THE ROLE OF BLUE SPACES ON HEALTH AND WELL-BEING

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Per tu, que des de que vas descobrir els espais blaus a Cambrils,
sempre has cregut en els seus beneficis.
"El mar ho cura tot..."

Acknowledgments

Studying Environmental Sciences at the university made me discover the world of environmental epidemiology. I was impressed by the association between the environment and the health of the population and I wanted to learn more. I got involved in research and my trajectory brought me to ISGlobal where I have done my PhD. This has been a really inspiring experience, and it is finally reaching its end.

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The current situation made me finish my PhD thesis under confinement while living a crucial moment in the history of public health. It is also a key moment to remind the importance of research and to keep working for promoting the health and well-being of all the population. TOT ANIRÀ BÉ.

Abstract

Non-communicable diseases, which account for over 85% of the deaths and 77% of the burden of disease in Europe, are usually linked to environmental factors and unhealthy lifestyles. A proper design and planification of cities might contribute to the promotion of public health. The incorporation and regeneration of natural settings in urban areas has been suggested to promote health and well-being in cities. Even though 70% of the Earth is covered by water, research on the effects of blue spaces (i.e., outdoor spaces with water like oceans, lakes, rivers or fountains) on health and well-being is still scarce. As a matter of fact, the present thesis aimed to evaluate the role of blue spaces and related infrastructure on the health and well-being of the population.

This thesis includes a (i) mixed methods pre-post intervention evaluation, and a (ii) Health Impact Assessment of an urban riverside regeneration project, as well as an (iii) experimental randomised cross-over study to evaluate health and well-being effects of acute exposure to blue spaces. On the one hand, findings of the first two studies suggest that the regeneration of a blue space in urban and peri-urban areas facilitates and promotes the use of such areas, particularly among those usually underrepresented in these environments, while enhancing physical activity and social interactions. This directly translates into health, well-being and health-related economic benefits through the prevention of disease and premature mortality. On the other hand, the experimental study shows positive effects

from the exposure to blue spaces on mood and well-being. Nevertheless, no effects were observed on cardiovascular health.

Further research is still necessary to fully comprehend the effects of blue spaces and related infrastructure on health. The pathways underlying such association remain unclear and need to be addressed, as well as the risks that might be related to the exposure to blue spaces.

Resum

Les malalties no transmissibles, que representen més del 85% del nombre morts i el 77% de la càrrega de malalties a Europa, sovint estan vinculades a factors ambientals i a estils de vida no saludables. Un disseny i planificació de les ciutats adequats pot contribuir a millorar la salut pública. S'ha suggerit que la incorporació i renovació d'espais naturals en àrees urbanes podria promoure la salut i el benestar a les ciutats. Tot i que el 70% de la Terra està coberta d'aigua, la investigació sobre els efectes dels espais blaus (i.e., espais oberts amb aigua com els oceans, llacs, rius o fonts) en la salut i el benestar encara és escassa. De fet, la present tesi té per objectiu avaluar el rol dels espais blaus i la infraestructura relacionada, en la salut i el benestar de la població.

Aquesta tesi inclou una (i) avaluació pre-post intervenció amb mètodes mixtes i una (ii) Avaluació d'Impacte en Salut d'un projecte de renovació de la llera d'un riu en una àrea urbana, així com un (iii) estudi experimental aleatori creuat per avaluar els efectes en la salut i el benestar de l'exposició aguda als espais blaus. D'una banda, els resultats dels dos primers estudis suggereixen que la renovació d'un espai blau en una àrea urbana o peri-urbana facilita i promou l'ús d'aquesta àrea, en particular entre aquells normalment infrarepresentats en aquests ambients, i redueix les desigualtats en salut, alhora que millora l'activitat física i les interaccions socials. Això es tradueix directament en beneficis per la salut, el benestar, i econòmics relacionats amb la salut, mitjançant la prevenció de malalties i la mortalitat prematura. D'altra banda, l'estudi

experimental mostra efectes positius de l'exposició a espais blaus en l'estat d'ànim i el benestar. No obstant, no es van observar efectes en la salut cardiovascular.

Encara és necessària més investigació per comprendre plenament els efectes dels espais blaus i la infraestructura relacionada en la salut. Els mecanismes subjacents a aquesta associació encara no són clars i cal abordar-los, així com els riscos que poden estar relacionats amb l'exposició a espais blaus.

Preface

The research described in this thesis has been carried out at the Barcelona Institute of Global Health (ISGlobal), Barcelona, Spain, between September 2016 and March 2020, and conducted under the supervision of Prof. Dr Mark Nieuwenhuijsen and Dr Mireia Gascon. The present thesis complies with the procedures and regulations of the Biomedicine PhD program of the Department of Experimental and Health Sciences of the University Pompeu Fabra, Barcelona (Spain). The results of this thesis are framed within BlueHealth (https://bluehealth2020.eu/), a pan-European research project led by the European Centre for Environment and Human Health of University of Exeter (UK) and funded by the European Union's Horizon 2020 research and innovation programme under grant agreement number 666773.

The present thesis contributes to the evidence of health and well-being benefits of the exposure to blue spaces (e.g., sea, rivers, lakes, canals, fountains, etc.) and their related infrastructures, a topic under-assessed until the start of the present work. The thesis shows the relevant impact of urban and landscape planning related to blue space environments on public health, and highlights the significance of nature-based interventions on the promotion of physical activity, the enhancement of social interactions, and the reduction of health inequalities, which have an effect on the health and well-being of the population.

This thesis contains three original research articles first-authored by the PhD candidate. In each of these articles, the PhD candidate combined different epidemiological study designs, methods and statistical analyses. This combination is one of the main strengths of the present thesis. In summary, *Paper I* and *Paper II* include the evaluation of an urban riverside regeneration project to estimate its impacts on the health and well-being of the population. A mixed methods pre-post intervention evaluation was conducted for *Paper I*. This evaluation was the first study using the System for Observing Play and Recreation in Communities (SOPARC) tool for the quantitative assessment of a blue space-related infrastructure. This was combined with individual face-to-face interviews, which were used for the qualitative assessment. For *Paper II,* and for the first time in the context of blue spaces' research, I conducted a comparative risk assessment using a quantitative model, which was based on a Health Impact Assessment (HIA) approach. Finally, *Paper III* used an experimental randomized cross-over study design to evaluate short-term health and well-being effects of acute exposure to blue spaces.

The PhD candidate was responsible for preparing the protocol and coordinating the fieldwork (for *Paper III*), recruiting participants, designing, and administering the questionnaires (for *Paper I* and *Paper III*). For all the studies included in this thesis, the PhD candidate was also responsible for collecting, cleaning and preparing the data, conducting the statistical analysis, interpreting and reporting the findings in scientific articles for publication, and doing the dissemination of the results (both to the general and specialized audience). Furthermore, the PhD candidate co-authored five other research articles (see Appendices). Two of these co-authored articles also contribute on the evidence of the association between blue spaces exposure and health. One of them is a systematic review which aimed to compile the quantitative evidence on the association between outdoor blue spaces and human health and well-being (Gascon et al. 2017). The other one, is a cross-sectional study that evaluates long-term exposure to residential green and blue spaces and anxiety and depression in adults (Gascon et al. 2018) (see Appendices). Moreover, the PhD candidate has been active in research dissemination, and she has participated in different activities with the involvement of stakeholders (see Appendices).

Within the BlueHealth project, the PhD candidate also contributed to Chapters 6 and 8 of the BlueHealth book (under preparation). Chapter 6 introduces and describes methods and tools used to capture and map the behaviour of users in a specific site. Chapter 8 discusses the use of different surveying tools in the BlueHealth project to investigate the impact of the exposure to blue spaces on the populations' health and well-being.

Finally, the PhD candidate conducted a research stay (from April to July 2018) at the *Institut de Santé Globale*, Faculty of Medicine at the University of Geneva (Switzerland), under the supervision of Prof Dr Emiliano Albanese (see Appendices).

Abbreviations

ART	Attention Restoration Theory
BEAT	BlueHealth Environmental Assessment Tool
BP	Blood pressure
CIs	Confidence Intervals
CVDs	Cardiovascular diseases
DALYs	Disability-Adjusted Life Years
GIS	Geographic Information Science
HF	High frequency power
HIA	Health Impact Assessment
HR	Heart Rate
HRV	Heart Rate Variability
LF	Low frequency power
LF/HF	Ratio of LF to HF
METs	Metabolic Equivalent of Task
MENE	Monitor for Engagement with the Natural Environment survey
PNS	Parasympathetic Nervous System
RMSSD	Root Mean Square of Successive NN interval Differences

SDNN	Standard deviation of NN intervals
SNS	Sympathetic Nervous System
SOPARC	System for Observing Play and Recreation in Communities
SRT	Stress Recovery Theory
UK	United Kingdom
VSL	Value of Statistical Life
WHO	World Health Organization
WPs	Work Packages
YLD	Years Lived with Disability
YLL	Years of Life Lost

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1. INTRODUCTION

1.1 Blue spaces and health

Water, a tasteless and odourless chemical substance composed of hydrogen and oxygen, is the basis of life on Earth. About 70% of the Earth is covered by water, and up to 60% of the human body is water as well (Water 2016; Water 2019; Water Science School 2019; Zumdahl 2019). This chemical substance is not only indispensable for human living, but it can also have a positive impact on our health and well-being. The attachment between humans and water is not a novelty. Water is a unique resource and logistically strategic (for transport, energy production, commerce, etc.) and humans yearn to live close to water bodies, already in the past and also nowadays (Grellier et al. 2017; Neumann et al. 2015; Völker et al. 2016; Völker and Kistemann 2011; White et al. 2010).

Water in small quantities looks colourless. However, it is inherently blue due to slight absorption of long wavelength light (Zumdahl 2019). Actually, water in large quantities looks blue because it mirrors the blueness of the sky when it is clear (Zumdahl 2019). Thus, appealing to its intrinsic colour, and given that water is mostly associated with the blue colour (Strang 2004), water bodies might be called "blue spaces". Blue spaces are defined as "*outdoor environments – either natural or manmade – that prominently feature water and are accessible to 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). Blue spaces are diverse and span a wide range of sizes. They include from oceans, seas, lakes, rivers and waterfalls to canals, ponds, fountains, splash ponds, or even swimming pools.

Blue spaces have been historically linked to restoration and well-being, considering water bodies as therapeutic landscapes with healing properties (Bell et al. 2015; Finlay et al. 2015; Foley and Kistemann 2015; Völker and Kistemann 2011). Recent studies have also suggested positive health and well-being effects of blue spaces (de Bell et al. 2017; Garrett et al. 2019a, 2019b; Gascon et al. 2017; Völker et al. 2018). Nevertheless, the research on this topic is limited and the methodologies employed are still very much diverse. This lack of consensus weakens the evidence found for the relationship between blue spaces and health (Gascon et al. 2017). Moreover, there are other aspects that might have an influence on the effects of blue spaces on people's health and well-being. For example, I acknowledge the importance of considering potential differences that might be observed depending on the type of blue space that is assessed (e.g. coastal area, inland area, urban or rural, etc.). Quality of blue spaces – in terms of, for example, biodiversity, cleanness, accessibility, or socio-cultural value – should also be considered when assessing its impacts on health and well-being. Likewise, blue spaces are also associated with different risks that might threaten public health (e.g. flooding, drowning, etc.), and these need to be considered in the evaluation of the health impacts of blue spaces (Grellier et al. 2017).

While the health benefits of green spaces – spaces known as surfaces partly or completely covered by vegetation such as grass, trees or shrubs – have been more extensively investigated (Nieuwenhuijsen et al. 2017a; WHO Regional Office for Europe 2016b), the potential health benefits of blue spaces have been under-assessed until now. Also, the impact on health and well-being of interventions in blue spaces' related infrastructure (i.e., blue infrastructure), have been barely assessed for many years (WHO Regional Office for Europe 1999). The provision and improvement of blue infrastructure in urban areas might be a strategy to address public health issues such as sedentarism, overweight and obesity, social isolation, or lack of contact with nature. The evaluation of these kind of interventions is important for identifying consequences and needs, for assessing whether the objectives of the intervention have been achieved or not, and for ensuring that all population groups are benefited from the intervention (WHO Regional Office for Europe 2016a). These evaluations are not only key to estimate their viability but to assess their impact on public health and, indirectly, on the economy, through the promotion of healthier cities.

Aiming to fill in this research gap, the BlueHealth project was launched in 2016 (http://bluehealth2020.eu/), with the objective of investigating the link between blue spaces and health. As part of this project, a systematic review published in 2017 (Gascon et al. 2017) aimed at synthesizing the quantitative evidence on human health and well-being benefits of outdoor blue spaces. This review found evidence suggesting an association between outdoor blue spaces' exposure, better well-being and mental health, and increased physical activity (Gascon et al. 2017). These findings, together with new insights, will be described in following sections.

1.1.1 Self-reported general health

Self-reported general health has been widely assessed in many international surveys because it reflects the own health status perceived by the questioned subjects (Elliott 2018; Ware et al. 1993). Also, it is highly associated with more complex and objective dimensions of physical and psychological health (Gascon et al. 2017; Wheeler et al. 2012). It is extensively used to analyse the association between the exposure to blue spaces and health because it is a non-invasive, cheap and easy method. It consists on a single question: "*In general, would you say your health is",* whose answers range from *"Excellent", "Very good", "Good", "Fair", and "Poor" (Ware et al. 1993)*".

The first study evaluating the association between blue spaces' exposure and self-reported general health did not find any association (de Vries et al. 2003). No association between residential proximity to blue spaces and general health was observed by Triguero-Mas et al., neither (Triguero-Mas et al. 2015). However, the evidence on blue spaces and general health is heterogeneous and some studies found a positive relationship between them. Four different studies – three with a cross-sectional design (Garrett et al. 2019a; Pasanen et al. 2019; Wheeler et al. 2012) and one with a longitudinal design (White et al. 2013a) – all conducted in England, have suggested a reported good health, being the effects stronger for socioeconomically-deprived populations (Wheeler et al. 2012). Thus, potentially reducing inequalities in these locations (Grellier et al. 2017). Also in England, an ecological study found positive effects on general health among subjects with a higher percentage of salt and coastal water in their census area (Wheeler et al. 2015). However, no association was observed with fresh water. In the Netherlands, a cross-sectional study found self-reported general health to be positively associated with blue spaces' availability (including fresh and salt water) in the residential environment (de Vries et al. 2016). Finally, a cross-sectional study conducted in Spain showed a higher probability of reporting better general health when residing close to the beach. These effects were found to be stronger among those with a low family income (Ballesteros-Olza et al. 2020).

The scientific evidence is principally concentrated in Europe, especially in England (Gascon et al. 2017). As an exception, a cross-sectional study with a sample of predominantly older adults in Hong Kong found an association between having views on blue spaces from home and good self-reported general health (Garrett et al. 2019b).

1.1.2 Physical health

Despite most of the evidence linking blue spaces and health is related to mental health and well-being (further details in the next section of this thesis), some insights also suggest benefits for physical health. The WHO defines health as "a state of complete physical, mental and social well-being and not merely the absence of disease or infirmity" (World Health Organization 1946). Thus, health comprises both physical and mental health. However, from now onwards, within the present thesis, these concepts will be distinguished.

In the present thesis, physical health has been assessed in terms of:

- cardiovascular health (Paper III)
- diseases including type 2 diabetes (usually linked to being overweight or obesity), and colon and breast cancers (Paper II)
- all-cause mortality (Paper II)

Cardiovascular health

Several epidemiological studies have reported robust associations between green spaces and cardiovascular health (Yeager et al. 2019). Similarly, blue spaces could have as well the potential to be environments that reduce the risk of cardiovascular diseases (CVDs). Given that CVDs are the leading cause of mortality in many parts of the world, including Europe, it is relevant and suitable to further explore these potential health benefits (Nieuwenhuijsen 2018).

Among the cardiovascular outcomes, heart rate variability (HRV) parameters and blood pressure (BP) are the most frequently used in epidemiological studies. Long-term high or raised BP (i.e.

hypertension) is the most important preventable cause of heart disease and stroke worldwide (World Health Organization 2015a).

The scientific evidence of a causal relationship between exposure to blue spaces and cardiovascular health is, to date, insufficient and contradictory (Gascon et al. 2017). As an example, three different studies with a similar design showed opposite results; a favourable response on HRV indicators related to blue spaces' exposure was only found in one study (Triguero-Mas et al. 2017b), whereas no association was observed in the other two studies (Brown et al. 2014; Gidlow et al. 2016).

Overweight and obesity

Even though overweight and obesity have not been directly assessed in the present thesis, they are health conditions characterised by fat accumulation that represent a major risk factor for different diseases, including type 2 diabetes, CVD, or cancer (World Health Organization 2020d), all assesed in this thesis. Moreover, overweight and obesity are partly determined by physical activity, which has been associated with exposure to blue spaces (further described in the next section).

Once again, the evidence related to blue spaces and overweight and obesity is not consistent (Gascon et al. 2017). However, some studies suggested a negative association between access and proximity to residential blue spaces, and overweight and obesity. For example, a study conducted in England found a slightly lower prevalence of childhood obesity at the coast (Wood et al. 2016), and best access to the beach was associated with lower normalised Body Mass Index among the population in New Zealand (Witten et al. 2008). Also, in a study conducted in China, they found a negative association between river proximity and overweight and obesity (Ying et al. 2015). Finally, in an 8-year follow-up study in Finland, residential proximity to blue spaces was associated with an increased odds of overweight (Halonen et al. 2014). However, overweight and obesity are also strongly conditioned by many other factors, such as the diet, and none of the analysis from the previously described studies has taken them into account.

All-cause mortality

Mortality can be distinguished between diseases-specific mortality (i.e., mortality caused by a specific health event), and all-cause mortality (accounting for all the deaths in the population, regardless of the cause). In the present thesis, all-cause mortality has been used as one of the health indicators of the impact of an intervention in a blue space setting. The association between exposure to blue spaces and the risk of mortality has been hardly assessed and existing results are inconsistent. Based on the existing evidence, blue spaces appeared to mitigate heat-related mortality among the elderly in Lisbon (Portugal) (Burkart et al. 2016). Also, a population-based cohort study of non-immigrant adults in Canada found a reduced risk of mortality among subjects living near blue spaces compared with those living further (Crouse et al. 2018). However, these results are inconsistent with those from a mega-cohort study conducted in Barcelona, which found an increased risk of mortality with an increase in the exposure to blue space (Nieuwenhuijsen et al. 2018). Nevertheless, the analysis of this study might not be sufficiently corrected by socioeconomic status. Also, in this particular study, exposure to the blue space could have led to exposure to chemicals, pollution and noise from the port, which might have a negative impact for health, resulting in increased mortality (Nieuwenhuijsen et al. 2018).

Compiling the evidence

Two recently-published systematic reviews, each with a different approach, have examined the association between exposure and use of blue spaces and related infrastructures, and physical health (Britton et al. 2018; Gascon et al. 2017). The first assessed the quantitative evidence on the effects of outdoor blue spaces on human health and well-being (Gascon et al. 2017). The second reviewed the impact on health and well-being of therapeutic interventions within blue spaces (Britton et al. 2018). Despite its differences, both systematic reviews coincided on reporting the lack of consistency among studies evaluating the physical health effects of blue spaces. Inconsistencies were mainly due to the reduced number of existing studies, the heterogeneity among them regarding the methods employed to assess the exposure to blue spaces and the outcomes assessed (Britton et al. 2018; Gascon et al. 2017).

1.1.3 Mental health and well-being

Good health is not complete without good mental health. According to the World Health Organization (WHO), mental health is defined as "*a state of well-being in which the individual realizes his or her own abilities, can cope with the normal stresses of life, can work productively and fruitfully, and is able to make a contribution to his or her community*" (Herman 2011). Thus, mental health comprises the absence of mental illness and the presence of psychological well-being (Bratman et al. 2019). Similarly to general health, mental health is determined not only by individuals' characteristics but also by socioeconomic and environmental factors (Herman 2011).

Up to now, scientific evidence has suggested an association between blue spaces and mental health (Gascon et al. 2017), considering different indicators of exposure to blue spaces (e.g. from the residential proximity to blue spaces to the real contact with those), and contemplating different mental health outcomes.

In cross-sectional and ecological studies, exposure to blue spaces has been assessed in different ways: having views to blue spaces (Dempsey et al. 2018; Nutsford et al. 2016), blue spaces' availability in the residential environment (i.e., the amount of blue space within 1 km of the participants' residents) (de Vries et al. 2016), blue spaces' use (Amoly et al. 2014), and blue spaces' distance from home (Korpela et al. 2010; Pasanen et al. 2019; Pearson et al. 2019). Regardless of the method, blue spaces have been associated with lower psychological distress (Nutsford et al. 2016), lower risk of depression (Dempsey et al. 2018), anxiety and mood disorders (de Vries et al. 2016), lower anxiety and mood disorder hospitalizations (Pearson et al. 2019), improved restoration (Korpela et al. 2010) and mental health (Pasanen et al. 2019), and better behavioural development in schoolchildren (Amoly et al. 2014).

