts of outdoor “blue exposure” but rather of several urban characteristics, and did not focus on these relationships in titles or abstracts despite having examined them. In this sense, the BlueHealth project aims to explore this concept and to provide recognition and importance to these spaces, both in research and in the implementation of policies to promote and protect public health. We also recognize that scoring the quality of the papers and classifying the evidence is associated with a degree of subjectivity (e.g. “was there careful consideration of confounders” is open to interpretation). In the present review, in order to reduce subjectivity and bias within the review process itself, two independent reviewers conducted the quality appraisal of each paper independently and disagreements discussed between the two reviewers, but again some bias may still have occurred. Even if this was the case, however, we do not feel that the overall conclusions from our review would substantially change if certain studies were reclassified as from fair to poor or good and vice versa, given the few number of available studies and the heterogeneity among them regarding study design. We also of course recognize the possibility of publication bias, which may be inflating the number of positive associations in the extant literature.

4.7. Other aspects to be considered

For this systematic review we decided to exclude qualitative research, as we aimed to focus on those studies quantifying the health impacts of blue spaces. However, we still think it is important to recognize the existing qualitative evidence in this field of research, which already suggests a range of benefits of being exposed to blue spaces (Finlay et al., 2015; Foley, 2015; Foley and Kistemann, 2015; Kearns et al., 2015; lker and Kistemann, 2015, 2011; lker and Kistemann, 2015, 2011), and indeed, addresses aspects that quantitative research often cannot or does not evaluate, such as perception, sensory exposure, or experiences that could explain the associations found by those studies conducting quantitative research. Moreover, this type of research is very relevant and should also be considered by policy makers when conducting interventions in urban or natural environments involving blue spaces.

In the current systematic review none of the studies addressed potential negative impacts of blue spaces or aspects related to blue spaces (e.g. drowning, pollution, flooding, etc). Far more work has been conducted on these issues already, which is why we focus on the benefits here, but there is no doubt that when a more complete picture of the benefits emerges it will be time to conduct the kind of full cost-benefit analyses usually required by policy makers (Grellier et al., 2017).

Finally, the relationship that people establish with blue spaces can be different across cultures and climates worldwide, and therefore blue spaces may have different meanings, functions and impacts on health and well-being. In the current review we included studies from different countries, but studies from the United Kingdom and Australia represented a large part of the included studies (49%). Therefore, our conclusions must be tentative at this point given the possibility of inherent "cultural bias". In this sense, international projects like BlueHealth, in which the same approaches and methodologies are applied in many countries or geographical areas at once, may help to better understand any cultural similarities or differences, and what role climatic factors may play in these issues.

5. Conclusion

As far as we are aware, this is the first systematic review of quantitative studies on outdoor blue spaces and human health and well-being. Results indicate this is emerging topic, as most of the studies have been conducted in the last five years. Also, results suggest potential health benefits of outdoor blue spaces, mainly with respect to mental health and well-being and the promotion of physical activity. However, further studies, with methodological improvements, standardized exposure and outcome measures enabling comparison across cultures and climates, and including urban health determinants other than outdoor blue spaces are needed in order to advance in our knowledge on the topic. Despite the limitations, current scientific evidence supports the promotion and recovery of outdoor blue spaces within urban planning as an interesting strategy for the promotion of health and well-being.

Funding

This project has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement No 666773. The authors have no conflicts of interest.

Acknowledgements

ISGlobal is a member of the CERCA Programme, Generalitat de Catalunya. The authors would like to thank Dieneke Schram, Jeroen Van Leuken and Tanja Wolf for their comments and advice.

Appendix A. Supplementary data

Supplementary data associated with this article can be found, in the online version, at http://dx.doi.org/10.1016/j.ijheh.2017.08.004.

References

Alcock, I., White, M.P., Lovell, R., Higgins, S.L., Osborne, N.J., Husk, K., Wheeler, B.W., 2015. What accounts for Englands green and pleasant land'? A panel data analysis of mental health and land cover types in rural England. Landsc. Urban Plan. 142, 38–46.