In support of these findings, experimental studies found better restoration, cognitive function and mood among participants exposed to a blue space compared with an urban space (Gidlow et al. 2016; Triguero-Mas et al. 2017b). Longitudinal studies suggest that being in blue spaces (assessed with GPS location data recorded with an application software developed ad-hoc for this study) (MacKerron and Mourato 2013), residential proximity to blue spaces (Dzhambov 2018; White et al. 2013a) and even coastal visits (White et al. 2013c) are associated with better mental health (Dzhambov 2018; White et al. 2013a), happiness (MacKerron and Mourato 2013), and restoration (White et al. 2013c). Also, a higher preference and more positive subjective reactions for both natural and built environments with water elements were observed in a study based on rating photography (White et al. 2010).

Qualitative research has been widely used to evaluate the well-being effects of blue spaces' exposure, interviews being the most employed method. Better well-being has been reported when people visited urban blue spaces as compared with urban green spaces (Völker and Kistemann 2015). Living close to the coast is considered good for mental health because it facilitates stress relief through amusement and close contact with nature (Ashbullby et al. 2013). It also improves people's well-being due to symbolic, social, achievement-oriented and immersive experiences in blue spaces (Bell et al. 2015). This is also true for older adults, whose well-being seems to improve after being exposed to blue spaces (Finlay et al. 2015).

All the research on blue spaces and mental health and well-being has been summarised on different occasions (Britton et al. 2018; Gascon et al. 2015, 2017; Völker and Kistemann 2011). A qualitative meta-analysis of studies evaluating the relationship between blue spaces and well-being highlighted the role of blue spaces on landscape perception, preference and design, and its effects on restoration, recreation and emotions (Völker and Kistemann 2011). A systematic review summarized all the evidence on residential blue spaces' exposure and mental health benefits up to the year 2015, suggesting that evidence was inadequate given the limited number of studies available (N=3) (Gascon et al. 2015). Two years later, another systematic review (N=35) evaluated quantitative studies and, based on twelve studies, suggested a positive association between outdoor blue spaces and mental health and well-being (Gascon et al. 2017). On the same line, the most recent systematic review (N=33), which assessed health and well-being effects of therapeutic interventions (i.e., pre-designed activities and programmes) in blue spaces, suggested benefits for mental health and psycho-social well-being (Britton et al. 2018).

Despite these encouraging results, all these studies agreed on stressing the lack of research on this topic available until the moment, and also on the heterogeneity among studies in terms, not only of main findings, but also of exposure assessment, type of blue space evaluated, and mental health outcome of interest (de Vries et al. 2003; Dzhambov et al. 2018; Gascon et al. 2018; Rogerson et al. 2016; Triguero-Mas et al. 2015). Variability among studies, complicates validating scientific evidence regarding the benefits of blue spaces on mental health.

In the present thesis, mental health has been assessed in terms of:

- well-being (*Paper I* and *Paper III*)
- mood (*Paper III*)
- dementia (*Paper II*)

Well-being

In the literature, well-being is defined differently depending on the field in which it is being assessed. In this thesis, well-being is taken to be a human's state characterised by feeling well considering the overall aspects of life rather than specific ones. Well-being might include having good mental health, high life satisfaction and happiness, feeling of fulfilment, the ability to be resilient to manage with potentially stressful situations, and having healthy social contacts (Bratman et al. 2019; Diener et al. 2009). In this thesis, well-being has been qualitatively (Paper I) and quantitatively (Paper III) assessed, using interviews and questionnaires, respectively.

Mood

Mood is an emotional state that can range from cheerfulness to anger or anxiety, through other intermediate states. In the present thesis, mood has been assessed (Paper III) through standardized questionnaires (e.g., Balaguer et al. 1993; Fuentes et al. 1995).

Dementia

Finally, dementia is a mental disease of the brain that affects memory, thinking, orientation, comprehension, calculation, learning capacity, language, and judgement (World Health Organization 2012). Dementia contributes to disability and dependence (World Health Organization 2015b). The number of people affected by dementia worldwide rises to almost 50 million people and it is expected to increase in the coming years (World Health Organization 2015b). The risk reduction of dementia is one of the mental health benefits of blue spaces' exposure assessed in this thesis (Paper III).

The methodology employed in the present thesis to assess mental health will be further discussed in the Methods section below.

1.2 Pathways between blue spaces and health

It is known that the scientific evidence suggesting positive health and well-being effects of green spaces is much more extensive, time-honoured, and consistent than the evidence related to blue spaces. Even though blue spaces might be associated with human's health and well-being benefits following similar pathways as green spaces (Markevych et al. 2017), only a very limited number of studies have evaluated the possible pathways that may underline this association (Cleary et al. 2017; Dzhambov et al. 2018; Triguero-Mas et al. 2017a). Even though these pathways are not yet clearly defined, some of them are suggested to explain the association between exposure to blue spaces and human's health and well-being. These are: (i) the promotion of physical activity, (ii) restoration, relaxation and stress reduction, (iii) the promotion of social interactions and social cohesion, (iv) the attenuation of the environmental conditions (e.g., heatwaves), and (v) the strengthening of the immune system.

1.2.1 Physical activity

Physical activity does not only improve physical health, but also mental health and well-being. Regular physical activity has been associated with a decreased risk of overweight and obesity, cardiovascular diseases, type 2 diabetes, different types of cancer, and psychological disorders (World Health Organization 2018). Moreover, it has been suggested that physical activity might provide greater health and well-being benefits when conducted in natural environments than indoors, or in non-natural settings, although the evidence is still not conclusive (Lahart et al. 2019; Shanahan et al. 2016).

Overall, scientific evidence suggests that there is a direct link between exposure to blue spaces and increasing levels of physical activity (Bauman et al. 1999; Edwards et al. 2014; Gascon et al. 2017;

Perchoux et al. 2015; White et al. 2014; Witten et al. 2008). However, up to now, the number of studies is limited, and there is heterogeneity in the methodology employed by the existing studies. Moreover, most of these studies have a cross-sectional design, thus the reverse causation cannot be discarded (Gascon et al. 2017). Moreover, most of the evidence is on coastal blue spaces, and thus other types of blue spaces are underrepresented.

Some studies have assessed the potential role of physical activity as a mediator on the association between exposure to blue spaces and human health. As an example, a cross-sectional study conducted in England found that an association between residential proximity to blue spaces and self-reported general and mental health was mediated by physical activity (mainly walking) (Pasanen et al. 2019). However, results are not always consistent (Dzhambov et al. 2018; Triguero-Mas et al. 2015). Furthermore, it is also important to identify the type and intensity of the physical activity practised in blue spaces (Elliott et al. 2015, 2018) to better understand why and how physical activity could explain the association between blue spaces' exposure and health. A cross-sectional study conducted in England found that visits to coastal environments were associated with more energy expenditure than visits to the countryside and urban green spaces. This was not because of the physical activity intensity, but due to the longer duration of these visits, suggesting that coastal environments might provide more occasions for longer visits because of their wide offer on recreational opportunities (Elliott et al. 2015).

1.2.2 Restoration, relaxation and stress reduction

Blue spaces might facilitate feelings of restoration and relaxation, and the reduction of stress (Grellier et al. 2017; Wheeler et al. 2012; White et al. 2013c), which in turn would benefit physical and mental health, and well-being. Stress is related to different physical and psychological impairments, including cardiovascular diseases, depression, or cognitive function (Castaldo et al. 2015). Purely the sound of water has been already related to feeling relaxed (Annerstedt et al. 2013). A cross-sectional study conducted in England found that the main motivation for participants to visit coastal environments was for relaxation and social reasons (Elliott et al. 2018).

This potential pathway might be explained by the Stress Recovery, and the Attention Restoration theories (SRT and ART, respectively). The SRT supports that natural environments facilitate human's recovery from psychological and physiological stress because of the emergence of calmness and pleasantness feelings, the mitigation of negative thoughts, and the activation of the parasympathetic system, which produces a feeling of relaxation and calmness. This is due to unconscious and innate response evoked by the presence of natural elements, including the presence of water (Ulrich et al. 1991). The ART emphasizes the role of nature on human's concentration, relieving mental fatigue. This theory suggests that in natural environments, the presence of natural elements such as water flowing in a river, request "effortless attention", which mitigates attention fatigue (Kaplan and Kaplan 1989).

1.2.3 Social interactions and social cohesion

Blue spaces are usually settings where people normally attend together with family and friends. Thus, these are spaces prone to facilitate social interaction and consequently to improve social cohesion (Ashbullby et al. 2013; Grellier et al. 2017). Social interaction involves a relationship between two or more people (American Psychological Association 2018), whereas social cohesion is referred to the sense of belonging to a community, with shared norms and values, and the positive and friendly relationships of its members within the community itself (Hartig et al. 2014; Manca 2014). In a more cohesive society, there might be fewer inequalities, which enhances public health. Also, people living in a cohesive society might be more respectful with others and provide social support, which would have a positive effect on health and well-being (Chuang et al. 2013). The association between social relationships and health has been extensively documented (Hartig et al. 2014). Social relationship and social cohesion have been related to better health, both physical and mental (Rios et al. 2012), and lower risk of mortality (Holt-Lunstad et al. 2010).

Nevertheless, not many studies have evaluated the role of social interaction and social cohesion as pathways between exposure to blue spaces and better health and well-being (Dzhambov et al. 2018; Triguero-Mas et al. 2015). The studies that aimed to do so were not consistent on reporting the mediation effects of social interaction or cohesion on the association between blue spaces and health (Dzhambov et al. 2018; Triguero-Mas et al. 2015). However, Triguero-Mas et al. found an association between access to blue spaces and more social support (Triguero-Mas et al. 2015). Furthermore, social interaction is considered to be one of the main benefits of visits to blue spaces (de Bell et al. 2017). And exposure to blue spaces might also encourage place attachment, which is linked to feelings of belonging and rootedness, both having a significant effect on people's mental health and well-being (Cleary et al. 2017; Gascon et al. 2017; Grellier et al. 2017).

1.2.4 Attenuation of detrimental environmental conditions

The potential pathways just described in the previous sections of this thesis are related to people's behaviour or direct effects of blue spaces on the health and well-being of the population. However, the presence of blue spaces in a particular setting might also have an effect on the environment, which in turn would lead to impacts on health and well-being.

The evidence suggests that blue spaces might contribute to reducing temperatures, and to lessening the urban heat island effect, which is characterised by increased temperatures in urban areas compared with surroundings and rural areas due to modifications of surface properties (Heaviside et al. 2017; Hongyu et al. 2016; Lai et al. 2019; Moyer and Hawkins 2017; Völker et al. 2013). This has an impact on human's morbidity and mortality, being the risk especially important for vulnerable populations like the elderly (Andreucci and Russo 2019; Grellier et al. 2017; Gunawardena et al. 2017; Heaviside et al.

2017). In fact, city planners and architects have already considered blue spaces to be useful components to reduce urban heat stress (Gunawardena et al. 2017). However, the evidence on the cooling capacity of blue spaces is still scant and sometimes controversial. The cooling capacity of blue spaces might be highly influenced by environmental conditions of the area, like microclimate, wind direction and velocity, urban design, temperature, humidity, the radiation balance, and also by the time of the day, the type, size and geometry of blue spaces (Gunawardena et al. 2017; Hongyu et al. 2016; Lai et al. 2019; Sun and Chen 2012; Völker et al. 2013). Some studies suggest a cooling effect of blue spaces in urban areas during the day, but a contrary effect at night, probably explained by variations in the evaporative flux (Gunawardena et al. 2017). Also, some studies found that the reflection of water surfaces might increase the temperature when the amount of reflected solar radiation if high (Lai et al. 2019). Hence, this gap in the knowledge needs to be filled.

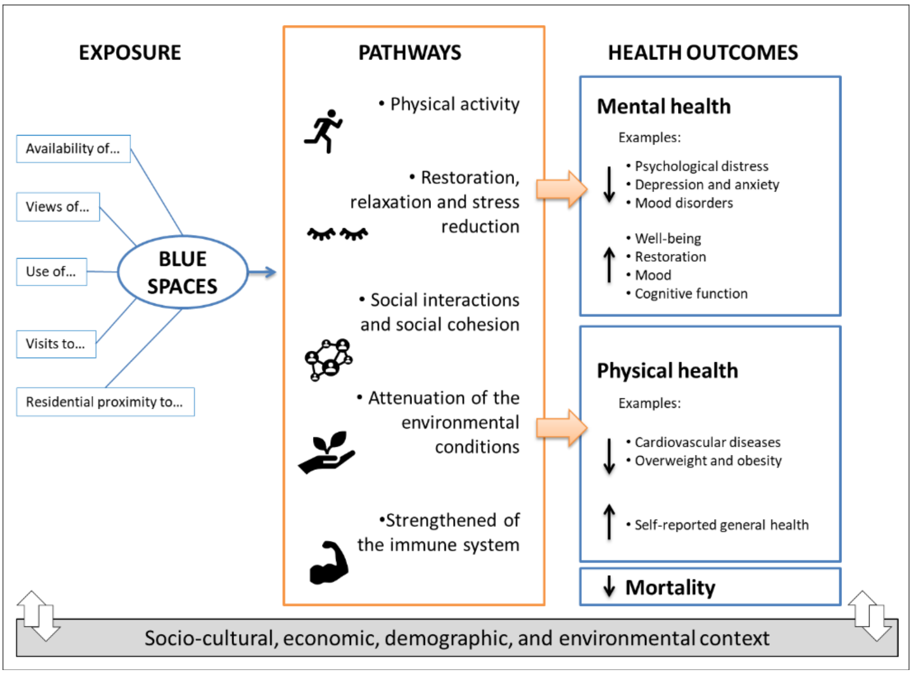
Likewise, not many studies have evaluated the role of temperature mitigation on the association between exposure to blue spaces and health. To our knowledge, only one study conducted in Lisbon (Portugal) found that blue spaces may have a mitigating effect on heat-related mortality in the elderly population (Burkart et al. 2016).

1.2.5 Strengthening of the immune system

Although not specifically for blue spaces, the scientific evidence has suggested that contact with nature might enhance the immune system

(Frumkin et al. 2017; Kabish et al. 2017; WHO Regional Office for Europe 2016b). This might be explained because contact with nature implies contact with microbial and other antigens, which might modify immune function. Finally, exposure to natural environments facilitates contact with natural substances, some of which have been associated with improved natural killer cell activity (Frumkin et al. 2017).

Figure 1. Framework of the health effects of blue spaces and the potential pathways underlying this association.



2. RATIONALE

The population in urban areas – which has rapidly grown and is expected to grow more in the next years – is exposed to several environmental factors [i.e. urban exposome (Andrianou and Makris 2018)] that have a negative effect on their health and well-being (e.g., air pollution, noise, extreme temperatures or lack of natural spaces). Likewise, urban planning and urban design highly influence the behaviour and lifestyle of the population (e.g., by promoting a sedentary lifestyle and unhealthy diet) threatening public health. Non-communicable diseases – such as obesity, type-2 diabetes or mental illnesses – are usually attributable to environmental factors and cause 88% of the total deaths in Europe (World Health Organization 2014b). Nevertheless, environmental factors are modifiable, as it has been shown by environmental interventions at the community level, having an effective impact on public health (Chokshi and Farley 2012).

The potential of natural settings, mainly green spaces, in urban areas has revealed to be effective for reducing air pollution and noise levels, mitigate the effect of urban heat islands and promote physical activity and social interactions. However, research on the evaluation of the effects of blue spaces on health and well-being is still scarce. Moreover, most of the existing studies have a cross-sectional design, which hinders the establishment of causality between blue spaces and health (Gascon et al. 2017).

Even though this apparent knowledge gap, humans are intrinsically linked to water, and the effects of blue spaces on restoration and well-being have been historically suggested (Bell et al. 2015; Finlay et al. 2015; Foley and Kistemann 2015; Völker and Kistemann 2011). Furthermore, we live on a planet whose more than 70% of the surface is covered by oceans. More than half of the global population live in areas by the coast, where the population density is higher than in inland areas. However, the evidence suggests disconnection and detachment from our natural surroundings in the last century (Depledge et al. 2019; Neumann et al. 2015; World Health Organization 2017b). Thus, there is a need for studies that contribute to a better understanding of the association between exposure to blue spaces and psychological and physiological health. Also, there should be a commitment to evaluate the impact on health of having blue infrastructures in urban areas. Likewise, interventions conducted in these infrastructures should be also assessed to maximize the benefits of blue spaces and mitigate the risks to contribute to healthy cities.

3. OBJECTIVES

The main goal of this thesis is to evaluate the role of blue spaces in urban areas in the promotion of health and well-being. In order to achieve this goal, I assessed the relationship between the population and blue spaces by using different quantitative and qualitative methodologies, which were employed to address the following specific objectives:

1. To estimate the impact of urban regeneration projects on blue spaces and related infrastructure in terms of:

    a. Changes on the use and self-perception of the area before and after the intervention (*Paper I*)

    b. Its influence on the behaviour of the population concerning physical activity and social interactions (*Papers I* and *Paper II*)

    c. Health and well-being effects (*Paper I* and *Paper II*).

2. To assess physical, mental health and well-being effects of being exposed to blue spaces for a short period of time (*Paper III*).

4. METHODS

4.1 The BlueHealth project

The present thesis is framed within BlueHealth (www.bluehealth2020.eu/), a pan-European project funded by the European Union's Horizon 2020 research and innovation programme under grant agreement number 666773 and with a duration of 4.5-years. It is an international multi-partner project led by the European Centre for Environment and Human Health of University of Exeter (UK). The other research institutions involved in the project are: ISGlobal Barcelona (Spain), National Institute for Public Health and the Environment (The Netherlands), WHO Regional Office for Europe (Germany), Lund University (Sweden), National Institute of Health (Italy), Estonian University of Life Sciences (Estonia), Euro-Mediterranean Centre on Climate Change (Italy), and Aristotle University of Thessaloniki (Greece) (Figure 2).

Figure 2. Localization of institutions involved in the BlueHealth project.

The BlueHealth project aims to understand better the association between blue spaces' exposure and health and well-being. For this purpose, the project is involved in a large-scale systematic programme of interdisciplinary research that investigates exposure to blue space and its effects on health and well-being in various geographical, climatic, socioeconomic and cultural contexts across Europe. Moreover, BlueHealth aims to explore the health impacts of existing, new, or renewed interventions and policy initiatives affecting blue spaces and related infrastructure. The project works to develop tools and to be able to make recommendations that support decision-making on future investments in Europe's blue infrastructure, to promote health and well-being.

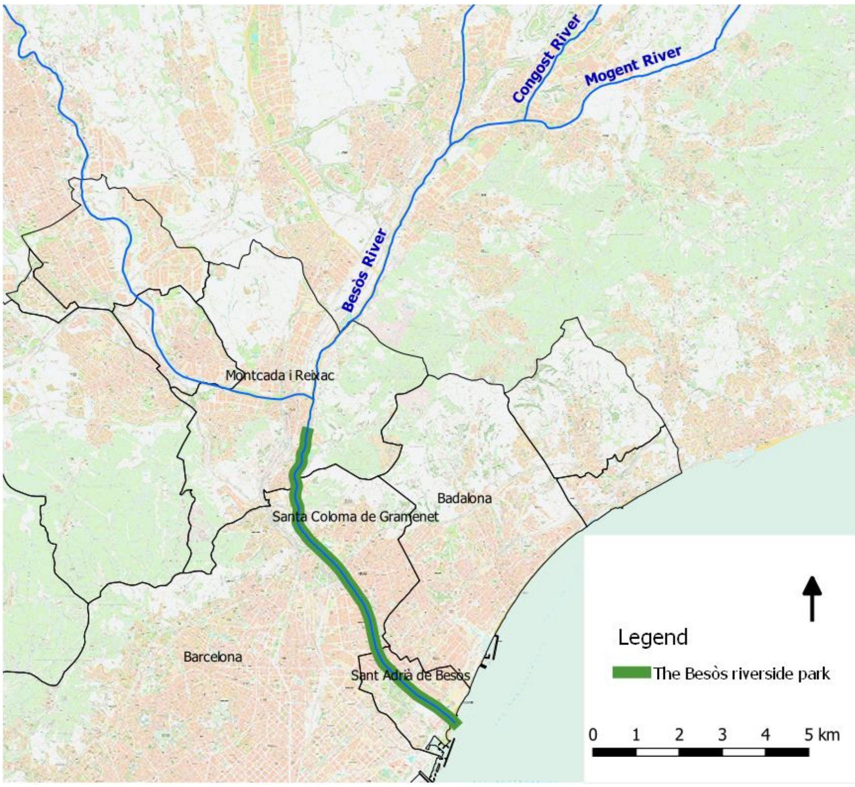
The BlueHealth project is divided into 8 Work Packages (WPs), dedicated to the management of the project, to contribute to the scientific evidence, and to disseminate the results and create several recommendations for stakeholders and policymakers. WP3, led by ISGlobal, is on "Community-level Interventions", and *Paper I*, *Paper II*, and *Paper III* of the present thesis are part of it. Each paper is the consequence of the work conducted on the three different case-studies described below.

4.2 Case-study 1: urban riverside regeneration (I)

The research objective number one of the present thesis has been assessed in the context of an urban riverside regeneration project in the Besòs River, in the province of Barcelona (Spain). Besòs is a 17.7

km length river, formed by the confluence of Mogent and Congost Rivers in Vallès Oriental (Catalonia, Spain), and ending in the Mediterranean Sea (Figure 3). It used to be a polluted river in the 1960s mainly because of its geographical situation, being located next to highly populated municipalities and industrialized areas. However, the Besòs River experienced an environmental and infrastructural improvement through an urban regeneration project started in 1996 (Ajuntament de Santa Coloma de Gramenet 2016; Diputació de Barcelona 2019).

Figure 3. Besòs River and the Besòs Riverside Park.



This intervention resulted in the *Parc Fluvial del Besòs* (Besòs Riverside Park), a recreation area created on the banks of the Besòs River affecting its last 9 km (Diputació de Barcelona 2019). The creation of the Besòs Riverside Park entailed improvements on the environmental conditions of the area and provided spaces for leisure and physical activity and to facilitate social interactions. The first stage of the intervention was initiated in 2000, and its health effects have been assessed in *Paper II* of the current thesis (next section).

In *Paper I*, I evaluated the second stage of the urban riverside regeneration project. It started in 2016 (Farrero i Compte et al. 2015) and affected the section of the Besòs river located in Montcada i Reixac, in between "*La Ribera*" neighbourhood and a water treatment plant (right and left side of the river downstream, respectively) (Farrero i Compte et al. 2015). This intervention affected 735 m along the right side of the river downstream, and a total surface area of approximately 52,619 m^2. It consisted in the construction of two paved walkways (one on the lower part of the river, and another one on the upper part), and four new access points to the riverbank (two wheelchair-accessible ramps and two sets of stairs connecting the upper and the lower parts of the river) (Farrero i Compte et al. 2015). Before the intervention, the lower and the upper parts of the river were not connected as there was no access to the riverbank.

"*La Ribera*" neighbourhood, as other parts in the city of Montcada i Reixac, was the result of a quick expansion of the city in the '60s and '70s to accommodate immigration from Southern Spain. Currently, it is characterized by a high proportion of migrants of different nationalities (38.2%), with Moroccan and Pakistani constituting the largest percentage (March and Batllet 2015).

Urban regeneration projects in blue infrastructures have been conducted in other cities (Centro Internazionale Citta' d'Acqua 2011; Doucet 2010; Gospodini 2001; Jauhiainen 2007), sometimes to facilitate interactions between the population and blue spaces to create healthier and more attractive urban areas. However, health and well-being impacts of these urban regeneration projects have been fairly investigated (Grellier et al. 2017). The research objectives of *Paper I* were (i) to quantitatively evaluate the impact of this urban riverside regeneration project in terms of changes in the use of the area and physical activity among users over time; and (ii) to assess the local community's use and perception of the urban riverside and its surroundings before and after the intervention, as well as their self-perceived health and well-being, through a qualitative assessment. For the first research objective, I employed the System for Observing Parks and Recreation in Communities (SOPARC) (Mckenzie and Cohen 2006), and for the second research objective, I conducted semi-structured face-to-face interviews. Both methodologies are further detailed in the following sections of this thesis.

4.2.1 System for Observing Play and Recreation in Communities (SOPARC)

SOPARC is a tool based on systematic observations and designed to assess park use on community environments (Mckenzie and Cohen

2006; McKenzie et al. 2006). Although it was primarily designed to assess use and activity in parks, SOPARC can also be used to assess these items in other types of – both, indoor and outdoor – settings such as school campuses or patios, walking/jogging tracks, or streets among others (Mckenzie and Cohen 2006; McKenzie et al. 2006). SOPARC is used to quantify the number of people using a specific area, and to assess their sociodemographic conditions, being park user's physical activity levels, gender, age and ethnicity the most commonly reported characteristics.

The SOPARC tool can be used to evaluate the impact of nature-based interventions in urban areas (Cohen et al. 2014, 2015; Evenson et al. 2017; King et al. 2015), while being a non-invasive and non-expensive method. It is useful to evaluate the success of this type of interventions in terms of usability and to assess the target population using the area. In *Paper I*, the aim was to evaluate the impact of an urban riverside regeneration project which consisted on a walkway where people usually walk, cycle or run. Thus, SOPARC was considered a suitable tool for this purpose.

Despite SOPARC can be adapted for the purpose of each study by including or excluding characteristics to be recorded and/or by incorporating methodological modifications (Evenson et al. 2017), it is encouraged to follow its procedure manual (Mckenzie and Cohen 2006) as much as possible to ensure validity, reliability and feasibility of the tool (Mckenzie and Cohen 2006; McKenzie et al. 2006). The four main steps that must be followed when using the SOPARC tool are described below.

- *Identification of target areas*

Firstly, Target areas must be identified prior to the assessment. Target areas are those sections of the setting that want to be assessed. It is very important to be familiar with the study setting before starting its assessment to identify the sections that better represent the area of study. Target areas must represent all the locations likely to provide spaces for park users to use. In each Target area, an observation location needs to be selected as well. This must be a location with good visibility, allowing an adequate observation of the whole Target area. The dimensions of the Target area must be adapted according to the number of people expected to use the area. Furthermore, Target areas might be divided into Sub-target areas to obtain more accurate measures (Mckenzie and Cohen 2006).

- *Preparation of observation materials and codes definition*

Observers intended to conduct the observations using the SOPARC tool must be trained in advance using support material, including video-tutorials and manuals (Active Living Research 2006). Observations might be recorded manually on a paper form or using the iSOPARC app, which allows data collection using a web browser, or an App for androids or iOS (Active Living Research 2006; Ciafel 2013). In any case, the coding form needs to be prepared before data collection. The original coding form can be found and downloaded from the SOPARC manual (Active Living Research 2006; Mckenzie and Cohen 2006), and it can be adapted according to the purpose and characteristics of each study. The coding form must include, at least, the following data:

a) Gender. It is generally categorized into women and men, although other categories might be included.

b) Age group. It is determined according to the following criteria: (i) child = 0 to 12 years old, (ii) teenager = 13 to 20 years old, (iii) adult = 21 to 59 years old, and (iv) senior ≥ 60 years old.

c) Ethnicity. This is usually categorized into the following categories: (i) Latino, (ii) Black, (iii) White, or (iv) Other. Nevertheless, in *Paper I* of the present thesis, and according to the characteristics of the population of the study area, the following categories were used: (i) Caucasian, (ii) Latin-American, (iii) Black, (iv) Asian, (v) Others. In some studies, information on ethnicity is not collected due to ethic reasons. However, this data can provide relevant insights into studies that aim to consider a specific population group characterized by, for example, a minority group.

d) Physical activity. It is usually classified into 3 different categories: (i) sedentary, when users are lying down, sitting, or standing in place, (ii) walking, when users are walking at a casual pace, or (iii) vigorous, when users are engaged in vigorous activity such as running or cycling (World Health Organization 2019). Only when physical activity is categorized as vigorous, the type of physical activity is specified (e.g. football, skating, jumping, etc.).

For *Paper I* of the present thesis, “location” was also included in the coding form to indicate whether users were walking, running, or doing any other activity in the lower (“L”) or the upper (“U”) part of the riverside area, as it was relevant for the study (Figure 4).

- *Observation procedure*

The duration of each observation, as well as the time sections (i.e. time divisions within each observation), have to be defined in advance. For a walking/jogging track (i.e. the type of area evaluated in *Paper I* of this thesis) the duration of a time section must be the time a person needs to walk from one side to the other of the track/path (Mckenzie and Cohen 2006). Thus, for example, if a time section has an observation length of 7 minutes, within a one-hour observation there will be 6-time sections (7min x 6-time sections = 42 min) with breaks of approximately 3 minutes in-between time sections.

Figure 4. Sample of the SOPARC form used in *Paper I* of the present thesis.

DATE:__________ **OBSERVER** (Name):_______________ **Time section**: 1 2 3 4 5 6

START TIME:________ **END TIME**:_________ **Temperature and weather**:_____________

TARGET AREA: A (La Ribera Neighbourhood) B (purifying plant)

# P	Locatio n		Gende r		Activity level			Activity (specify)	Age group				Ethnicity	Notes
1	**U**	**L**	**F**	**M**	**S**	**W**	**V**		**Child**	**Teen**	**Adult**	**Senior**	**C LA B A O**	
2	**U**	**L**	**F**	**M**	**S**	**W**	**V**		**Child**	**Teen**	**Adult**	**Senior**	**C LA B A O**	
3	**U**	**L**	**F**	**M**	**S**	**W**	**V**		**Child**	**Teen**	**Adult**	**Senior**	**C LA B A O**	
4	**U**	**L**	**F**	**M**	**S**	**W**	**V**		**Child**	**Teen**	**Adult**	**Senior**	**C LA B A O**	
5	**U**	**L**	**F**	**M**	**S**	**W**	**V**		**Child**	**Teen**	**Adult**	**Senior**	**C LA B A O**	
6	**U**	**L**	**F**	**M**	**S**	**W**	**V**		**Child**	**Teen**	**Adult**	**Senior**	**C LA B A O**	
Etc...	**U**	**L**	**F**	**M**	**S**	**W**	**V**		**Child**	**Teen**	**Adult**	**Senior**	**C LA B A O**	

NOTES:

Time section: each time section will last 7 minutes (in total we will have 6 sections of 7 minutes, so 42 minutes observation time, with breaks of 3 minutes between sections, in total 60 minutes).
Start time: time at which the observation process starts.
End time: time at which the observation process ends.
#P: number of the subject observed.
Location: U=upper part of the section (sidewalk), L=lower part of the section (near the river)
Gender: F=female, M=male
Activity level: S=sedentary (lying down, sitting, standing in a place), W=walking, V=vigorous (increasing heart rate, sweating: jogging, biking…)
Activity (specify): indicate the specific activity the person is doing.
Age group: Child (<12 years), Teen (13 to 20 years), Adults (21 to 59 years), Seniors (>60 years)
Ethnicity: C=Caucasian, LA=Latin-American, B=Black, A=Asian, O=others
Note: Please indicate any events or observations of interest, including close calls, unlawful behaviour, or any other information that may affect your count, or observed behaviours such as significant events or background information, i.e. free zoo day, formal event at the park, etc.

The observation procedure consists of systematically scanning Target areas during a specific period of time to quantify the number of people using the area and their characteristics and levels of physical activity. Scans are visual sweeps from left to right across the Target area along the established time for each time-section (Figure 5). Before each observation, observers need to fill in the heading of the form indicating the date, time, temperature and weather conditions, and other information relevant for the study. The time length of each time section is measured with a chronometer and, during this time, observers annotate all the observations in the SOPARC form.

Figure 5. Observer filling in the SOPARC coding form of observations. She does it from a predefined location from which she can observe and assess the target area defined for the study. Photo taken by Glòria Carrasco (ISGlobal) in November 2017.

Observations must be conducted on different moments of the day (e.g. morning, afternoon, evening) and several days per week (including weekdays and weekends) to capture the whole use of the area. Observations can be conducted by a single observer, although it is highly recommended to have more than one observer at the same time and location, as done in *Paper I* of the present thesis. In this way, the risk of recording wrong observations is reduced because observers can correct and complement each other. The degree of agreement between observers can be assessed, for example, using the Intraclass Correlation Coefficient (Hallgren 2012).

❖ *Data management and scoring*

All the data recorded in the SOPARC coding forms must be transferred in a spreadsheet, and then imported into statistical software to conduct the analysis. The scoring procedure consists of data aggregation by the categories of interest, to conduct descriptive analysis and statistical comparisons between categories (Mckenzie and Cohen 2006). For the assessment of physical activity levels, physical activity observations must be converted into energy expenditure units, which refer to the amount of energy a person uses. The total number of sedentary, moderate, and vigorous users must be summed and then multiplied by the respective Metabolic Equivalent of Task (METs) for each physical activity category according to the compendium of physical activities developed by (Ainsworth et al. 2011).

The procedure indications previously described, are suitable for the assessment of walking or jogging tracks, which was the aim of *Paper I* of the present thesis. However, SOPARC can also be used to assess other settings with different characteristics. In this case, the recording procedure has some differences, which are properly described in the SOPARC manual (Mckenzie and Cohen 2006).

4.2.2 Qualitative methods: personal interviews

Qualitative research is characterised by the understanding of the study setting described by the individuals' perspective, being them part of this setting. It relies on a flexible and iterative research strategy that permits the discovery of unexpected characteristics of the study setting that allows a better apprehension of the findings (Berenguera et al. 2014; World Health Organization 1994). Qualitative research has been historically associated with social science, although it is increasingly used in other disciplines such as public health (World Health Organization 1994). Qualitative research does not need to be an alternative to quantitative research, but both can be employed together. Their complementarity benefits the comprehension of the reality of the study setting having a holistic understanding of it (Berenguera et al. 2014).

For research objectives of *Paper I*, it was considered relevant to obtain the perspectives of the affected community and to understand the social context of the study area to better comprehend changes on users' behaviour towards the urban riverside park before and after the intervention. Thus, the employment of mixed methods, including qualitative research, was considered a strength of the study design of *Paper I* of the present thesis.

Data collection in qualitative research can be conducted through conversational (e.g. individual or group interviews such as focus group discussions), observational, or documentary techniques (Berenguera et al. 2014). In this case, semi-structured face-to-face interviews were selected. This is an individual conversational technique based on the use of an interview guide, which is a list of questions or topics that need to be covered during the interview. The order in which the questions are asked is not relevant, and the content of the interview can be modified according to the interviewee's inquisitiveness (World Health Organization 1994).

For *Paper I* it was appropriate to use individual face-to-face interviews because it was possible to approach a relatively small, but a representative sample from "*La Ribera*" neighbourhood to converse with them, asking specific open-ended questions, giving them the opportunity of explaining what was really relevant for them regarding their neighbourhood, the urban riverside park and its regeneration project. Also, by using semi-structured face-to-face interviews I aimed to assess changes on self-perceived health and well-being of "*La Ribera*" neighbours towards the urban riverside regeneration project.

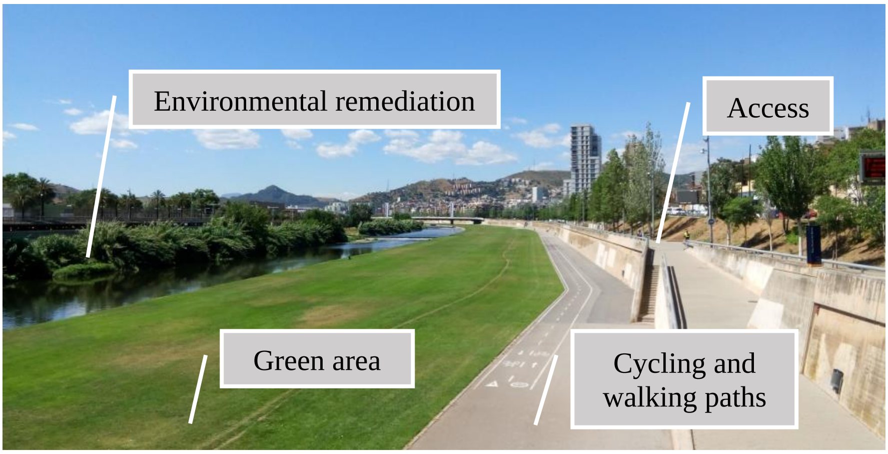
Thus, for *Paper I* of the present thesis, a sample of adult residents of "*La Ribera*" neighbourhood was interviewed. This was done both before and after the intervention, to allow to compare their responses

[N(pre-intervention)=17; N(post-intervention)=6]. The interview content was based on in-depth semi-structured interview protocols developed by the PHENOTYPE project (www.phenotype.eu/en/) and adapted to our study. Interviews were audio-recorded, transcribed verbatim, and coded using ATLAS.ti 7.5 computer-assisted qualitative data analysis software.

4.3 Case-study 2: urban riverside regeneration (II)

The main description of the Besòs Riverside Park has been described in section "*4.2. Case-study 1: urban riverside regeneration (I)*" of the present thesis. As stated before, the first stage of the Besòs Riverside Park was initiated in 2000, and its impacts on the population's health have been assessed in case-study 2 and reported on *Paper II* of the present thesis. The urban riverside regeneration project included environmental remediation, the development of a green area on the riverbanks, the provision of paths for walking and cycling along the river, and of spaces for leisure and physical activity and to facilitate social interactions (Diputació de Barcelona 2019). Also, the urban riverside regeneration project facilitated access to the riverbanks, which were not available before the intervention (Figure 6).

Figure 6. The Besòs Riverside Park. Photo taken by Cristina Vert, May 2017.



The aim of *Paper II* of the present thesis was to investigate whether the urban riverside regeneration project in the Besòs River encourages physical activity and which is the health and health-related economic impact of it. For this purpose, I assessed the health and health-related economic benefits derived from the physical activity conducted in the Besòs Riverside, once the urban riverside regeneration project was concluded.

4.3.1 Health Impact Assessment (HIA)

The most commonly tool to evaluate health impacts of urban policies or other interventions is the HIA. This is a methodology employed to assess health effects – either positive or negative – of non-healthcare policies or interventions. These health impacts estimates provide evidence for policymakers for avoiding or reducing detrimental health effects, and for promoting health benefits of a specific project, policy, programme or intervention (Mindell et al. 2003; Mindell and

Joffe 2003; Mueller et al. 2015). Depending on the time at which the assessment takes place, HIA can be prospective, concurrent, or retrospective. A prospective HIA is conducted before the implementation of the project, policy, programme or intervention. It aims to provide evidence to be used in the decision-making process. A concurrent HIA is carried out during the implementation of a project, policy, programme or intervention, to identify changes as they occur. This is particularly relevant for health impacts that are unknown or uncertain. Finally, a retrospective HIA is conducted after a project, policy, programme or intervention is implemented. It is useful to identify impacts on health outcomes after implementation and suggest modifications to mitigate or reduce these impacts (Joffe and Mindell 2005; Mindell et al. 2003). HIAs can also be distinguished into two types according to the methodology that it uses. A qualitative HIA is based on the identification of health determinants associated with the project, policy, programme or intervention that is being assessed. A qualitative HIA also identifies the direction of the impacts, suggesting whether these are considered a risk or a benefit for the populations' health (Nieuwenhuijsen et al. 2017b). Even though qualitative HIA is most commonly used, there also exist quantitative HIA, which is based on a comparative risk assessment approach. In a quantitative HIA, the burden of disease is estimated, and then it is compared with the health impacts that have been estimated for the project, policy, programme or intervention that wants to be assessed. The main differential characteristic of quantitative HIA, as compared with qualitative HIA, is that the first one brings quantitative estimates of the health impact, thus providing information on the direction and the magnitude of the impact. Also, measurable outcomes might have a stronger impact on decision-making (Joffe and Mindell 2005; Nieuwenhuijsen et al. 2017b). A quantitative HIA is characterised by a methodology that comprises the following steps (Joffe and Mindell 2005; Mindell et al. 2003; Nieuwenhuijsen et al. 2017b):

a) *Screening.* The first step before starting any HIA is to select which are the proposals that may require a HIA and which are not. Selected proposals might be those that are expected to have an impact on health and that might be able to produce changes on the decision-making process.

b) *Scoping.* This step comprises the characterization of the HIA by defining its objective, the health impacts that will be assessed and its determinants, the study population, the data sources, the analytical plan, and the identification of stakeholders involved in the assessment.

c) *Appraisal.* The third step encompasses data collection and data analysis to estimate health impacts. In this step, the method to quantify the impacts on health is defined. This would depend on the type of HIA that is used, and the resources available (e.g. dose-response functions for a specific population or health outcome). There is a difference between a HIA using a rapid appraisal (also known as "mini-HIA"), which employs existing and available information, and a comprehensive HIA (or “maxi-HIA”), which involves the collection of new data.

d) *Recommendations.* Identify and report practical strategies to reduce or mitigate health risks and amplify health benefits. This should be done with stakeholders, who could implement these recommendations.

e) *Reporting and dissemination.* In this step, results of the HIA might be reported and communicated to decision-makers, and all the other stakeholders involved in the assessment procedure.

f) *Monitoring and evaluation.* The last step of a HIA includes the evaluation of its process, outcomes, and impact.

In *Paper II* of the present thesis, I employed the methodology of a HIA to retrospectively quantify health and health-related economic impacts associated with physical activity in an urban riverside park regeneration project in Barcelona, Spain. For this purpose, the “*Blue Active Tool*” was developed. The “*Blue Active Tool*” is a bespoke quantitative spreadsheet model based on a comparative risk assessment approach designed and employed to estimate the health and health-related economic benefits of physical activity performed in the riverside study area (i.e., the blue space evaluated in this study). The tool provides estimates of the health impacts in terms of all-cause mortality, morbidity, and disability-adjusted life years (DALYs) – defined as the years of potential life lost due to premature mortality (YLL) and the years lived with disability (YLD) (World Health

Organization 2020b) –. It also provides estimates of the health economic assessment in terms of the value of statistical life (VSL) and direct health costs, providing a central estimate with 95% confidence intervals (CIs) in both cases.