Amoly, E., Dadvand, P., Forns, J., López-Vicente, M., Basagaña, X., Julvez, J., Alvarez-Pedrerol, M., Nieuwenhuijsen, M.J., Sunyer, J., 2014. Green and blue spaces and behavioral development in barcelona schoolchildren: the BREATHE project. Environ. Health Perspect. 122 (December (2)), 1351–1358.

Ball, K., Timperio, A., Salmon, J., Giles-Corti, B., Roberts, R., Crawford, D., 2007. Personal, social and environmental determinants of educational inequalities in walking: a multilevel study. J. Epidemiol. Commun. Health 61, 108–114.

Bauman, A., Smith, B., Stoker, L., Bellew, B., Booth, M., 1999. Geographical influences upon physical activity participation: evidence of a coastal effect. Aust. N. Z. J. Public Health 23, 322–324.

Bell, S.L., Phoenix, C., Lovell, R., Wheeler, B.W., 2015. Seeking everyday wellbeing: the coast as a therapeutic landscape. Soc. Sci. Med. 142.

Bergovec, M., Reiner, Z., Milicić, D., Vrazić, H., 2008. Differences in risk factors for coronary heart disease in patients from continental and Mediterranean regions of Croatia. Wien. Klin. Wochenschr. 120, 684–692.

Bort-Roig, J., Gilson, N.D., Puig-Ribera, A., Contreras, R.S., Trost, S.G., 2014. Measuring and influencing physical activity with smartphone technology: a systematic review. Sports Med. 44, 671–686.

Bovenberg, J.A., Knoppers, B.M., Hansell, A., de Hoogh, K., 2016. Exposing participants?: Population biobanks go geo. Eur. J. Hum. Genet. 24, 155–156.

Brereton, F., Clinch, J.P., Ferreira, S., 2008. Happiness, geography and the environment. Ecol. Econ. 65, 386–396.

Burkart, K., Meier, F., Schneider, A., Breitner, S., Canário, P., Alcoforado, M.J., Scherer, D., Endlicher, W., 2016. Modification of heat-related mortality in an elderly urban population by vegetation (Urban green) and proximity to water (Urban blue) evidence from Lisbon, Portugal. Environ. Health Perspect. 124, 927–934.

Dadvand, P., Bartoll, X., Basagaña, X., Dalmau-Bueno, A., Martinez, D., Ambros, A., Cirach, M., Triguero-Mas, M., Gascon, M., Borrell, C., Nieuwenhuijsen, M.J., 2016. Green spaces and General Health Roles of mental health status, social support, and physical activity. Environ. Int. 91, 161–167.

de Vries, S., Verheij, R.A., Groenewegen, P.P., Spreeuwenberg, P., 2003. Natural environments − healthy environments? An exploratory analysis of the relationship between greenspace and health. Environ. Plan. A 35, 1717–1731.

Donaire-Gonzalez, D., de Nazelle, A., Seto, E., Mendez, M., Nieuwenhuijsen, M.J., Jerrett, M., 2013. Comparison of physical activity measures using mobile phone-based CalFit and Actigraph. J. Med. Internet Res. 15, e111. http://dx.doi.org/10.2196/jmir.2470.

Dzhambov, A.M., Dimitrova, D.D., 2014. Urban green spaces' effectiveness as a psychological buffer for the negative health impact of noise pollution: a systematic review. Noise Health 16, 157–165.

Dzhambov, A.M., Dimitrova, D.D., Dimitrakova, E.D., 2014. Association between residential greenness and birth weight: systematic review and meta-analysis. Urban For. Urban Green. 13.

Edwards, N.J., Giles-Corti, B., Larson, A., Beesley, B., 2014. The effect of proximity on park and beach use and physical activity among rural adolescents. J. Phys. Act. Heal. 11, 977–984.