To use the "*Blue Active Tool*", it was needed to provide the input data, i.e., physical activity behaviour of the study population, described in METs (Ainsworth et al. 2011). This information was estimated by using the Besòs park user survey (N = 973) and data from a counting campaign conducted in 2014–2015 by Barcelona local authorities to characterize Besòs park users (Consorci Besòs 2015). Base levels of physical activity throughout the Barcelona population were characterised using the Barcelona Health Survey (Bartoll et al. 2013; Idescat 2017), assuming that those were similar to base levels of physical activity of the study population (i.e. population living nearby the studied area), whose data was not available. Besides the input data, the use of the "*Blue Active Tool*" also required data provided by other epidemiological studies (meta-analysis and prospective cohort studies) to obtain exposure-response functions between physical activity and a variety of health outcomes (Hamer and Chida 2009; Kyu et al. 2016; Woodcock et al. 2011). This included all-cause mortality and specific diseases [ischemic heart disease, ischemic stroke, type 2 diabetes, colon cancer, breast cancer, and dementia]. The tool needs to be adjusted to the specific study population. In this case, Barcelona health records were employed to characterize the age- and sex-specific mortality and incidence rates (Bartoll et al. 2013; Rodríguez-Sanz et al. 2011; SIDIAP 2015).

The “*Blue Active Tool*” was designed for the specific objectives of *Paper II,* although it can also be adapted for other purposes (e.g. risk assessment of any other health determinant such as social interactions) as long as the indicated input data and exposure-response functions are available.

4.4 Case-study 3: Experimental study

For research objective 2 of the present thesis, I conducted an experimental study with a randomized cross-over design to evaluate the causal relationship between the exposure to blue spaces and health and well-being. I used a sample of 59 healthy adult participants, and each week of the study they were randomly assigned to the blue space, urban space or the control site. For each study week, participants were instructed to either walk on their own for 20 minutes per day in the blue or the urban space, or to rest for 20 minutes at the control site. Before, during and/or after the exposure I measured the well-being and mood of participants, and cardiovascular health indicators aiming to assess whether walking along blue spaces have a positive impact on both physical and mental health.

Before and after the exposure, a set of questionnaires to assess well-being and mood were administered to the participants. Blood pressure was also measured before and after the exposure, using a calibrated digital BP monitor (Model M10-IT, OMRON Healthcare, UK). Finally, HRV parameters were continuously measured from the time before until the time after the exposure using the wireless chest-based wearable device Zephyr BioHarness (Zephyr Technology Corporation, Annapolis, MD, US) (Medtronic 2019). Heart rate variability parameters included in this study were: heart rate (HR); high frequency (HF; 0.15–0.40 Hz) power; low frequency (LF; 0.05–0.15 Hz) power; the ratio of LF to HF (LF/HF); the standard deviation of NN intervals (SDNN); and the root mean square of successive NN interval differences (RMSSD). Heart rate variability raw data were obtained using the BioHarness Log Downloader 9500.0078.V1c (1.0.29.0), processed and cleaned using the R package RHRV (García Martínez et al. 2017).

5. RESULTS

- **Paper I**

Impact of a riverside accessibility intervention on use, physical activity, and wellbeing: A mixed methods pre-post evaluation

- **Paper II**

Health Benefits of Physical Activity Related to an Urban Riverside Regeneration

- **Paper III**

Physical and mental health effects of repeated short walks in a blue space environment: a randomised crossover study

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Bibliographic citations of these papers can be found below, at the beginning of the section of each paper

5.1 Paper I

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Impact of a riverside accessibility intervention on use, physical activity, and wellbeing: A mixed methods pre-post evaluation

Landscape and Urban Planning. 2019; 190: 103611.

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Research Paper

Impact of a riverside accessibility intervention on use, physical activity, and wellbeing: A mixed methods pre-post evaluation

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A B S T R A C T

Introduction: Access to natural outdoor environments can promote physical activity, social cohesion, and improved psychological well-being. In 2016, an urban riverside regeneration project to facilitate access to the riverbank for pedestrians and cyclists was conducted in Barcelona (Spain). We aim to evaluate its effect in terms of changes in use and physical activity of users, and changes in local's use and perception of the urban riverside, and their corresponding self-perceived health and well-being.

Methods: We conducted systematic observations, before and after the intervention, using the System for Observing Parks and Recreation in Communities (SOPARC) to quantify the use and physical activity levels of users and compared them over time. Qualitative assessment consisted of semi-structured face-to-face interviews with the locals.

Results: We observed a 25% increase in users of the renovated area of the river after the intervention. There was an increase in sedentary users and those engaged in moderate levels of physical activity [7.7% vs. 12.0% sedentary users, and 66.9% vs. 68.7% moderately active users before and after the intervention respectively, $p < 0.001$]. The growth of users in the renovated area was mainly driven by females, adults, children, and the non-Caucasian population. Resident interviewees, in general, reported to be happy to live near the river, where they usually go for a stroll, and thought living near the riverside area might benefit their health and well-being. Overall, residents seemed satisfied with the intervention.

Conclusions: Nature-based interventions in socioeconomically-deprived neighbourhoods might reduce inequalities in access to natural areas, creating attractive destinations for residents, promoting physical activity and/or creating opportunities for social interactions, and improving their health and well-being.

1. Introduction

Urban planning plays an important role in the promotion of human health and well-being (Sarkar & Webster, 2017). Urban design might influence human behaviour in terms of physical activity and social cohesion, which are both determinants of physical and mental health and well-being (Chuang, Chuang, & Yang, 2013; Nieuwenhuijsen, 2018; De Vries, Van Dillen, Groenewegen, & Spreeuwenberg, 2013). Regular physical activity is positively associated with the prevention and treatment of non-communicable diseases like obesity, diabetes, cancer, cardiovascular diseases (CVD), as well as improved mental health and well-being (National Institute for Health and Clinical Excellence, 2012; World Health Organization, 2018). Physical inactivity is a risk factor for mortality and is linked with many non-communicable diseases (Lee, Shiroma, Lobelo, & Puska, 2012). Despite the overwhelming evidence of the benefits of physical activity on health, in high-income countries 26% of men and 35% of women were insufficiently physically active in 2010 (World Health Organization, 2019) and this trend has remained stable over time (Guthold, Stevens, Riley, & Bull, 2018).

Green spaces are considered to be open surfaces with vegetation such as parks or gardens (WHO Regional Office for Europe, 2016), while blue spaces are considered "outdoor environments – either natural or manmade – that prominently feature water and are accessible to humans" (Grellier et al., 2017). There is evidence suggesting that access to these natural outdoor environments promotes physical activity, social cohesion, and improved psychological well-being (Gascon, Zijlema, Vert, White, & Nieuwenhuijsen, 2017; Nieuwenhuijsen, Khreis, Triguero-Mas, Gascon, & Dadvand, 2017). However, cities do not always have sufficient, accessible natural outdoor environments for the population (Nieuwenhuijsen et al., 2018). Given the health benefits

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associated with access to these environments, urban planners and policy makers should ensure that all the population have access to them to facilitate regular physical activity, promote social cohesion, and reduce stress (World Health Organization, 2018).

One way of achieving this is through the regeneration of natural urban areas. In this sense, a growing body of studies have been assessing the health benefits of a variety of urban regeneration projects (Hunter et al., 2015; Kramer, Lakerveld, Stronks, & Kunst, 2017; Macmillan et al., 2018; Moore et al., 2018; Stappers, Van Kann, Ettema, De Vries, & Kremers, 2018). A recent review of the impacts and effectiveness of urban green space interventions and health reveals that there is still inconclusive evidence on the effectiveness of some urban green space interventions (World Health Organization, 2017). However, the same review acknowledges the powerful opportunities for public health improvements that these interventions might bring, given their capacity of providing environmental, social, and health benefits (World Health Organization, 2017). Nature-based interventions might bring benefits for all the population, especially among lower socioeconomic status groups (World Health Organization, 2017). This is particularly important given that socioeconomically-deprived populations tend to have worse health than their wealthier counterparts (Ball, 2015; Beenackers et al., 2012).

Systematic evaluations of urban regeneration projects are key in providing professionals (e.g. urban planners, parks planners, housing development professionals, public health professionals, or medical practitioners) and policy makers with reliable information to properly design, implement, and maintain nature-based interventions, or to improve those that are already part of our cities, considering the health perspective and maximizing health benefits. The aims of the present study are (1) to quantitatively evaluate the impact of an urban riverside regeneration project in a socioeconomically-deprived neighbourhood in terms of changes in: i) use of the area and, ii) physical activity among users over time; and (2) to assess the local community's use and perception of the urban riverside and its surroundings before and after the intervention, as well as their self-perceived health and well-being, through a qualitative assessment.

2. Methods

2.1. The intervention: an urban riverside regeneration project in the Besòs river

In August 2016, the Barcelona Metropolitan Area, a public administration responsible of social and environmental policies in the metropolitan territory of Barcelona, started an intervention (Farrero et al., 2015) to regenerate a section of *Parc Fluvial del Besòs* (Besòs Riverside Park), located in the northeast of Barcelona (Catalonia, Spain) (Fig. 1A). The section of the riverbank affected by this intervention was between "La Ribera" neighbourhood and a water treatment plant (right and left side of the river downstream, respectively) (Fig. 1B). "La Ribera" neighbourhood is in Montcada i Reixac, a city in the Barcelona metropolitan area with 35,599 inhabitants (Idescat, 2018). As with other parts of the city, the creation of this neighbourhood was the result of a quick expansion of the city in the 60 s and 70 s to accommodate immigration from Southern Spain. Currently, it is characterized by a high proportion of migrants of different nationalities (38.2%), with Moroccan and Pakistani constituting the largest percentage (March & Batllet, 2015). The urban riverside regeneration project aimed to provide access to the riverbank to promote its use and enjoyment by the population. The intervention affected 735 m along the right side of the river downstream, and a total surface area of approximately 52.619 m^2. It included the construction of two paved walkways: one on the lower part of the river, and another one on the upper part (Fig. 2A). Moreover, four new access points to the riverbank were provided: two wheelchair-accessible ramps and two sets of stairs connecting the upper and the lower parts of the river (Fig. 2B) (Farrero et al., 2015). Before the intervention, the lower and the upper parts of the river were not connected as there was no access to the riverbank.

2.2. Pre/post-intervention evaluation

We conducted a mixed-methods pre/post-intervention evaluation to assess the number of users in the study area, their physical activity level, and the local community's use and perception of the new intervention over time. We followed the same procedure, described below, for both the pre- and post-evaluation.

2.2.1. Systematic observations of riverside users

We employed the System for Observing Parks and Recreation in Communities (SOPARC) (Mckenzie & Cohen, 2006) to conduct systematic observations which quantified the number of users and their socio-demographic characteristics and current physical activity levels. The reliability and feasibility of the SOPARC tool has been shown previously (McKenzie, Cohen, Sehgal, Williamson, & Golinelli, 2006), and it is widely used in similar studies (Cohen et al., 2014, 2015, 2011; Evenson, Jones, Holliday, Cohen, & Mckenzie, 2017; King, Litt, Hale, Burniece, & Ross, 2015; Van Hecke et al., 2017). For this study, four researchers were trained using the SOPARC protocol and training videos, whose methodology has been adapted for this study (Mckenzie & Cohen, 2006).

We divided the study area into two target areas: i) the renovated area, on the right side of the river downstream, where "La Ribera" neighbourhood is located, and; ii) the non-renovated area, on the left side of the river, next to the water treatment plant. Target areas were sub-divided into two locations: i) the lower part, at the riverbank level; and ii) the upper part, above the riverbank level (Fig. 1B). The observations were conducted in November-December 2016 (pre-evaluation: during the implementation of the intervention, although this did not affect normal use of the area) and then again in November 2017 (post-evaluation: when the intervention was finished). Observations were conducted in 13 one-hour sessions for each period of evaluation (i.e. pre and post) in largely comparable timeframes (Fig. S1 – Supplementary Material). Sessions were spread across weekdays and weekend days, and between different time slots: 5 sessions in the morning (8:30–9:30 h), 5 sessions in the midday (11:30–12:30 h), and 3 sessions in the afternoon (16:30–17:30 h) (Fig. S1 – Supplementary Material). Each one-hour session included 6 observation periods of 7 min each, with breaks of 3 min in between. Observations were performed from a predefined position (on each side of the river), allowing the visibility of the whole study area (Fig. 1). Observers worked in pairs (two observers per position) visually scanning from left to right within the defined area to document the following characteristics of each observed user: location (upper or lower), perceived gender (female or male), perceived age group (child = 0–12 years old; teenager = 13–20 years old; adults = 21–59 years old; or seniors ≥ 60 years old), perceived ethnicity [Caucasian – i.e. white-skinned, of European origin –, Latin-American, Black, Asian, North African, or other (these are the predominant ethnic groups in the study area)], and activity level (sedentary = lying down, sitting or standing; moderate (walking) = walking at a casual pace; or vigorous = any activity that expended more energy than casual walking). The type of activity (e.g. running, cycling, skating, etc.) was only specified for vigorous physical activity (Fig. S2 – Supplementary Material). Temperature and weather conditions were also reported for each session. Observations were not conducted on rainy days but were rescheduled for another day.

2.2.2. Physical activity assessment

To assess the energy expended by the observed users, for each target area, period of evaluation, and location (i.e. lower and upper part of the river) we summed the total number of sedentary, moderate, and vigorous users and we multiplied it by the respective Metabolic Equivalent

A) Location of the section of the Besòs Riverside Park affected by the urban riverside regeneration project (Farrero i Compte et al. 2015).

B) Renovated (pink) and non-renovated (yellow) area of the Besòs Riverside Park. Dark and light colours indicate the upper and lower location of the area, respectively. The intervention (i.e. paved walkway, ramps, and stairs) is marked in blue. Red dots indicate the position at which observers made their recordings (Adapted from the Map of Newnham Campus, Seneca College from: "Toronto, Ontario." Map, Google Maps. Accessed 23 Apr. 2014).

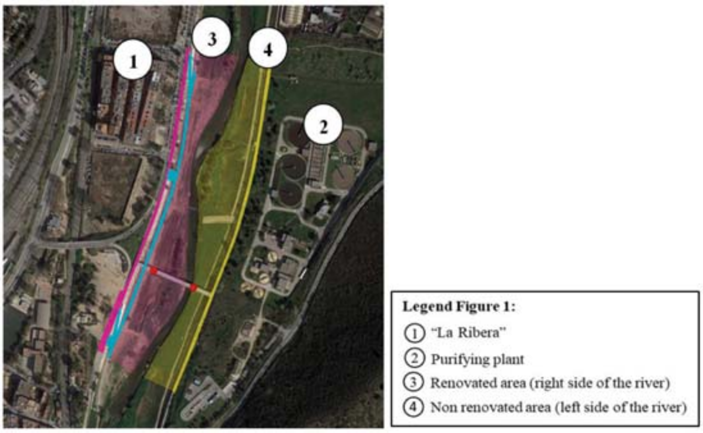


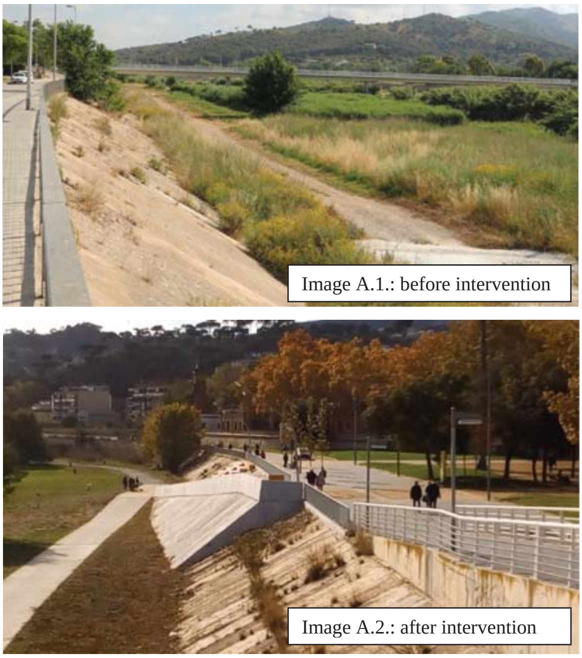
Fig. 1. Setting of the study area: A) Location of the section of the Besòs Riverside Park affected by the urban riverside regeneration project; B) Renovated and non-renovated area of the Besòs Riverside Park.

of Task (METs) for each category. For sedentary observations, corresponding to the specific activity "sitting quietly, general" of the compendium of physical activities developed by Ainsworth et al. (2011), we used a score of 1.3 METs; for moderate observations, corresponding to "walking for pleasure", we used a score of 3.5 METs; and for vigorous observations, corresponding to "bicycling, general", we used a score of 7.5 METs. We summed the respective values for each category and divided the total by the observed number of users in each assessment area; a convention used previously (Van Dyck et al., 2013; Van Hecke et al., 2017).

2.2.3. Interviews with the local community

We conducted semi-structured face-to-face interviews to assess the attitudes of the residents of "La Ribera" in relation to the natural environment around their neighbourhood, and particularly the Besòs Riverside Park and the urban riverside regeneration project. Interviews were also conducted to evaluate potential changes in self-perceived health and well-being of the local community over time. The interview content was based on in-depth semi-structured interview protocols developed by the PHENOTYPE project (http://www.phenotype.eu/en/) and was adapted to our study. It included questions on the use and perception of green and blue spaces and about the neighborhood, on how participants interact with these spaces, health and well-being status of the participants, physical activity behavior, and social interactions (Table S1 – Supplementary Material). For the pre-evaluation, study participants were recruited by contacting the municipality and

A) Right side of the Besòs Riverside Park (renovated area), before and after the urban riverside regeneration project [Photos taked by: Mireia Gascon in June 2016 (image A.1.) and Cristina Vert in November 2017 (image A.2.)].



B) Ramps and stands stairs, constructed on the right side of the Besòs Riverside Park (renovated area), to provide access to the riverbank (Photos taken by Cristina Vert, November 2017).

Fig. 2. Images of the renovated area of the Besòs Riverside Park: A) Renovated area of the Besòs Riverside Park, before and after the intervention; B) Provision of access to the riverbank.

organizing informative talks about the project. We also recruited participants in the neighbourhood streets, the local civic centre, and other relevant public spaces of “La Ribera” neighbourhood until theoretical saturation. This is a criterion for discontinuing data collection when more data do not provide more information related to the research question (Saunders et al., 2018). For the post-evaluation, the same participants were contacted by phone and researchers arranged a meeting with them to conduct the interview. All participants were 18 years old or older and resided in “La Ribera” neighbourhood. These interviews were mainly conducted on the street, but also in the civic centre, in a bar, or at the participant’s residence. Interviews were conducted in Spanish or Catalan and were audio recorded. Information about the project was given to the participants, and before enrollment in the study all participants were asked to indicate their informed consent to participate. Participants did not receive any financial incentive for their participation in this study. All the methods were approved by the Clinical Research Ethics Committee of the Parc de Salut MAR.

Interviews were transcribed verbatim and coded using ATLAS.ti 7.5 computer-assisted qualitative data analysis software. We identified significant quotes in the transcriptions, and developed thematic codes (grouped in different categories and sub-categories). Codes were created inductively, based on the identification of relevant topics during the interview assessment. Interviews were separately coded and compared by two different researchers to ensure consistency and reliability. If necessary, codes were merged, deleted, created, or renamed if both researchers agreed. Based on the grounded theory approach (Noble & Mitchell, 2016), we theorised about the main topics identified within the interviews and ended up with an explanatory statement summarizing the most relevant information extracted from the interviews. We used ATLAS.ti to count the frequency that codes were discussed before and after the intervention. We also assessed potential differences between genders, age groups, and ethnicities.

2.3. Data analysis

SOPARC observations were manually recorded on a paper form, entered into a Microsoft Excel database, and then imported into STATA version 14. We measured the degree of agreement between observers using the Intraclass Correlation Coefficient (ICC) (Hallgren, 2012). Then, for each day, time slot, and target area we randomly selected one of the two observations in order to avoid duplicates. If there were missing values for the selected observer, we replaced them with the values provided by the excluded partner observer. Otherwise, we coded missing observations as men, adults, Caucasian, and walking because these were the main characteristics of the study population. Observations were summarized by year and target area, and stratified by location, gender, age group, ethnicity, and activity level. We employed chi-square tests to compare categorical variables describing socio-demographic characteristics of the users before and after the intervention. We also assessed if the weather conditions and temperature significantly varied between assessment periods using chi-square tests and Student's *t*-test, respectively. Moreover, we have used multinomial logistic regression models to assess the effects of the urban riverside regeneration project (i.e. pre/post intervention) and the target area (i.e. renovated and non-renovated area) on the user's physical activity levels. We assessed effect modification using likelihood ratio test (LRT). We also assessed the influence of other covariates (i.e. gender, age, ethnicity, location, day of the week, and time slots). Our analysis was based on the methodological approach proposed by SOPARC (Mckenzie & Cohen, 2006).