Elliott, L.R., White, M.P., Taylor, A.H., Herbert, S., 2015. Energy expenditure on recreational visits to different natural environments. Soc. Sci. Med. 139, 53–60.

Elmagarmid, A., Fedorowicz, Z., Hammady, H., Ilyas, I., Khabsa, M., Ouzzani, M., 2014. Rayyan: a systematic reviews web app for exploring and filtering searches for eligible studies for Cochrane Reviews. Evidence-Informed Public Health: Opportunities and Challenges. Abstracts of the 22nd Cochrane Colloquium. John Wiley & Sons, Hyderabad, India, India.

Finlay, J., Franke, T., McKay, H., Sims-Gould, J., 2015. Therapeutic landscapes and wellbeing in later life: impacts of blue and green spaces for older adults. Health Place 34, 97–106.

Foley, R., Kistemann, T., 2015. Blue space geographies: enabling health in place. Health Place 35, 157–165.

Foley, R., 2015. Swimming in Ireland: immersions in therapeutic blue space. Health Place 35, 218–225.

Gascon, M., Triguero-Mas, M., Martínez, D., Dadvand, P., Forns, J., Plasència, A., Nieuwenhuijsen, M., 2015. Mental health benefits of long-term exposure to residential green and blue spaces: a systematic review. Int. J. Environ. Res. Public Health 12 (April 22 (4)), 4354–4379.

Gascon, M., Triguero-Mas, M., Martínez, 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.

Gilmer, M.J., Harrell, J.S., Miles, M.S., Hepworth, J.T., 2003. Youth characteristics and contextual variables influencing physical activity in young adolescents of parents with premature coronary heart disease. J. Pediatr. Nurs. 18, 159–168.

Grellier, J., White, M.P., Albin, M., Bell, S., Elliott, L.R., Gascón, M., Gualdi, S., Mancini, L., Nieuwenhuijsen, M.J., Sarigiannis, D.A., van den Bosch, M., Wolf, T., Wuijts, S., Fleming, L.E., 2017. BlueHealth: a study programme protocol for mapping and quantifying the potential benefits to public health and well-being from Europe's blue spaces. BMJ Open 7, e016188.

Halonen, J.I., Kivimäki, M., Pentti, J., Stenholm, S., Kawachi, I., Subramanian, S.V., Vahtera, J., 2014. Green and blue areas as predictors of overweight and obesity in an 8-year follow-up study. Obesity (Silver Spring) 22, 1910–1917.

Hartig, T., Mitchell, R., de Vries, S., Frumkin, H., 2014. Nature and health. Annu. Rev. Public Health 35, 207–228.

Humpel, N., Owen, N., Iverson, D., Leslie, E., Bauman, A., 2004a. Perceived environment attributes, residential location, and walking for particular purposes. Am. J. Prev. Med. 26, 119–125.

Humpel, N., Owen, N., Leslie, E., Marshall, A.L., Bauman, A.E., Sallis, J.F., 2004b. Associations of location and perceived environmental attributes with walking in neighborhoods. Am. J. Health Promot. 18, 239–242.

Huynh, Q., Craig, W., Janssen, I., Pickett, W., 2013. Exposure to public natural space as a protective factor for emotional well-being among young people in Canada. BMC Public Health 13, 407.

IARC, (International Agency for Research on Cancer), 2006. Preamble to the IARC Monographs (amended January 2006). Scientific Review and Evaluation. [WWW Document]. http://monographs.iarc.fr/ENG/Preamble/currentb6evalrationale0706.php.

Kabisch, N., Qureshi, S., Haase, D., 2015. Human–environment interactions in urban green spaces—a systematic review of contemporary issues and prospects for future research. Environ. Impact Assess Rev. 50, 25–34.

Karusisi, N., Bean, K., Oppert, J.-M., Pannier, B., Chaix, B., 2012. Multiple dimensions of residential environments, neighborhood experiences, and jogging behavior in the RECORD Study. Prev. Med. (Baltim.) 55, 50–55.