3. Results

3.1. Agreement between observers and good reproducibility of the procedure

For each SOPARC evaluation session there were two observers assessing the same target area. Before assuming that missing values corresponded to adult Caucasian males walking, the overall ICC between observers was 0.996 (95% CI; 0.994, 0.998), showing the highest agreement for activity level [0.998 (95% CI; 0.997, 0.999)], and the lowest agreement for ethnicity [0.866 (95% CI; 0.806, 0.908)]. After replacing missing values, results were very similar (data not shown). For gender we replaced 0.7% missing values, 1.6% for age, 4.4% for ethnicity, and 0.3% missing values for activity level (data not shown). In any case, ICC values ranged from 0.866 to 0.999 indicating high agreement between observers and good reproducibility of the procedure.

3.2. Use of the urban riverside area

Following the completion of the urban riverside regeneration project, the total number of users in the whole Besòs riverside area slightly increased from 3478 to 3631 (Table 1). The number of users significantly increased in the renovated area (30.2% in 2016 vs. 36.1% in 2017, $p < 0.001$), while significantly decreased in the non-renovated area (69.8% in 2016 vs. 63.9% in 2017, $p < 0.001$]. More specifically, in the lower part (riverbank) of the renovated area, we observed a noticeable increase of users (1.7% in 2016 vs. 15.9% in 2017, $p < 0.001$), whereas in the upper part the number of users decreased (98.3% in 2016 vs. 84.1% in 2017, $p < 0.001$) (Table 1). However, the total number of users was higher in the non-renovated area both before and after the intervention compared to the renovated area (Table 1).

Overall, more males were observed in the riverside area than females, both before and after the intervention. However, after the intervention, we observed a 43% increase in females at the renovated area of the river while the number of females decreased 26% in the non-renovated area (Tables 1 & S2 – Supplementary Material). The pattern for males was the opposite (Tables 1 & S2 – Supplementary Material). When looking at both areas of the river, gender differences over time were not statistically significant ($p = 0.227$) (Table 1).

The most prevalent age group was adults (59.8% and 59.5% of the users in 2016 and 2017, respectively), followed by seniors (34.1% and 36.1% of the users in 2016 and 2017, respectively). Teenagers and children were underrepresented (i.e. from 6.1% in 2016 to 4.4% in 2017 of the total users), although the percentage of children in the renovated area significantly increased after the intervention (1.7% in 2016 vs. 4.0% in 2017, $p < 0.001$), whereas in the non-renovated area the percentage of children decreased (1.8% in 2016 vs. 1.2% in 2017, $p < 0.001$) (Tables 1 & S3 – Supplementary Material). To ensure that our results were not strongly influenced by the presence of a school group (N children = 23; N teenagers = 50) conducting an organized activity on the upper part of the non-renovated area during one session in the pre-evaluation, we conducted a sensitivity analysis excluding these users. Results were similar when compared to the full sample (Table S4 – Supplementary Material).

More than 90% of the users were coded as Caucasians. However, a significant increase of non-Caucasian users was observed in the renovated area after the intervention (2.6% of non-Caucasian users in 2016 vs. 7.8% in 2017, $p < 0.001$) (Table 1).

We observed 110 and 209 users with at least one dog in 2016 and 2017, respectively. These users were mainly Caucasians, adults or seniors, and predominantly males (data not shown). Although the intervention was designed to enable use by people of all physical abilities, we only observed 8 disabled users (6 in 2016 and 2 in 2017) during the whole study period (data not shown).

Finally, regarding the potential influence of temperature and weather conditions, the proportion of sunny days in 2016 was exactly the same as in 2017 (i.e. 61.5%) (data not shown). However, the mean temperature in 2016 was higher than in 2017 [12.8 °C (95% CI; 10.9, 14.6) in 2016 vs. 9.3 °C (95% CI; 6.0, 12.6) in 2017, $p = 0.056$]. And the minimum values reported in 2016 were also higher than in 2017 (6 °C and 2 °C, respectively). The maximum values were similar for both years (18 °C in 2016 and 19 °C in 2017) (data not shown).

3.3. Energy expenditure

On average, for the pre- and post-evaluation period and for both areas of the river, users were most often moderately (46.5%) or vigorously (47.0%) active, while a smaller proportion were sedentary (6.5%) (Table 1). The most predominant activity among vigorously active users in both study periods was cycling (84.5%) followed by running (11.7%). The rest of the vigorously active users practised other activities such as roller skating, skateboarding, or playing with a dog (data not shown). When pooling data from both sides of the river, the percentage of users engaging in sedentary, moderate, or vigorous levels of physical activity barely changed from 2016 to 2017 ($p = 0.447$) (Table 1). However, when we looked at each side of the river (i.e. renovated and non-renovated area), we observed a significant increase of users engaging in sedentary and moderate levels of physical activity in the renovated area (7.7% of sedentary users in 2016 vs. 12.0% in 2017; and 66.9% of moderately active users in 2016 vs. 68.7% in 2017, $p < 0.001$), and a significant increase of users engaging in vigorous levels of physical activity in the non-renovated area (56% in 2016 vs. 62.4% in 2017, $p < 0.001$) (Table 1). Thus, in the post-intervention evaluation period, the risk being sedentary and moderate compared

Table 1
Characteristics of the total number of users observed in Besòs Riverside Park by target area, for the pre and post-evaluation SOPARC assessment.

	Renovated area			Non-renovated area			Both areas		
	PRE (2016) N = 1049	POST (2017) N = 1312	p-value[b]	PRE (2016) N = 2429	POST (2017) N = 2319	p-value[b]	PRE (2016) N = 3478	POST (2017) N = 3631	p-value[b]
Location [N, (%)]									
Upper	1031 (98.3)	1103 (84.1)	0.000	2072 (85.3)	2047 (88.3)	0.003	3103 (89.2)	3150 (86.6)	0.001
Lower	18 (1.7)	209 (15.9)		357 (14.7)	272 (11.7)		375 (10.8)	481 (13.3)	
Demographic characteristics of the users [N, (%)]									
Gender									
Female	282 (26.9)	403 (30.7)	0.041	484 (20.0)	356 (15.4)	0.000	768 (22.1)	759 (20.9)	0.227
Male	767 (73.1)	909 (69.3)		1943 (80.0)	1963 (84.7)		2710 (77.9)	2872 (79.1)	
Age group									
Children [a]	18 (1.7)	52 (4.0)	0.000	43 (1.8)	27 (1.2)	0.000	61 (1.8)	79 (2.2)	0.000
Teens [a]	71 (6.8)	36 (2.7)		80 (3.3)	42 (1.8)		151 (4.3)	78 (2.2)	
Adults	484 (46.1)	734 (56.0)		1595 (65.7)	1428 (61.6)		2079 (59.8)	2162 (59.5)	
Seniors	476 (45.4)	490 (37.3)		711 (29.3)	822 (35.4)		1187 (34.1)	1312 (36.1)	
Ethnicity									
Caucasian	1022 (97.4)	1215 (92.6)	0.000	2390 (98.4)	2276 (98.1)	0.147	3412 (98.1)	3491 (96.1)	0.000
Latin-American	9 (0.9)	23 (1.8)		13 (0.5)	4 (0.2)		22 (0.6)	27 (0.7)	
Black	2 (0.2)	8 (0.6)		5 (0.2)	5 (0.2)		7 (0.2)	13 (0.4)	
Asian	10 (0.9)	26 (1.9)		8 (0.3)	14 (0.6)		18 (0.5)	40 (1.1)	
North-African	6 (0.6)	23 (1.8)		10 (0.4)	16 (0.7)		16 (0.5)	39 (1.1)	
Other	0 (0.0)	17 (1.3)		3 (0.1)	4 (0.2)		3 (0.1)	21 (0.6)	
Physical activity level [N, (%)]									
Sedentary	81 (7.7)	158 (12.0)	0.000	130 (5.4)	89 (3.8)	0.000	211 (6.1)	247 (6.8)	0.447
Moderate	702 (66.9)	901 (68.7)		928 (38.2)	782 (33.7)		1630 (46.8)	1683 (46.3)	
Vigorous	266 (25.4)	253 (19.3)		1371 (56.4)	1448 (62.4)		1637 (47.1)	1701 (46.9)	

[a] During one sampling session in 2016, observers observed a group of scholars (N child = 23; N teen = 50) doing an organized academic activity along the study setting. We conducted a sensitivity analysis excluding these users (Table S4 – Supplementary Material).
[b] P-values based on Chi-squared tests to compare the distribution of sociodemographic characteristics of users between the pre (year 2016) and post (year 2017) intervention evaluation.

Table 2
Association [Relative Risk Ratio (RRR) 95% CI] between post intervention evaluation period (year 2017) – having the pre-intervention evaluation period (year 2016) as the reference – and covariates, with user's physical activity level [i.e. sedentary, moderate and vigorous (reference)], for the renovated and non-renovated area.

	Renovated area Physical activity level (Reference = Vigorous)		Non-renovated area Physical activity level (Reference = Vigorous)	
	Sedentary RRR (95% CI)	Moderate RRR (95% CI)	Sedentary RRR (95% CI)	Moderate RRR (95% CI)
POST (2017) [Reference = PRE (2016)]	1.78 (1.26; 2.51)*	1.25 (0.99; 1.57) *	0.68 (0.49; 0.94) *	0.67 (0.58; 0.78) *
Covariates				
Females (Ref = males)	2.73 (1.74; 4.29) *	6.55 (4.68; 9.17) *	8.23 (5.66; 11.96) *	10.12 (8.19; 12.51) *
Age group (Ref = adults)				
Children	5.22 (2.23; 12.26) *	1.57 (0.70; 3.55)	41.84 (18.89; 92.65) *	11.06 (5.70; 21.48) *
Teens	0.78 (0.33; 1.83)	1.18 (0.69; 2.01)	19.95 (11.53; 34.51) *	1.08 (0.61; 1.91)
Senior	2.41 (1.66; 3.51) *	4.80 (3.71; 6.22) *	7.26 (5.03; 10.46) *	8.30 (7.06; 9.75) *
Non-Caucasian (Ref = Caucasian)	2.99 (1.44; 6.21) *	2.19 (1.24; 3.88) *	8.77 (3.55; 21.65) *	6.17 (3.43; 11.08) *
Lower location (Ref = Upper location)	4.14 (2.21; 7.77) *	4.40 (2.62; 7.38) *	0.33 (0.16; 0.67) *	0.39 (0.30; 0.51) *
Weekend (Ref = weekday)	0.48 (0.33; 0.70) *	0.50 (0.39; 0.65) *	0.27 (0.18; 0.40) *	0.43 (0.37; 0.51) *
Time of the day (Ref = midday)				
Morning	0.18 (0.11; 0.30) *	0.54 (0.42; 0.69) *	0.11 (0.06; 0.21) *	1.02 (0.86; 1.21)
Afternoon	0.66 (0.40; 1.08)	0.94 (0.65; 1.36)	0.79 (0.54; 1.15)	1.49 (1.20; 1.85) *

RRR: Relative Risk Ratio.
Ref = Reference.
* Statistically significant ($p < 0.05$).

with vigorous was significantly higher for users in the renovated area (e.g. RRR for sedentary users = 1.78 (95% CI 1.26; 2.51)), and lower for those in the non-renovated (e.g. RRR for moderately active users = 0.67 (95% CI 0.58; 0.78)) (Table 2). Sedentary users in the renovated area mainly used the stairs to sit or lie on, although some users also sat on the benches, or leant against the fence, both in the upper and the lower part of the river (Fig. 2-A.2).

Even though in both areas of the river females and males were mainly moderately and vigorously active users respectively (Fig. S3 – Supplementary Material); in the post-intervention evaluation period sedentary use of the renovated area increased for both females and males (Fig. 3). Nevertheless, females had a significant higher risk being sedentary and moderately active both in the renovated and in the non-renovated area, compared with males (Table 2).

Of all the age groups identified in this study, children had the highest risk being sedentary (e.g. RRR for sedentary children in the renovated area = 5.22 (95% CI 2.23; 12.26)) in both areas of the river (Table 2). Despite this, the increase of moderately active users over time

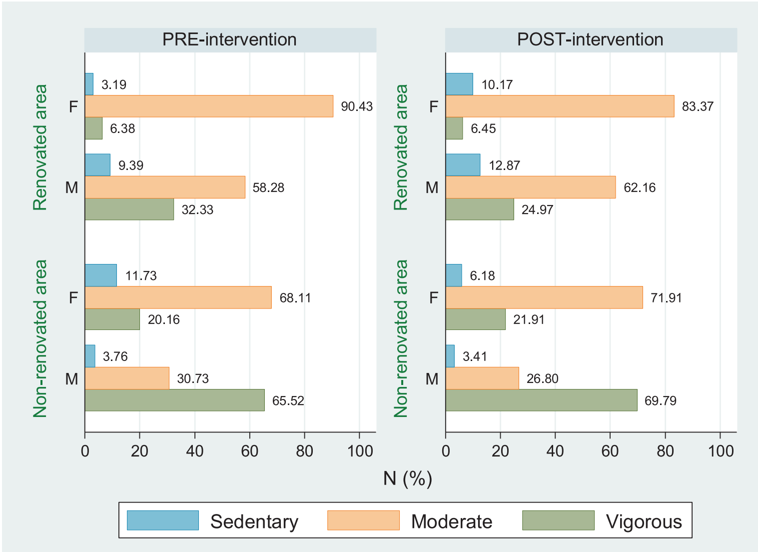


Fig. 3. Levels of physical activity by target area (i.e. renovated and non-renovated area) and period of evaluation (i.e. pre/post-evaluation), and stratified by gender (F = female; M = male).

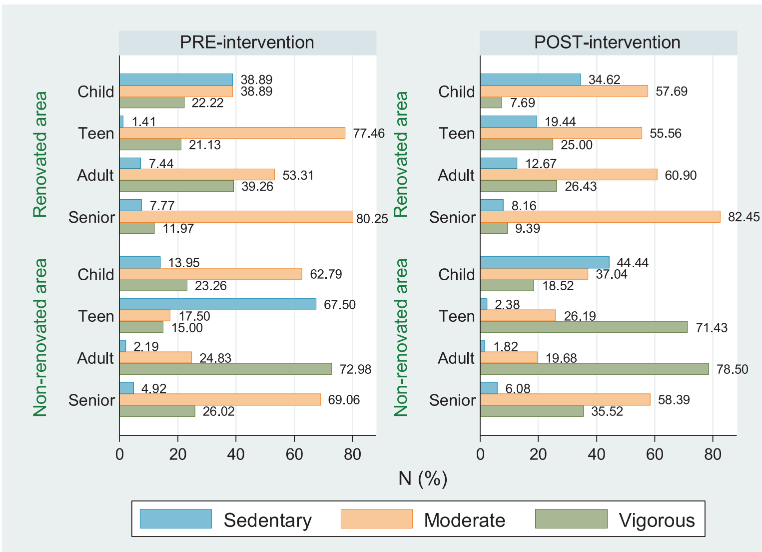


Fig. 4. Levels of physical activity by target area (i.e. renovated and non-renovated area) and period of evaluation (i.e. pre/post-evaluation), and stratified by age group.

in the renovated area was mainly driven by children (38.9% in 2016 vs. 57.7% in 2017) and adults (53.3% in 2016 vs. 60.9% in 2017), although the proportion of moderately active seniors also increased (Fig. 4). In the non-renovated area, teenagers experienced the highest increase of vigorous physical activity levels (from 15.0% in 2016 to 71.4% in 2017) (Fig. 4). We also observed an increase of vigorous levels of physical activity for adults and seniors, but not for children (Fig. 4).

Non-Caucasians had a significantly higher risk of being sedentary and moderately active users than Caucasians (Table 2). The risk was higher in the non-renovated area than in the renovated area (e.g. RRR for moderate non-Caucasian in the non-renovated area = 6.17 (95% CI 3.43; 11.08)) (Table 2). However, in the post-evaluation, the proportion of sedentary non-Caucasian users increased in both the renovated (from 0% in 2016 to 18.6% in 2017) and the non-renovated area (from 2.6% in 2016 to 16.3% in 2017) (Fig. 5). Likewise, the proportion of Caucasian vigorously active users increased in the non-renovated area (from 56.8% in 2016 to 63.4% in 2017), while the proportion of non-Caucasian vigorously active users decreased (from 35.9% in 2016 to 11.6% in 2017) (Fig. 5).

Users in the lower part of the renovated area had a significant higher risk being sedentary and moderately active than those in the upper part. In the non-renovated area the pattern was the opposite

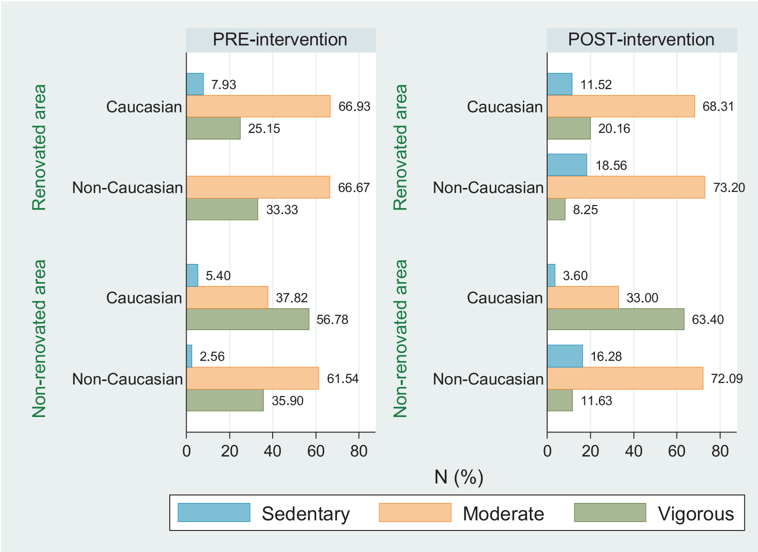


Fig. 5. Levels of physical activity by target area (i.e. renovated and non-renovated area) and period of evaluation (i.e. pre/post-evaluation), and stratified by ethnicity.

(Table 2). The users' risk being sedentary and moderately active, compared with being vigorously active, decreased in the weekend (e.g. RRR for moderately active users in the weekend in the renovated area = 0.50 (95% CI 0.39; 0.65)), compared with the rest of the week, in both areas of the river (Table 2).

Overall, we did not observe changes in energy expenditure (expressed in METs/observation) after the intervention (Table 3). However, we observed an 8% decrease of METs/observation in the renovated area and 5% increase in the non-renovated area (Table 3). This was mainly driven by the decrease of energy expended in the lower part of the river, and the increase of energy expended in the upper part of the river in the renovated and non-renovated area respectively (Table 3). Nevertheless, moderately active users were the most prevalent activity group in the renovated area, whereas in the non-renovated area it was vigorously active users (Table 1).

3.4. Local community's use and perception of the urban riverside

For the qualitative assessment of the intervention we interviewed a total of 17 participants in the pre-evaluation, and 6 of them were interviewed again in the post-evaluation period (Table S5 – Supplementary Material). The rest of the participants did not participate in the post-evaluation due to different reasons: they moved to another neighbourhood (N = 2), they experienced health problems or hospitalizations (N = 2), they did not answer phone calls (N = 4), or they were not willing to participate due to incompatibility with their workday schedule (N = 3). The length of the interviews ranged between 15 and 40 min.

3.4.1. Socio-economic context

All the participants were residents of "La Ribera" neighbourhood, and most of them mentioned they were living there due to affordable housing. Some participants had been living in "La Ribera" for a long time, and others were newcomers (mainly from outside Spain). Most of the participants reported to be satisfied with the neighbourhood. They liked the area, they were familiar with it, and they had many social interactions, either in the street or the civic centre. In fact, participants highlighted social cohesion among residents, especially among those who had lived there for longer. However, many participants also complained about anti-social behaviour of the residents (e.g. offensive language, disrespectful behaviour, noise, dirtiness, etc.).

3.4.2. Use and perception of the urban riverside

Most of the participants reported using the riverside area, especially for walking or walking the dog, but also for cycling, running, or playing with their children:

> *"I always follow the same route because, as I told you, hmm…we walk, then we stop, we look at…in the river, we look at some ducks…you know…we look at them for a while, then we keep walking a little bit more, and so on. And we like it…to walk and…looking around" (Adult, female, Caucasian)*

A few elderly people mentioned they used to go to the riverside area but no longer visited it due to health reasons. Some participants

Table 3
Energy expenditure (in mean METs/observation) by target area and for the pre and post-evaluation SOPARC assessment.