Kearns, R.A., Collins, D., Conradson, D., 2015. Reprint of: a healthy island blue space: from space of detention to site of sanctuary. Health Place 35, 178–186.

Kern, J., Polasek, O., Milanović, S.M., Dzakula, A., Fister, K., Strnad, M., Ivanković, D., Vuletić, S., 2009. Regional pattern of cardiovascular risk burden in Croatia. Coll. Antropol. 33 (Suppl 1), 11–17.

Lee, A.C.K., Maheswaran, R., 2011. The health benefits of urban green spaces: a review of the evidence. J. Public Health (Oxf.) 33, 212–222.

MacKerron, G., Mourato, S., 2013. Happiness is greater in natural environments. Glob. Environ. Chang. 23, 992–1000.

McKenzie, T.L., Cohen, D.A., Sehgal, A., Williamson, S., Golinelli, D., 2006. System for observing play and recreation in communities (SOPARC): reliability and feasibility measures. J. Phys. Act. Health 3 (Suppl 1), S208–S222.

Modesti, P.A., Bamoshmoosh, M., Rapi, S., Massetti, L., Al-Hidabi, D., Al Goshae, H., 2013. Epidemiology of hypertension in Yemen: effects of urbanization and geographical area. Hypertens. Res. 36, 711–717.

Moher, D., Liberati, A., Tetzlaff, J., Altman, D.G., 2010. Preferred reporting items for systematic reviews and meta-analyses: the PRISMA statement. Int. J. Surg. 8, 336–341.

Nieuwenhuijsen, M.J., Khreis, H., Triguero-Mas, M., Gascon, M., Dadvand, P., 2017. Fifty shades of green: pathway to healthy urban living. Epidemiology 28, 63–71.

Nutsford, D., Pearson, A.L., Kingham, S., Reitsma, F., 2016. Residential exposure to visible blue space (but not green space) associated with lower psychological distress in a capital city. Health Place 39, 70–78.

Pasanen, T.P., Tyrväinen, L., Korpela, K.M., 2014. The relationship between perceived health and physical activity indoors outdoors in built environments, and outdoors in nature. Appl. Psychol. Health Well Being 6, 324–346.

Pearce, J., Shortt, N., Rind, E., Mitchell, R., 2016. Life course, green space and health: incorporating place into life course epidemiology. Int. J. Environ. Res. Public Health 13. http://dx.doi.org/10.3390/ijerph13030331.

Perchoux, C., Kestens, Y., Brondeel, R., Chaix, B., 2015. Accounting for the daily locations visited in the study of the built environment correlates of recreational walking (the RECORD Cohort Study). Prev. Med. (Baltim.) 81, 142–149.

Qin, X., Zhang, Y., Cai, Y., He, M., Sun, L., Fu, J., Li, J., Wang, B., Xing, H., Tang, G., Wang, X., Xu, X., Xu, X., Huo, Y., 2013. Prevalence of obesity, abdominal obesity and associated factors in hypertensive adults aged 45–75 years. Clin. Nutr. 32, 361–367.

Rogerson, M., Brown, D.K., Sandercock, G., Wooller, J.-J., Barton, J., 2016. A comparison of four typical green exercise environments and prediction of psychological health outcomes. Perspect. Public Health 136, 171–180.

Shanahan, D.F., Lin, B.B., Bush, R., Gaston, K.J., Dean, J.H., Barber, E., Fuller, R.A., 2015. Toward improved public health outcomes from urban nature. Am. J. Public Health e1–e8.

Triguero-Mas, M., Dadvand, P., Cirach, M., Martínez, D., Medina, A., Mompart, A., Basagaña, X., Gražulevičienė, R., Nieuwenhuijsen, M.J., 2015. Natural outdoor environments and mental and physical health: relationships and mechanisms. Environ. Int. 77, 35–41. http://dx.doi.org/10.1016/j.envint.2015.01.012.

Turek, S., Rudan, I., Smolej-Narancić, N., Szirovicza, L., Cubrilo-Turek, M., Zerjavić-Hrabak, V., Rak-Kaić, A., Vrhovski-Hebrang, D., Prebeg, Z., Ljubicić, M., Janićijević, B., Rudan, P., 2001. A large cross-sectional study of health attitudes, knowledge, behaviour and risks in the post-war Croatian population (the First Croatian Health Project). Coll. Antropol. 25, 77–96.

World Urbanization Prospects – The 2014 Revision – Highlights. United Nations, New York. https://esa.un.org/unpd/wup/Publications/Files/WUP2014-Highlights.pdf.

Völker, S., Kistemann, T., 2011. The impact of blue space on human health and well-being − Salutogenetic health effects of inland surface waters: a review. Int. J. Hyg. Environ. Health 214, 449–460.

Völker, S., Kistemann, T., 2015. Developing the urban blue: comparative health responses to blue and green urban open spaces in Germany. Health Place 35, 196–205.

WHO, 2016. Urban Green Space and Health: A Review of the Evidence. WHO Regional Office for Europe, Copenhagen. http://www.euro.who.int/_data/assets/pdf_file/0005/321971/Urban-green-spaces-and-health-review-evidence.pdf?ua=1.

WHO, 2012. Environmental Health Inequalities in Europe. Assessment Report. WHO European Centre for Environment and Health, Bonn.

Wheeler, B.W., White, M., Stahl-Timmins, W., Depledge, M.H., 2012. Does living by the coast improve health and wellbeing? Health Place 18, 1198–1201.

Wheeler, B.W., Lovell, R., Higgins, S.L., White, M.P., Alcock, I., Osborne, N.J., Husk, K., Sabel, C.E., Depledge, M.H., 2015. Beyond greenspace: an ecological study of population general health and indicators of natural environment type and quality. Int. J. Health Geogr. 14, 17.

White, M.P., Alcock, I., Wheeler, B.W., Depledge, M.H., 2013a. Would you be happier living in a greener urban area?: A fixed-effects analysis of panel data. Psychol. Sci. 24, 920–928.

White, M.P., Alcock, I., Wheeler, B.W., Depledge, M.H., 2013b. Coastal proximity, health and well-being: results from a longitudinal panel survey. Health Place 23, 97–103.

White, M.P., Pahl, S., Ashbully, K., Herber, S., Depledge, M.H., 2013c. Feelings of restoration from recent nature visits. J. Environ. Psychol. 35, 40–51.

White, M.P., Wheeler, B.W., Herbert, S., Alcock, I., Depledge, M.H., 2014. Coastal proximity and physical activity: is the coast an under-appreciated public health resource? Prev. Med. (Baltim.) 69, 135–140.

Wilson, L.-A.M., Giles-Corti, B., Burton, N.W., Giskes, K., Haynes, M., Turrell, G., 2011. The association between objectively measured neighborhood features and walking in middle-aged adults. Am. J. Health Promot. 25, e12–21.

Witten, K., Hiscock, R., Pearce, J., Blakely, T., 2008. Neighbourhood access to open spaces and the physical activity of residents: a national study. Prev. Med. (Baltim.) 47, 299–303.

Wolf, K.L., Robbins, A.S.T., 2015. Metro nature, environmental health, and economic value. Environ. Health Perspect. 123, 390–398.

Wood, S.L., Demougin, P.R., Higgins, S., Husk, K., Wheeler, B.W., White, M., 2016. Exploring the relationship between childhood obesity and proximity to the coast: a rural/urban perspective. Health Place 40, 129–136.

Ying, Z., Ning, L.D., Xin, L., 2015. Relationship between built environment, physical activity, adiposity, and health in adults aged 46–80 in shanghai, China. J. Phys. Act. Health 12, 569–578.

Zhang, Y., Zhao, J., Chu, Z., Tan, H., 2014. Prevalence and regional disparities in abdominal obesity among children and adolescents in Shandong China, surveyed in 2010. Ann. Nutr. Metab. 64, 137–143.