	Renovated area			Non-renovated area			Both areas		
	PRE (2016)	POST (2017)	Comparison between years [% of change]	PRE (2016)	POST (2017)	Comparison between years [% of change]	PRE (2016)	POST (2017)	Comparison between years [% of change]
Mean METs/observation									
Upper	4,34	4,12	−5	5,44	5,80	7	5,08	5,21	3
Lower	4,59	3,41	−26	6,79	6,74	−1	6,69	5,29	−21
Total	4,34	4,01	−8	5,64	5,91	5	5,25	5,22	0

expressed their discomfort of sharing the area with dogs mainly due to the presence of animal excrement, but also because they considered that dogs damaged the riverside area:

“Another of the measures that they would have to do is not to let people walk the dogs by the river, because…because there are nests, because there are animals and they break them down. Also, they should stop bringing the dogs [to the riverside] because it seems to me that it does a lot of damage to the river” (Senior, male, Caucasian)

Frequency of visits to the riverside varied among participants (from daily to sporadic visits). However, participants usually used the riverside more during the summer months than during the winter months. The majority of the participants went to the riverside with someone else (e.g. relative, friends, their children, etc.), and only a few of them went alone. Nevertheless, the reasons given for visiting the riverside with others varied amongst participants. Thus, we do not know whether this was due to safety reasons or other factors. However, most of the participants thought the riverside area was a safe place, at least during the day because there was light. Participants did not report going to the riverside area at night, indicating the lack of lighting as a reason:

“Yes, it is safe [the riverside area] Well…yes, it’s safe during the day. At night I do not know… It must …that must be as insecure as anywhere else…” (Adult, male, Caucasian)

Although most of the participants mentioned the affordable cost of the apartments as the main reason to move to “La Ribera” neighbourhood, the majority acknowledged the proximity to the river as a plus for the neighbourhood. They liked either seeing the river from home (if possible), walking along it, or even observing and playing in the river being in contact with the water. In their opinion, having the river close to their home might benefit their health and well-being. In fact, many participants highlighted the importance of having natural environments around their residence:

“Well…as I told you it's a troubled neighbourhood…When I feel comfortable, when I go up the mountain…When I go to the Serralada la Marina or when I'm walking along the river. Then I feel comfortable” (Senior, male, Caucasian)

It gave them a sense of restoration, calmness and enjoyment. The self-perceived health and well-being benefits of practising physical activity along the river versus practising it in urban areas were also mentioned by several participants.

One of the participants’ favourite aspects of the river was the presence of a variety of animals and vegetation. They highlighted the importance of preserving the nature of the area:

“Well… [I like] the vegetation, the animals that have come, like the seagulls, the ducks…Since…in the eighties…there were not [animals], not at all! In the nineties either” (Senior, female, Caucasian)

Other participants though, complained about wild boars because there are many of them and they perceived that their presence is encouraged by residents who continue to feed them. Also, some participants complained about the maintenance of the vegetation:

”Well there are too many plants…too many herbs…that's what I do not like…I would like them [those responsible for park maintenance] to come more often to take care of what is the, the herbs of the river… And that they could cut them…they might take care of them to keep nature alive, right?” (Adult, female, Caucasian)

In general, long-time residents of “La Ribera” neighbourhood perceived the quality of the river water as improved compared to its past condition, when it was more polluted. They thought the river and riverbank had improved over time, in terms of cleanliness, beauty, flora, and fauna of the area. However, other participants considered the river and its surroundings as dirty, and most of them reported this as a result of anti-social behaviour of some people who threw rubbish in the river or did not respect the area. In line with this, many participants reported annoyance at the bad odour that came from the river. Some of them suspected it originated from the water treatment plant located next to the river. The bad odour was worse in summer and sometimes residents of “La Ribera” reported that this caused throat irritation.

“I don’t like the odour…well, when you walk along the river…i don’t know…the odour…it’s horrible next to the river!” (Adult, female, non-Caucasian)

Another concern of the participants using the riverside area was the presence of both walkers and cyclists, using the same lanes. They thought there should be a bicycle line separate from the walkway because they perceived it to be unpleasant or even dangerous to share the space with cyclists. For some participants this was a reason to not use the riverside.

Nevertheless, one of the main complaints reported by the participants before the intervention was that access to the riverbank was not properly provided, and they wanted it to be improved. Before the intervention, some people jumped the fences to reach the riverbank, which was a dangerous practice:

“When it is not cold, we go on a picnic with my children down there [lower part of the riverside area]…it's fine (…). What happens, of course… is that we have to jump the fence, and it is uncomfortable. Otherwise you have to walk for…I don’t know, about 1 km!” (Adult, female, Caucasian)

3.4.3. Assessment of the urban riverside regeneration project

As mentioned before, the main aim of the urban riverside regeneration project was to facilitate access to the riverbank. In general, participants knew that an intervention was being conducted, but they did not know about the details. Among participants, it was very common to both positively and negatively compare this urban riverside regeneration project with another one conducted some kilometers further away, next to Barcelona, which was larger and more ambitious than the one assessed in this study. For this one, some participants highlighted the necessity of keeping the river as natural as possible, respecting the original fauna and flora, and avoiding the incorporation of artificial elements such as paved walkways, or newly planted grass.

Overall, participants were satisfied with the renovation. They said that the access to the riverbank significantly improved. They liked the appearance of the riverside park, and some participants mentioned that more people were going to the riverbank after the intervention:

“[The access provided by the renovation] It's good for the people… for… for the children…for everything…for doing sport. Also for the residents of the neighbourhood” (Adult, female, non-Caucasian)

Participants highlighted the fact that riverside users were mainly physically active along the river. They mainly walked for pleasure, although some users also reported to run or cycle:

“My reason [to go to the riverside area] is…because I like it, I’ve already told you that I like so much the river, the birds and so, but I also go [to the riverside area] because…I like walking. I go for a stroll with my husband” (Adult, female, Caucasian)

Nevertheless, many participants had the feeling that the intervention was unfinished (e.g. unconnected walkway, some access points were closed, lack of equipment like benches, toilets, etc.). Also, some participants thought some users may not respect the renovated area. Finally, a participant mentioned that the walkway could be closer to the river to be able to see and listen to the water when walking.

4. Discussion

4.1. Main findings

According to our assessment, the urban riverside regeneration project undertaken in a section of the Besòs Riverside Park, in the municipality of Montcada i Reixac, showed increased use, mainly due to a greater presence of females, adults, children, and the non-Caucasian population. The highest increase of users was observed in the lower part of the renovated area, indicating that users employed the stairs and ramps dedicated to facilitate access to the riverbank. Our results also suggest an increase in vigorously active users in the non-renovated area, and an increase of users engaging in sedentary and moderate levels of physical activity in the renovated area. Thus, in this study, the renovation of the Besòs Riverside Park seemed to mostly facilitate relaxation rather than increased physical activity. However, previous studies have suggested that a number of strategies such as introducing signage, organised activities, and promotional incentives, may increase the physically active use of a park, at least in the short-term (Roberts, McEachan, Margary, Conner, & Kellar, 2018).

A study examining the effect of improved safe access to a park in a low-income and majority African-American neighborhood in the USA reported similar results (Schultz, Wilhelm Stanis, Sayers, Thombs, & Thomas, 2017). This is also in line with a realist review suggesting that urban regeneration projects might stimulate leisure-time walking (i.e. moderate physical activity) among adults in deprived areas (Kramer et al., 2017). A predominance of sedentary and moderate physical activity behavior in the renovated area (closer to “La Ribera” neighborhood) might indicate this area is being used as a destination for residents for activities such as leisure or strolling. Moreover, the segregation of types of physical activity practiced on each side of the river might ease concerns the local community has about cyclists and walkers sharing the same space. Our findings indicate that vigorously active users prefer to use the upper part of the non-renovated area, whereas moderate and sedentary users prefer to use the renovated area, thus reducing the potential conflicts of uses, particularly between cyclists and walkers. Sedentary activities in parks or other open spaces may promote social benefits and so improve human’s mental health and well-being (Van Hecke et al., 2017). Moreover, reaching the Besòs Riverside Park promotes physical activity among those users walking or cycling to the park, even if they are sedentary once they arrive to their destination (Cohen et al., 2007; Van Hecke et al., 2017). According to this, it may be equally important to provide appropriate infrastructure that supports active travel (e.g. walking or cycling) to the river, as it is providing activity-supportive infrastructure at the river.

The demographic profile of the users was slightly different from before to after the intervention. First, we observed a significant increase of female users – adults and children – in the renovated area. In line with other studies (Joseph & Maddock, 2016), they were mainly engaged in moderate physical activity, although we observed an increase of female users engaged in sedentary activities as well. A potential hypothesis to explain the increase of adult females could be that these were at the riverside park together with their children, whose age group significantly increased in the renovated area as well. Findings of the interviews conducted in this study did not suggest that the increase of females in the renovated area was due to improved perceptions of safety after the intervention. However, having an outdoor natural space available and accessible closer to their homes might be more convenient to use, especially if they go with their children. Moreover, a qualitative review reported that females viewed parks as safe places to meet and socialize with each other (McCormack, Rock, Toohey, & Hignell, 2010). In any case, our results suggest a reduction of gender inequalities in the park after the intervention even though the number of males was substantially higher than females on both sides of the river, and males were more engaged in vigorous physical activity than females, which are similar results to those reported by other similar studies (Evenson et al., 2017; Joseph & Maddock, 2016; King et al., 2015; McKenzie et al., 2006; Van Dyck et al., 2013; Van Hecke et al., 2017). Second, we observed that adults and seniors were more likely to visit the Besòs Riverside Park than children and teenagers. This is consistent with other studies, although not for seniors which are usually an underrepresented group of users in the parks (Evenson et al., 2017; Joseph & Maddock, 2016; Schultz et al., 2017). As children and teenagers were also not frequent users, strategies to engage them to actively use the riverside area (e.g. skate park, climbing wall, organization of dancing events, etc.) might be considered to ensure that the area appealing to different age groups. Finally, we observed a large difference in the amount of Caucasian and non-Caucasian users in the whole riverside park, non-Caucasians being less prevalent, which does not reflect the population characteristics of “La Ribera” neighborhood. However, our findings suggested an increase over time on the engagement of non-Caucasian users, both in the renovated and in the non-renovated area. Reducing inequalities of access to natural environments for different ethnic groups remains a public health priority.

Our results do not seem to be influenced by weather conditions because, as mentioned before, we did not conduct observations on rainy days, and the proportion of sunny days was the same in the pre and post-evaluation period. Moreover, temperatures were similar in both periods of evaluation. Thus, the increase of users reported in the post-evaluation period was not influenced by warmer temperatures in this period.

5. Limitations

Our study faced some limitations. First, we conducted the pre-evaluation during the construction period and thus were not able to obtain a true baseline. However, we do not think this affected our results because characteristics of the study area during the construction work were similar to those before the job started (e.g. access to the riverbank was not provided in either situation). Nevertheless, we acknowledge the construction could deter people from visiting due to presence of – for example – noise, dust, or debris. Second, in line with other studies (Evenson et al., 2017), we conducted systematic observations only in one season (autumn). Thus, it may not be representative of the use of the park during the whole year. However, this does not affect our results because the aim of this study was to compare the use of the park between two comparable periods of evaluation. Future research might investigate how improvements to natural environments might differentially affect its use according to seasonality. Third, SOPARC is a feasible and reliable tool, but sometimes it was difficult to identify the gender, age group, or ethnicity of the users due to the distance between them and the researchers, or because users were obscured by a scarf, hat, coat, etc. This was acknowledged, and two researchers did the same observations at the same time in order to avoid misclassification. Fourth, although researchers tried to obtain a representative sample of the local community, interviews were mainly conducted with females, adults, and Caucasians of the “La Ribera” neighborhood. This implies that different recruitment strategies are needed in order to recruit “harder-to-reach” demographic groups (i.e. non-Caucasians). Finally, we acknowledge the risk of gentrification as in any other urban regeneration project (Cole, Garcia Lamarca, Connolly, & Anguelovski, 2017; McCartney et al., 2017). Urban regeneration projects should be always accompanied with policies and regulations (e.g., to safeguard affordable housing, protect senior homeowners, to regulate land use, etc.) that impede or reduce potential gentrification effects.

5.1. Strengths

An important strength of the current study is that it combines quantitative and qualitative methodologies. It helps interpreting the results given that each method is complemented by the other one, exploiting the benefits, and reducing their own limitations (Shenton, 2004). Moreover, triangulation by using different methods may be a strategy to ensure credibility of the results (Gaber & Overacker, 2012; Shenton, 2004). On the one hand, we used the SOPARC tool, which has been typically used in the USA (Evenson et al., 2017; Joseph & Maddock, 2016). This is one of the first studies employing SOPARC in a European country (Pawlowski et al., 2017; Van Dyck et al., 2013; Van Hecke et al., 2017). SOPARC allowed us to easily quantify the number of people using the park before and after the intervention and to estimate their levels of physical activity in the park, using a non-invasive technique. It is a non-expensive method, although it is time-consuming. Further studies may consider other technological options to avoid this problem [e.g. apps that facilitate data collection and management (Evenson et al., 2017)]. On the other hand, interviews allowed us to better understand the behaviour, needs and concerns of the local community. This is an effective method widely used in other studies evaluating health effects of nature-based interventions (World Health Organization, 2017). Moreover, in this study we have mainly focused on the benefits related to the use of and practice of physical activity in the Besòs Riverside Park, but, thanks to the qualitative assessment, we have also considered some risks or concerns related to it (e.g. pollen allergies, vandalism, or incidents with cyclists). Another strength of the current study is that, given the study design, it is relatively easy and affordable to conduct a follow-up to assess the persistence or not of the effects of this intervention. Moreover, the design of this study allowed us to conduct a pre/post-evaluation and assess changes produced after the intervention. Finally, a key strength of this study is the ability to compare the renovated area with the non-renovated area, which has been used as a control.

Results of this study will be shared with stakeholders (including the local community, the municipality, healthcare professionals, and those responsible for the civic centre, etc.) because these findings might be helpful to identify the strengths and desired improvements for the Besòs Riverside Park, and thus underline its importance as a public health resource.

6. Conclusions

We found that the urban riverside regeneration project undertaken in the Besòs Riverside Park in “La Ribera” neighbourhood in Montcada i Reixac, promoted the use of this area by improving the accessibility to the riverbanks. Results suggest a reduction in inequalities, mainly in the renovated area, in terms of gender and ethnicity. Physical activity levels did not increase after the intervention because of the redistribution of uses in each side of the river: increase of vigorously active users in the non-renovated area, and increase of moderately active and sedentary users in the renovated area. Nature-based interventions in socio-economically-deprived neighborhoods might reduce inequalities in access to natural areas for deprived communities, thereby creating destinations for residents, promoting physical activity and/or creating opportunities for social interactions, and thus improving their health and well-being.

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Appendix A. Supplementary data

Supplementary data to this article can be found online at https://doi.org/10.1016/j.landurbplan.2019.103611.

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Supplementary Material

Paper I

Supplementary Material

Impact of a riverside accessibility intervention on use, physical activity, and wellbeing: A mixed methods pre-post evaluation

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- **Figure S1.** Calendar of days doing systematic observations at the Besòs Riverside Park

PRE-EVALUATION (2016)

NOVEMBER

Mon	Tue	Wed	Thu	Fri	Sat	Sun
	1	2	3	4	5	6
7	8	9	10	11	12	13
14	15	16	17	18	19	20
21	22	23	24	25	26	27
28	29	30				

DECEMBER

Mon	Tue	Wed	Thu	Fri	Sat	Sun
			1	2	3	4
5	6	7	8	9	10	11
12	13	14	15	16	17	18
19	20	21	22	23	24	25
26	27	28	29	30	31	

POST-EVALUATION (2017)

NOVEMBER

Mon	Tue	Wed	Thu	Fri	Sat	Sun
		1	2	3	4	5
6	7	8	9	10	11	12
13	14	15	16	17	18	19
20	21	22	23	24	25	26
27	28	29	30			

Legend*

Morning
Midday
Afternoon

*Different colors indicate whether systematic observations were conducted in the morning, midday or afternoon.

- **Figure S2.** SOPARC coding form

DATE: __________ **OBSERVER** (Name):_______________ Observations: 1 2 3 4 5 6

START TIME: ________ **END TIME**: _________ **Temperature and weather**:_____________

TARGET AREA: A (La Ribera Neighborhood) B (purifying plant)

# P	Location		Gender		Activity level			Activity (specify)	Age group				Ethnicity	Notes
1	U	L	F	M	S	W	V		Child	Teen	Adult	Senior	C LA B A O	
2	U	L	F	M	S	W	V		Child	Teen	Adult	Senior	C LA B A O	
3	U	L	F	M	S	W	V		Child	Teen	Adult	Senior	C LA B A O	
4	U	L	F	M	S	W	V		Child	Teen	Adult	Senior	C LA B A O	
5	U	L	F	M	S	W	V		Child	Teen	Adult	Senior	C LA B A O	
6	U	L	F	M	S	W	V		Child	Teen	Adult	Senior	C LA B A O	
7	U	L	F	M	S	W	V		Child	Teen	Adult	Senior	C LA B A O	
8	U	L	F	M	S	W	V		Child	Teen	Adult	Senior	C LA B A O	
9	U	L	F	M	S	W	V		Child	Teen	Adult	Senior	C LA B A O	
10	U	L	F	M	S	W	V		Child	Teen	Adult	Senior	C LA B A O	
11	U	L	F	M	S	W	V		Child	Teen	Adult	Senior	C LA B A O	
12	U	L	F	M	S	W	V		Child	Teen	Adult	Senior	C LA B A O	
13	U	L	F	M	S	W	V		Child	Teen	Adult	Senior	C LA B A O	
14	U	L	F	M	S	W	V		Child	Teen	Adult	Senior	C LA B A O	
15	U	L	F	M	S	W	V		Child	Teen	Adult	Senior	C LA B A O	
16	U	L	F	M	S	W	V		Child	Teen	Adult	Senior	C LA B A O	
17	U	L	F	M	S	W	V		Child	Teen	Adult	Senior	C LA B A O	
18	U	L	F	M	S	W	V		Child	Teen	Adult	Senior	C LA B A O	
19	U	L	F	M	S	W	V		Child	Teen	Adult	Senior	C LA B A O	
20	U	L	F	M	S	W	V		Child	Teen	Adult	Senior	C LA B A O	
21	U	L	F	M	S	W	V		Child	Teen	Adult	Senior	C LA B A O	
22	U	L	F	M	S	W	V		Child	Teen	Adult	Senior	C LA B A O	

NOTES:

Observation: each observation will last 7 minutes (in total we will have 6 observations of 7 minutes each, so 42 minutes observation time, with breaks of 3 minutes between sections, in total 60 minutes).
Start time: time at which the observation process starts.
End time: time at which the observation process ends.
#P: number of subject observed.
Location: U=upper part of the section (sidewalk), L=lower part of the section (near the river)
Gender: F=female, M=male
Activity level: S=sedentary (lying down, sitting, standing in a place), W=walking, V=vigorous (increasing heart rate, sweating: jogging, biking…)
Activity specify: indicate the specific activity the person is doing.
Age group: Child (<12 years), Teen (13 to 20 years), Adults (21 to 59 years), Seniors (>60 years)
Ethnicity: C=Caucasian, LA=Latin-American, B=Black, A=Asian, O=others
Note: Please indicate any events or observations of interest, including close calls, unlawful behavior, or any other information that may affect your count, or observed behaviors such as significant events or background information, i.e. free zoo day, formal event at park, etc.

- **Table S1.** Semi-structured face-to-face interviews

MONTCADA Qualitative interviews – Guide questions **Introduction** • Interviewer's introduction • Description and objectives of the interview • Permission to record the interview and sign of the informed consent • Choice of language: Spanish or Catalan
Attitudes to the natural environment, use and perception • What do you think about natural environments (green/blue spaces) in your neighbourhood? And in particular, the Besòs River. • What do you like/dislike of these natural environments, and especially of the Besòs River? (E.g. accessibility, facilities, beauty, security, etc.) • Do you use these spaces (and in particular the Besòs River)? Why? Why not? What activities do you do? • What do you think about the non-natural (artificial) environment in your neighbourhood? (E.g. buildings, streets, services, traffic, etc.) • Why do you live in this neighbourhood? • Was the natural environment (quantity/quality) a reason to move to this neighbourhood? Why? Could you explain this? • How much is natural environment in your neighbourhood important for you? Why? Could you explain this? • Has natural environment in your neighbourhood changed over time? How has it changed? Has it improved/get worse? • What would your "ideal neighbourhood" be like? Describe the main characteristics (e.g. green/blue spaces, buildings, services, facilities, civic responsibility, traffic, etc.). • Do you do group activities (e.g. workshops, courses, neighbourhood association, etc.)? Do you interact with your neighbours? • Do you go to the river alone or with someone else? • Do you think your behaviour or well-being is related to the type of environment in which you are? How do you think it is related? Could you tell me an example? • Do you feel good/satisfied with your live? Is there anything that worries you? • Did you use to spend much time outdoors when you were a child? • What is your main mean of transport (to commute, to go shopping, to take children to school, etc.)?

- Do you ever walk or cycle? If yes, why do you walk/cycle (to commute, or for pleasure)? Where do you go? Do you usually use a route next to green/blue spaces? Why (faster, nicer, shorter...)? If not, why not? Security reasons, lack of facilities, mobility problem...?
- What other places do you usually visit during the week/weekend (e.g. parks, forest, canals, lakes, beach, etc.)? Why? Could you describe it?

Table S2. Comparison (% of change) of the number of users in the renovated area, the non-renovated area, and in both areas of the river before (year 2016) and after (year 2017) the urban riverside regeneration project

	Renovated area			Non-renovated area			Both areas		
	PRE (2016)	POST (2017)	**Comparison between years [% of change]**	PRE (2016)	POST (2017)	**Comparison between years [% of change]**	PRE (2016)	POST (2017)	**Comparison between years [% of change]**
	1049	1312	25	2429	2319	-5	3478	3631	4
Location [N]									
Upper	1031	1103	7	2072	2047	-1	3103	3150	2
Lower	18	209	1061	357	272	-24	375	481	28
Demographic characteristics of the users [N]									
Gender									
Female	282	403	43	484	356	-26	768	759	-1
Male	767	909	19	1943	1963	1	2710	2872	6
Age group									
Children	18	52	189	43	27	-37	61	79	30
Teens	71	36	-49	80	42	-48	151	78	-48
Adults	484	734	52	1595	1428	-10	2079	2162	4
Seniors	476	490	3	711	822	16	1187	1312	11
Ethnicity									
Caucasian	1022	1215	19	2390	2276	-5	3412	3491	2
Latin-American	9	23	156	13	4	-69	22	27	23
Black	2	8	300	5	5	0	7	13	86
Asian	10	26	160	8	14	75	18	40	122
North-African	6	23	283	10	16	60	16	39	144
Other	0	17	0	3	4	33	3	21	600
Physical activity level [N]									
Sedentary	81	158	95	130	89	-32	211	247	17
Moderate	702	901	28	928	782	-16	1630	1683	3
Vigorous	266	253	-5	1371	1448	6	1637	1701	4

Table S3. Distribution [N (%)] of riverside park users according to their age group, by gender and period of evaluation (i.e. pre/post-evaluation).

	PRE (2006)				POST (2007)			
[N (%)]	Children	Teens	Adults	Senior	Children	Teens	Adults	Senior
Females	6 (2.1)	29 (10.3)	114 (40.3)	133 (47.2)	17 (4.2)	20 (5.0)	235 (58.3)	131 (32.5)
Males	12 (1.6)	42 (5.5)	370 (48.2)	343 (44.7)	35 (3.9)	16 (1.8)	499 (54.9)	359 (39.5)

Table S4. Sensitivity analysis excluding a group of scholars [N(child)=23; N(teen)=50] observed during one session in 2016 conducting an organized academic activity on the upper part of the non-renovated area.

	Renovated area			Non-renovated area			Both areas		
	PRE (2016) **N=1,049**	POST (2017) **N=1,312**	p-value*	PRE (2016) **N=2,356**	POST (2017) **N=2,319**	p-value*	PRE (2016) **N=3,405**	POST (2017) **N=3,631**	p-value*
Location [N, (%)]									
Upper	1,031 (98.3)	1,103 (84.1)	0.000	1,999 (84.9)	2,047 (88.3)	0.001	3,030 (89.0)	3,150 (86.7)	0.004
Lower	18 (1.7)	209 (15.9)		357 (15.1)	272 (11.7)		375 (11.0)	481 (13.3)	
Demographic characteristics of the users [N, (%)]									
Gender									
Female	282 (26.9)	403 (30.7)	0.041	450 (19.1)	356 (15.4)	0.001	732 (21.5)	759 (20.9)	0.542
Male	767 (73.1)	909 (69.3)		1,906 (80.9)	1,963 (84.6)		2,673 (78.5)	2,872 (79.1)	
Age group									
Child	18 (1.7)	52 (4.0)	0.000	20 (0.8)	27 (1.2)	0.000	38 (1.1)	79 (2.2)	0.000
Teen	71 (6.8)	36 (2.7)		30 (1.3)	42 (1.8)		101 (2.9)	78 (2.2)	
Adult	484 (46.1)	734 (56.0)		1,595 (67.7)	1,428 (61.6)		2,079 (61.1)	2,162 (59.5)	
Senior	476 (45.4)	490 (37.3)		711 (30.2)	822 (35.4)		1,187 (34.9)	1,312 (36.1)	
Ethnicity									
Caucasian	1,022 (97.4)	1,215 (92.6)	0.000	2,317 (98.4)	2,276 (98.1)	0.156	3,339 (98.1)	3,491 (96.1)	0.000
Latin-American	9 (0.8)	23 (1.7)		13 (0.6)	4 (0.2)		22 (0.6)	27 (0.7)	
Black	2 (0.2)	8 (0.6)		5 (0.2)	5 (0.2)		7 (0.2)	13 (0.4)	
Asian	10 (1.0)	26 (2.0)		8 (0.3)	14 (0.6)		18 (0.5)	40 (1.1)	
North-African	6 (0.6)	23 (1.8)		10 (0.4)	16 (0.7)		16 (0.5)	39 (1.1)	
Other	0 (0.0)	17 (1.3)		3 (0.1)	4 (0.2)		3 (0.1)	21 (0.6)	
Physical activity level [N, (%)]									
Sedentary	81 (7.7)	158 (12.0)	0.000	80 (3.4)	89 (3.8)	0.004	161 (4.7)	247 (6.8)	0.001
Moderate	702 (66.9)	901 (68.7)		905 (38.4)	782 (33.7)		1,607 (47.2)	1,683 (46.4)	
Vigorous	266 (25.4)	253 (19.3)		1,371 (58.2)	1,448 (62.4)		1,637 (48.1)	1,701 (46.8)	

*P-values based on Chi-squared tests to compare the distribution of sociodemographic characteristics of users between the pre (year 2016) and post (year 2017) intervention evaluation.

Figure S3. Levels of physical activity by gender (F=female; M=male).

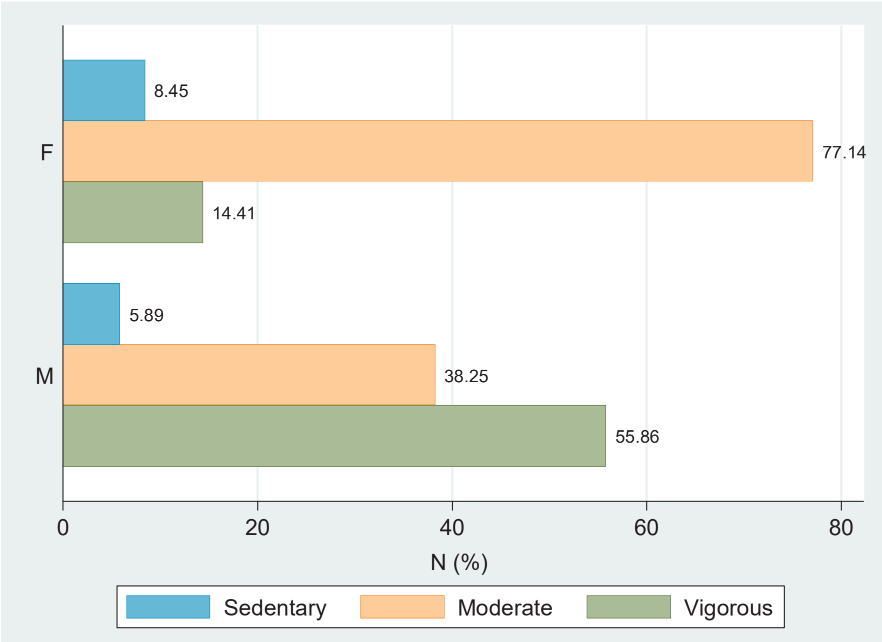

Table S5. Demographic characteristics of the participants interviewed.

	PRE (2016)	POST (2017)
Gender [N]		
Female	11	4
Male	6	2
Age group [N]		
Adult	13	4
Senior	4	2
Ethnicity [N]		
Caucasian	13	5
Non-Caucasian	4	1
TOTAL [N]	17	6

5.2 Paper II

Cristina Vert [1,2,3], Mark Nieuwenhuijsen [1,2,3], Mireia Gascon [1,2,3], Lora E. Fleming [4], Mathew P. White [4], David Rojas-Rueda [1,2,3]

Health benefits of physical activity related to an urban riverside regeneration

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Article

Health Benefits of Physical Activity Related to an Urban Riverside Regeneration

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Abstract: The promotion of physical activity through better urban design is one pathway by which health and well-being improvements can be achieved. This study aimed to quantify health and health-related economic impacts associated with physical activity in an urban riverside park regeneration project in Barcelona, Spain. We used data from Barcelona local authorities and meta-analysis assessing physical activity and health outcomes to develop and apply the "Blue Active Tool". We estimated park user health impacts in terms of all-cause mortality, morbidity (ischemic heart disease; ischemic stroke; type 2 diabetes; cancers of the colon and breast; and dementia), disability-adjusted life years (DALYs) and health-related economic impacts. We estimated that 5753 adult users visited the riverside park daily and performed different types of physical activity (walking for leisure or to/from work, cycling, and running). Related to the physical activity conducted on the riverside park, we estimated an annual reduction of 7.3 deaths (95% CI: 5.4; 10.2), and 6.2 cases of diseases (95% CI: 2.0; 11.6). This corresponds to 11.9 DALYs (95% CI: 3.4; 20.5) and an annual health-economic impact of 23.4 million euros (95% CI: 17.2 million; 32.8 million). The urban regeneration intervention of this riverside park provides health and health-related economic benefits to the population using the infrastructure.

Keywords: urban regeneration; urban health; blue spaces; physical activity; health impacts

1. Introduction

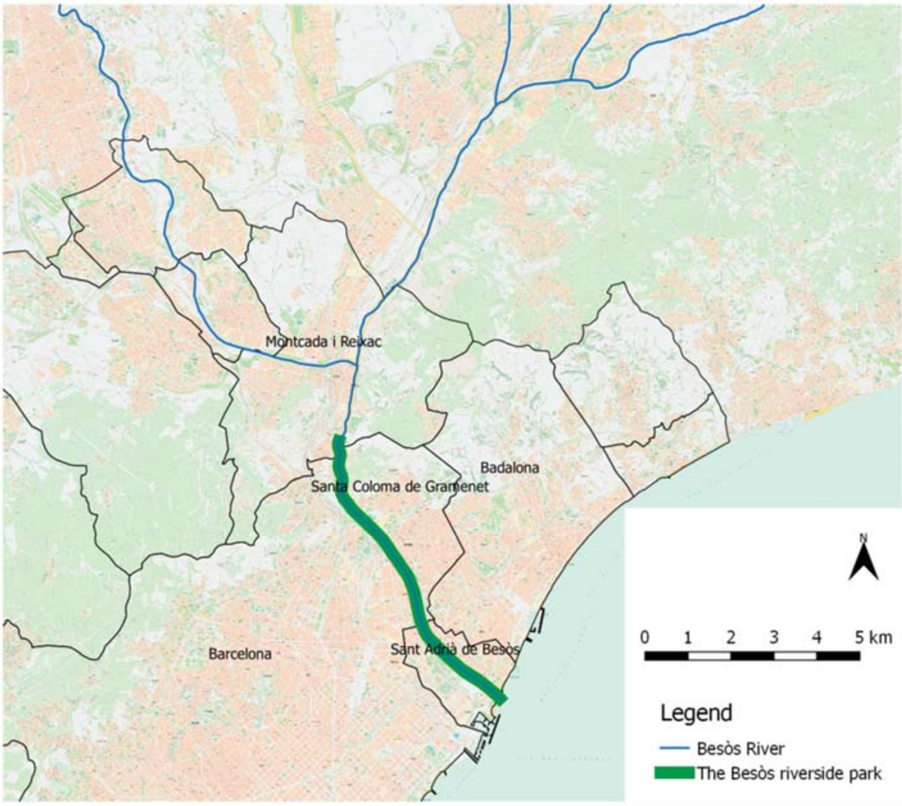
Natural outdoor environments in cities have positive impacts on health and well-being [1]. Living in a green environment has been positively related to better general health [2], self-perceived general health and better mental health [3], reduced perceived stress [4], slower cognitive decline [5], and reduced mortality [6,7]. Visits to green spaces have been found to increase mental well-being [8–10]. Some studies suggest that higher levels of greenness are associated with higher levels of physical activity [11].

The health impacts of blue spaces, defined in the European Commission H2020-funded project BlueHealth (https://bluehealth2020.eu/) as "outdoor environments—either natural or manmade—that prominently feature water and are accessible to humans either proximally (being in, on, or near water) or distally/virtually (being able to see, hear or otherwise sense water)" [12], have been studied less than those related to green spaces [13]. A recent systematic review suggests that exposure to outdoor blue spaces is positively associated with improved mental health and well-being, and promotes physical activity [13]. For example, living nearer to the coast is associated with increased numbers of people achieving physical activity guidelines [14–16], which may in turn lead to better general and mental health [17].

Physical activity in natural environments is associated with increased well-being compared to physical activity in built environments [18,19]; and efforts to quantify the benefits of physical activity in these natural environments, in terms of welfare gains and lives saved, have begun to emerge [20]. These results are important, given that physical inactivity is the fourth-leading risk factor for mortality worldwide; and it has major implications for the prevalence of non-communicable diseases and general health [21]. Regular physical activity may prevent overweight and obesity, cardiovascular disease, type 2 diabetes, some cancers, and psychological disorders [16,22].

The world is increasingly urbanized: 50% of the world population was living in urban settlements in 2016, and this is expected to rise to 60% by 2030 [23]. Moreover, a third of all people will live in large cities with at least half a million inhabitants by this time [23]. Considering that some aspects of cities—such as scarcity of natural environment—can negatively affect human health, the incorporation of natural (blue and green) outdoor environments in urban planning is a fundamental characteristic of a healthy city [24]. With an adequate urban design, healthy natural and built environments can be achieved in cities [25]; and these may promote healthier behaviors and lifestyles, therefore reducing health-related costs as well as other co-benefits [26]. Such co-benefits may play an important role in reducing the disease burden associated with aspects of urban living such as air pollution, noise, and lack of natural spaces where people can engage in health-promoting physical activities, sedentary behavior, obesity, poor mental health, and other non-communicable chronic diseases [27–30]. The regeneration of under-used, inadequately designed, or decayed urban spaces (including natural outdoor environments located in urban areas) is now a relatively common phenomenon globally, but not many studies have estimated the impacts of existing interventions in terms of health and well-being [31–37].

This study focuses on an urban regeneration project on the Besòs River, located in the northeast of Barcelona (Catalonia, Spain). The final stages of the Besòs River flow through an industrialized area prior to entering the Mediterranean Sea (Figure 1a). Since the mid-1990s, the river and its surroundings have undergone considerable infrastructural improvements through urban riverside regeneration. A nine-kilometer long stretch of recreation area—the *Parc Fluvial del Besòs* (Besòs Riverside Park)—was created on the banks of the river, spanning the cities of Barcelona (1.6 million inhabitants), Santa Coloma de Gramenet (117,153 inhabitants), and Sant Adrià de Besòs (36,496 inhabitants) (Figure 1a) [38]. The first stage of this urban riverside regeneration was completed in 2000, and included environmental remediation and the development of a green area on the riverbanks (i.e., 22 hectares mostly covered by grass, being one of the most important green areas of the Barcelona metropolitan area nowadays), as well as the provision of paths for walking and cycling along the river [39] (Figure 1b). The urban riverside park regeneration project was developed to improve the environmental conditions of the area—mainly in terms of its ecological state—as well as to provide spaces for leisure and physical activity and to facilitate social interactions. Prior to the project's completion, the riverbanks were not accessible and the public was not able to use the area. The aim of this study was to quantify potential health and health-related economic impacts derived from the physical activity related to this new urban riverside park.



(a)

(b)

Figure 1. Setting of the study area: (**a**) Map of the Besòs Riverside Park, which spans the last 9 km of the Besòs River [40]; (**b**) The Besòs Riverside Park (Image: Cristina Vert/ISGlobal, May 2017).

2. Methods

2.1. Input Data

For this study, we used data collected in 2014–2015 by Barcelona local authorities to characterize park users [41]. Two different data sets were used: (1) surveys administered to the park users (N = 973) to characterize the main activities performed in the park; and (2) a counting campaign (manual and automated) to estimate the total number of users per year [specifying whether they were cyclists (N = 1,030,000) or pedestrians (N = 1,070,000)] in the park. The survey was administered to users in the park between 8 am and 8 pm both on weekdays and weekends, in three different points in time: November 2014, July 2015, and September 2015, in order to take seasonality into account. The survey included questions about user characteristics (sex, age, and city of residence), the main activity performed in the park (e.g., walking, cycling, running, etc.), the duration (hours/day), and the frequency of their visits (days/week) (Supplementary Material—Table S1).

In this study, we focused on adult respondents (≥18 years old) because the majority of the quantitative epidemiological evidence on associations between physical activity and health is derived from adult cohorts [42–44]. Thus, from the surveys, we excluded 22 subjects (<18 years old). Additionally, we excluded 94 subjects who did not go to the park regularly (i.e., those only going to the park on weekends and for less than three times per week), because even though we acknowledge the possible health benefits of practicing physical activity on weekends, the epidemiological evidence for long-term benefits of physical activity is more robust for those regularly practicing physical activity. Finally, we excluded 196 subjects whose activity in the park could not be classified in a physical activity category according to the physical activity classification described by Ainsworth et al., 2011 [45]. Figure S1 (Supplementary Material) shows the number of subjects excluded from the initial sample of survey respondents; and the final number of survey respondents included for our analysis (N = 661) (Supplementary Material—Figure S1).

We estimated the daily number of users visiting the park using both survey data and data from the counting campaign. The study population was classified into distinct groups according to the main activity they conducted in the park: walking for leisure, walking commuters, cyclists, and runners. We subsequently divided each of these groups by age (18 to 64 years old, and ≥65 years old), with the aim of assigning appropriate age-specific incidence rates and exposure-response functions [42–44] (Supplementary Material—Table S2). We ended excluding runners and walking commuters ≥65 years old due to the low response rate (N = 21 runners, and N = 5 walking commuters) obtained for this group of users [41]. Energy expenditures associated with the four different types of physical activity were defined in terms of the metabolic equivalent of task (MET) [45].

Other input data sources used in this study to model the health impacts were: (1) The Barcelona Health Survey, used to characterize the base levels of physical activity throughout the Barcelona population [46,47]; (2) epidemiological studies (meta-analysis and prospective cohort studies) to obtain the exposure-response functions between physical activity and a variety of health outcomes [42–44]; and (3) Barcelona health records to characterize the age- and sex-specific mortality and incidence rates [46,48,49] (Figure 2).

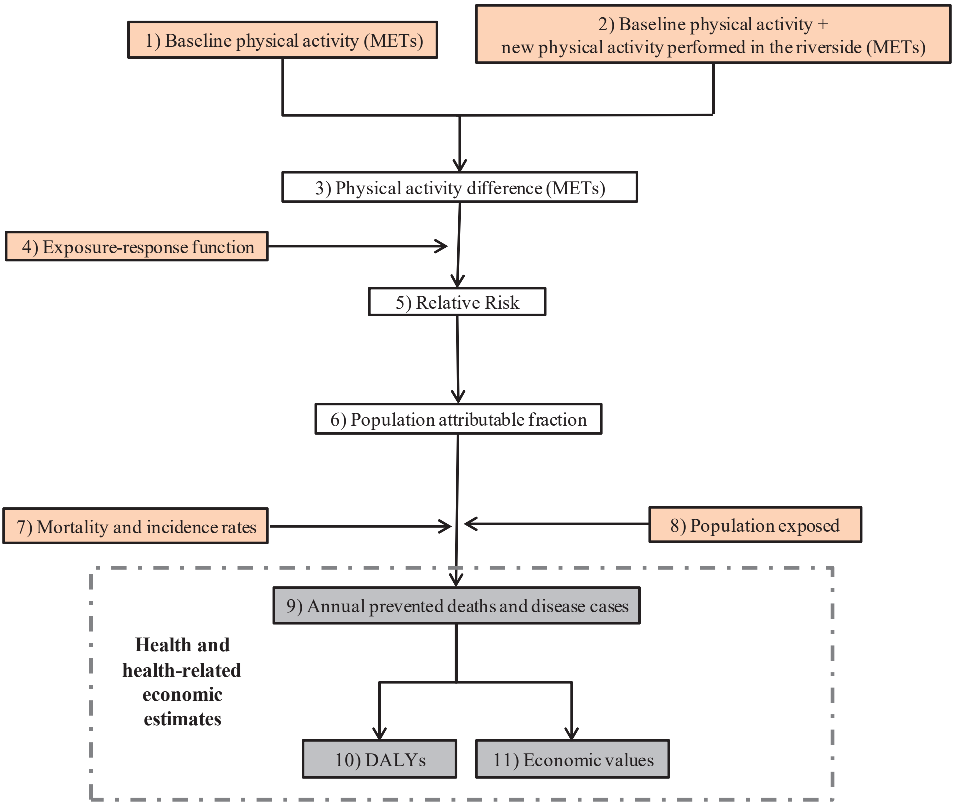


Figure 2. Methodological approach of the "Blue Active Tool". In orange, the input data used in this study to estimate health and health-related economic impacts of the physical activity related to the urban riverside park. METs: Metabolic equivalent of task; DALYs: Disability-adjusted life years.

2.2. Study Design and the "Blue Active Tool"

We designed and employed a bespoke quantitative spreadsheet model, the "Blue Active Tool", using Excel 2007 (Microsoft Corp., Albuquerque, NM, USA) (available from the authors upon request). It is a quantitative tool based on a comparative risk assessment approach. The tool executes the risk characterization of the comparative risk assessment, integrating hazard identification, exposure-response function assessment, and exposure assessment, previously performed by the authors. Thus, the "Blue Active Tool" estimates health and health-related economic benefits of physical activity. Input data (i.e., physical activity behavior of the study population) needs to be provided by the authors, and this is complemented with data provided by other epidemiological studies to obtain exposure-response functions between physical activity and health outcomes. The tool needs to be adjusted to the specific study population in terms of mortality and incidence rates, and population exposed. Using the "Blue Active Tool", we quantified potential health and health-related economic benefits of performing physical activity in the park using two scenarios. Scenario 1 assumed that 100% of the reported physical activity was new since the park regeneration and related directly to the new infrastructure. Scenario 2 was more conservative, assuming that only 50% of the reported physical activity was new and related to the new infrastructure. We define "new physical activity" as an activity that did not exist before the new infrastructure. In other words, this is not a physical activity that was previously done elsewhere (e.g., in a gym or another park) and moved to the new infrastructure due to the urban riverside regeneration.

The "Blue Active Tool" provides estimates of the health impacts in terms of all-cause mortality, morbidity, and disability-adjusted life years (DALYs), as well as health economic assessment in terms of the value of statistical life (VSL) and direct health costs (Figures 2 and 3). The tool estimates the impacts for each type of physical activity and age groups, providing a central estimate with 95% confidence intervals (CIs). The individual parts of the "Blue Active Tool" are described below.

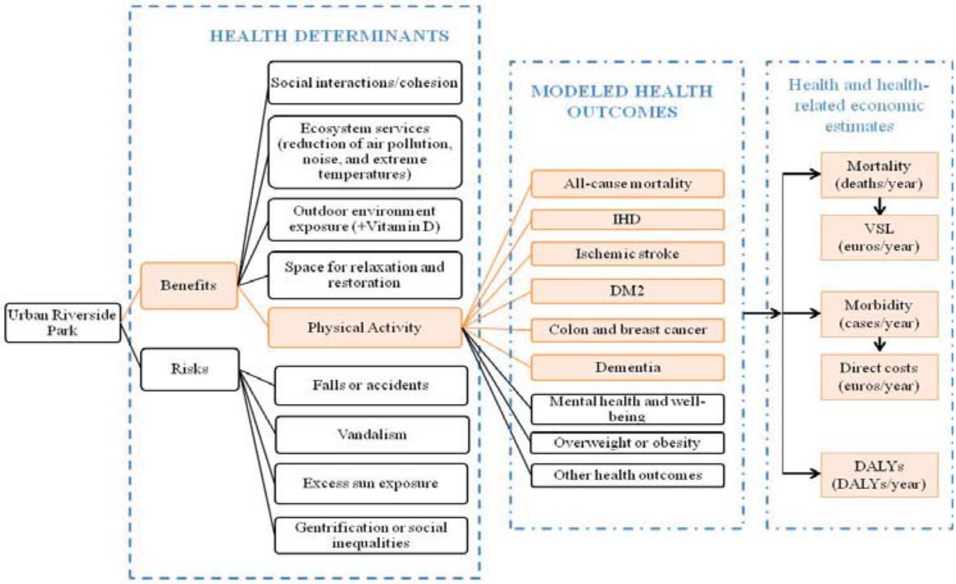


Figure 3. Pathways modeled (in orange) and non-modeled (in black) related to health impacts derived of the urban riverside park. IHD: ischemic heart disease; DM2: diabetes mellitus type 2; VSL: value of statistical life; DALYs: Disability Adjusted Life Years.

2.2.1. The "Blue Active Tool": Physical Activity and Health Outcomes Modelling

The "Blue Active Tool" modelled exposure-response between physical activity and all-cause mortality in a non-linear function [44]. For morbidity outcomes, the non-linear exposure-response function was also applied using the same function as for mortality [42–44] (Supplementary Material—Figures S2 and S3, and Table S3). It was assumed that the base levels of physical activity of the study population were similar to those reported for the population of Barcelona [46,47], because data on the base levels of physical activity of the specific study population was not available (Supplementary Material—Tables S3 and S4). Levels of the new physical activity performed in the Besòs Riverside Park were estimated in METs, using the park user survey and counting campaign data as previously described. We obtained age- and sex-specific exposure-response of physical activity and all-cause mortality and specific diseases [including ischemic heart disease (IHD), ischemic stroke, type 2 diabetes (DM2), colon cancer, breast cancer, and dementia (Supplementary Material—Table S2)] from prior meta-analyses and prospective cohort studies [42–44]. These exposure-response functions were employed to calculate the relative risk (RR) and the population attributable fraction (PAF) for each health outcome, stratified by age and sex, for both scenarios. Using this, we estimated the annual prevented deaths and cases of disease by age and sex [50–52]. The analysis was based on age- and sex-specific all-cause mortality and incidence rates derived from the Barcelona population [41,47–49]. Health results were also translated into DALYs using a standard approach [53,54]. We multiplied the age- and sex-specific attributable fraction to the corresponding DALYs estimation from Spain, scaled to the study population size, from the Global Burden of Disease Project [55] (Figure 2).

2.2.2. The "Blue Active Tool": Health Economic Assessment

The health economic assessment was conducted for all-cause mortality (based on the VSL), and for all morbidity outcomes (based on direct health-care costs). We estimated the monetary value of mortality multiplying the VSL for Spain (3,202,968 Euros) [56] by the expected cases of death avoided for each type of physical activity. Direct health costs (i.e., morbidity costs) were estimated multiplying by the expected sex- and age-specific cases of diseases and the direct health-care costs reported for each morbidity outcome in Spain [57,58] (Supplementary Material—Table S5). The tool also reports total economic values based on summing the monetary value of mortality and direct health costs.

3. Results

3.1. Characteristics of the Study Population

It was estimated that the Besòs Riverside Park attracted 5753 adult users per day, engaging in one of the four physical activities included in the analysis (i.e., cycling, running, walking for leisure or walking for commuting) (Table 1). The mean age of our sample was 48 years old, ranging from 18 to 85 years old, with more male than female users (65% vs. 35%, respectively). We estimated that 49% of the users cycled as the main activity conducted in the park; 38% of the users walked for leisure; 12% were runners; and 1% were walking commuters (Supplementary Material—Table S6). According to the surveys, the majority of the users came from towns and cities located next to the Besòs River [41].

3.2. Health and Health-Related Economic Impacts

Among the 5753 users, in Scenario 1, assuming that 100% of the physical activity conducted in the Park was new and occurred due to the park regeneration intervention, we estimated an annual reduction of 7.3 deaths (95% CI: 5.4; 10.2), 6.2 cases of different diseases (95% CI: 2.0; 11.6), and 11.1 DALYs (95% CI: 3.4; 20.5) (Table 2). Among morbidity outcomes, dementia had the greatest number of cases avoided, with 1.1 annual cases for women (95% CI: 0.4; 2.1) and 3.5 (95% CI: 1.4; 6.3) for men. In terms of annual DALYs, the greatest benefit was also for dementia [3.5 DALYs avoided for men (95% CI: 1.4; 6.4)], followed by IHD [1.8 (95% CI: 0.6; 3.1) and 3.3 (95% CI: 1.2; 5.7) DALYs avoided for women and men, respectively] (Table 2). In Scenario 2, assuming that only 50% of the physical activity conducted in the park was new and due to the intervention, this would result in an annual reduction of 4.8 deaths (95% CI: 3.6; 6.7), 4.1 cases of different diseases (95% CI: 1.0; 7.6), and 7.4 DALYs (95% CI: 1.9; 13.5) (Table 2). In terms of type of activity, in both scenarios, the largest benefit was found for those cycling in the park [e.g., 7.9 DALYs avoided per year (95% CI: 2.4; 14.6) in Scenario 1] (Table 3).

Benefits to population health were converted into estimates of health-related economic benefits. Our estimate of reduced mortality in one year would correspond to a reduction of 23,403,186 euros (95% CI: 14,148,033; 32,787,354) for Scenario 1, and 15,524,195 euros (95% CI: 11,414,915; 21,541,777) for Scenario 2 (Table 2). In terms of direct health-care costs, we estimated an annual reduction of 29,934 euros (95% CI: 10,748; 55,278) for Scenario 1, and 19,849 euros (95% CI: 5171; 36,085) for Scenario 2 (Table 2). The total health-related economic benefits due to the intervention would then be 23,433,120 euros (95% CI: 17,158,781; 32,842,631) per year for Scenario 1, and 15,544,044 euros (95% CI: 11,420,085; 21,577,862) per year for Scenario 2 (Table 2). Cycling, followed by walking for leisure, had the greatest health-related economic impacts in both scenarios (e.g., 84.5% and 15% of the health-related economic impact, respectively in Scenario 1). Only 0.6% of the economic impact was related to running and walking for commuting in both scenarios (Table 3).

Table 1. Input data (for Scenario 1 and Scenario 2) on adult users of the park and key assumptions used in the model.

Types of Physical Activity	METs per Type of Physical Activity [a]	Mean Duration of Visits to the Park [b] (min/Day)	Mean Frequency of Visits to the Park [c] (Days/Week)		Estimated Visits/Day [d]	Estimated METs Hour/Week per Subject [e]		Estimated Park Users/Day [f] (*N*)
			Scenario 1	Scenario 2		Scenario 1	Scenario 2	
Walking for leisure								
≥18 and ≤64 years old	3.5	59	5	2.5	1	17	9	1566
≥65 years old	3.5	63	5	2.5	1	18	9	619
Cycling								
≥18 and ≤64 years old	7.5	65	5	2.5	1	41	20	535
≥65 years old	7.5	65	5	2.5	1	41	20	2287
Running								
≥18 and ≤64 years old	7.0	58	5	2.5	1	34	17	686
Walking for commuting								
≥18 and ≤64 years old	4.0	98	5	2.5	2	65	33	60
Total (all users)								5753
≥18 and ≤64 years old								2848
≥65 years old								2905

[a] METs = Metabolic Equivalent of Task. These values have been assigned for each type of physical activity according to Ainsworth et al. 2011 [45]. [b,c] Mean duration and frequency of user's visits to the park, based on the data provided by the surveys [41] (Supplementary Material—Table S1) for Scenario 1. For Scenario 2, we have considered the 50% of the frequency values reported. [d] This information was not provided by the surveys. Thus, we assumed that in Scenario 1 subjects would visit the Park once a day. Except the walking commuters, who need to go to and from work. Thus, we assumed that in Scenario 1, this group of users would visit the park twice a day (Supplementary Material—Table S3). [e] Value obtained by multiplying the input data [(METs) × (mean duration) × (mean frequency) × (number of visits/day)]. [f] The number of "park users/day" was estimated by using the total users from counting campaign, and the proportion of users by type of activity from the surveys.

Table 2. Results in annual cases of mortality, diseases, DALYs, and health-related economic outcomes due to the intervention. Results provided for Scenario 1 (assuming that 100% of the physical activity conducted in the park was new physical activity), and Scenario 2 (assuming that 50% of the physical activity conducted in the park was new physical activity).

Health Outcomes	Scenario 1			Scenario 2		
	Cases/Year (95% CI)	DALYs/Year (95% CI)	Euros/Year (95% CI)	Cases/Year (95% CI)	DALYs/Year (95% CI)	Euros/Year (95% CI)
All-cause mortality	−7.3 (−10.2, −5.4)	–	−23,403,186 (−32,787,354, −17,148,033)	−4.8 (−6.7, −3.6)	–	−15,524,195 (−21,541,777, −11,414,915)
Diseases						
IHD (W)	−0.1 (−0.1, 0.0)	−1.8 (−3.1, −0.6)	−61 (−105, −22)	0.0 (−0.1, 0.0)	−1.2 (−2.1, −0.4)	−41 (−70, −15)
IHD (M)	−0.4 (−0.6, −0.1)	−3.3 (−5.7, −1.2)	−421 (−727, −151)	−0.3 (−0.4, −0.1)	−2.2 (−3.8, −0.8)	−282 (−485, −102)
Stroke (W)	−0.1 (−0.3, 0.0)	−0.1 (−0.3, 0.0)	−271 (−590, 0)	−0.1 (−0.2, 0.0)	−0.1 (−0.2, 0.0)	−182 (−393, 0)
Stroke (M)	−0.8 (−1.8, 0.0)	−0.5 (−1.1, 0.0)	−1790 (−3903, 0)	−0.5 (−1.2, 0.0)	−0.4 (−0.8, 0.0)	−1206 (−2601, 0)
DM2 (W)	−0.1 (−0.1, 0.0)	−0.1 (−0.2, 0.0)	−199 (−336, −39)	0.0 (−0.1, 0.0)	−0.1 (−0.2, 0.0)	−135 (−227, −26)
DM2 (M)	−0.1 (−0.2, 0.0)	−0.3 (−0.4, −0.1)	−365 (−615, −71)	−0.1 (−0.1, 0.0)	−0.2 (−0.3, 0.0)	−247 (−416, −48)
Colon C (W)	0.0 (0.0, 0.0)	−0.1 (−0.4, 0.1)	−21 (−60, 14)	0.0 (0.0, 0.0)	−0.1 (−0.3, 0.1)	−14 (−41, 10)
Colon C (M)	0.0 (−0.1, 0.0)	−0.3 (−0.8, 0.2)	−70 (−204, 48)	0.0 (0.0, 0.0)	−0.2 (−0.5, 0.1)	−47 (−137, 33)
Breast C (W)	0.0 (0.0, 0.0)	0.0 (−0.1, 0.0)	−11 (−25, 2)	0.0 (0.0, 0.0)	0.0 (−0.1, 0.0)	−7 (−17, 2)
Dementia (W)	−1.1 (−2.1, −0.4)	−1.0 (−1.8, −0.4)	−6573 (−11,980, −2589)	−0.7 (−1.3, −0.2)	−0.7 (−1.2, −0.2)	−4350 (−7795, −1235)
Dementia (M)	−3.5 (−6.3, −1.4)	−3.5 (−6.4, −1.4)	−20,154 (−36,733, −940)	−2.3 (−4.1, −0.6)	−2.3 (−4.2, −0.7)	−13,337 (−23,903, −3788)
All diseases	−6.2 (−11.6, −2.0)	−11.1 (−20.5, −3.4)	−29,934 (−55,278, −10,748)	−4.1 (−7.6, −1.0)	−7.4 (−13.5, −1.9)	−19,849 (36,085, −5171)
Total (euros/year)			−23,433,120 (−32,842,631, −17,158,781)			−15,544,044 (−21,577,862, −11,420,085)

DALYs: Disability Adjusted Life Years; IHD: ischemic heart disease; DM2: diabetes mellitus type 2; M: men; W: women.

Table 3. Results by type of physical activity, in annual DALY, direct health-care costs, and value of statistical life (Scenario 1 and Scenario 2).

Types of Physical Activity	Scenario 1			Scenario 2		
	DALYs/Year (95% CI)	Direct Costs (Euros/Year) (95% CI)	VSL (Euros/Year) (95% CI)	DALYs/Year (95% CI)	Direct Costs (Euros/Year) (95% CI)	VSL (Euros/Year) (95% CI)
Cycling	−7.9 (−14.6, −2.4)	−25,284 (−46,826, −9108)	−15,629,701 (−21,916,593, −11,401,939)	−5.3 (−9.7, −1.3)	−16,818 (−30,648, −4090)	−10,426,408 (−14,505,355, −7,651,506)
Walking for leisure	−2.4 (−4.3, −0.7)	−4487 (−8154, −1608)	−7,255,016 (−10,144,657, −5,367,509)	−1.6 (−2.8, −0.5)	−2920 (−5236, −1059)	−4,753,055 (−6,557,344, −3,510,218)
Running	−0.8 (−1.4, −0.2)	−146 (−264, −28)	−460,256 (−643,971, −336,315)	−0.5 (−0.9, −0.1)	−99 (−178, −19)	−305,284 (−423,907, −224,357)
Walking to work	−0.1 (−0.2, 0.0)	−18 (−33, −3)	−58,213 (−82,133, −42,271)	−0.1 (−0.1, 0.0)	−13 (−23, −2)	−39,448 (−55,172, −28,834)
TOTAL	−11.1 (−20.5, −3.4)	−29,934 (−55,278, −10,748)	−23,403,186 (−32,787,354, −17,148,033)	−7.4 (−13.5, −1.9)	−19,849 (−36,085, −5171)	−15,524,195 (−21,541,777, −11,414,915)

DALYs: Disability Adjusted Life Years; VSL: value of statistical life.

3.3. Sensitivity Analysis

We conducted a sensitivity analysis considering the minimum visit duration to the park reported by walking commuters (i.e., 30 min/day), instead of the mean visit duration reported by this group of users (Table 1), resulting in a minimum change in the overall results (Supplementary Material—Table S7) in both scenarios. This was done because the mean duration reported by walking commuters was longer (98 min/day) than that reported by other user groups (between 58 and 65 min/day, Table 1) [41]. We also performed a sensitivity analysis for those cyclists older than 65 years old, considering that the mean visit duration to the park was 30 min/day, compared to the mean duration reported by this group of users (65 min/day, Table 1). In this case, we still observed health and health-related economic benefits (Supplementary Material—Table S8), although these were lower than the benefits observed in the main analysis, both for Scenario 1 and Scenario 2 (Table 3).

4. Discussion

4.1. Principal Findings

The development of the Besòs Riverside Park in Barcelona was primarily undertaken to improve the ecology of the area, but our assessment demonstrated that this intervention provides health benefits to the population using this infrastructure, by encouraging physical activity. We developed and applied the "Blue Active Tool" to estimate health and health-related economic benefits associated with this physical activity. The results estimated a potential annual health benefit of 11.1 DALYs (95% CI: 3.4; 20.5) among park users. These health benefits were translated into a health-related economic cost reduction of 23.4 million euros per year (95% CI: 17.2; 32.8). The largest health and health-related economic benefits were mainly due to the number of users cycling and walking for leisure (Supplementary Material—Table S6). The health and health-related economic benefits were mainly driven by mortality rather than morbidity, similar to those reported by previous studies [51,59].

Previous studies have examined the impacts on health of other types of urban regeneration projects: urban regeneration programs in deprived Dutch districts [31,35] and in Northern Ireland [36]; urban regeneration implying neighborhood demolition and relocation [32]; the regeneration of a port area in a deteriorated region of the Bay of Pasaia—Spain [33]; a vacant lot greening program in Philadelphia U.S. [37]; and the regeneration of a street in the historical centre of Seville—Spain [34]. Results are mixed, with some projects showing positive relationships to health outcomes [31,37]; some reporting little or no benefits [35,36], and others finding inconsistent results [32–34]. However, to our knowledge, this is the first study assessing health and health-related economic impacts of an urban riverside park regeneration project.

This study also contributes to the growing evidence on health benefits of both green and blue spaces, given that the Besòs Riverside Park is a combination of both types of natural spaces, which may reinforce the benefits from the two types of natural environments. Our study also shows the potential importance and the impact of urban planning on public health at the city scale. The regeneration of natural environments in urban settings is highly relevant given rapid urbanization globally, and the potentially negative health and well-being impacts of living in cities.

4.2. Strengths and Limitations

The aim of this study was to assess health and health-related economic impacts of the physical activity performed on the renovated banks of an urban river. We found health benefits related to physical activity (Tables 2 and 3), although we only included adults who were regular users, and who reported one of the four main activities (cycling, walking to work or for leisure and running) (Supplementary Material—Table S1). Even larger benefits could be expected if all users—including those of other age groups (e.g., children), less frequent users, and users doing other types of physical activity—had been included in the analysis.

An important advantage of the current analysis is that the "Blue Active Tool" modelled the relationship between physical activity and the health outcomes with a non-linear function, providing more conservative estimations of the health benefits compared to using a linear relationship. The tool took into account the base levels of physical activity of the study population (based on Barcelona population data), assuming that health benefits would be distributed according to the base physical activity levels, and acknowledging that more health benefits will be expected in those populations that were originally more sedentary and fewer benefits in those that were already more active prior to the intervention. Due to the lack of available data specific on physical activity levels from those living in the surroundings of the riverside park, we assumed that physical activity levels of the study population were similar to the Barcelona population, despite potential differences between socioeconomic characteristics (Supplementary Material Table S3). In addition, this study also captured the possible seasonal variability on outdoor physical activity practice, considering user surveys, with data from three different months of the year.

Although multiple health outcomes have been related to physical activity, the "Blue Active Tool" only estimates the health impacts of those outcomes with available exposure-response functions from previous meta-analyses (i.e., all-cause mortality, IHD, ischemic stroke, DM2, colon and breast cancer, and dementia) (Figure 3) [42–44]. In addition, this study only focused on physical activity, although other health determinants could be related to the Urban Riverside Park as well (Figure 3). For example, the promotion of social cohesion or social interaction (which in turn have impacts on mental health and well-being); or the attenuation of noise, air pollution, and extreme temperatures—ecosystem services (i.e., direct and indirect contributions of ecosystems to health and well-being) which were not considered within the scope of this study—Figure 3. Besides this, the exposure-response functions employed by the "Blue Active Tool" were obtained from other epidemiological studies, which already considered other covariates [42–44].

Besides the health benefits associated with physical activity, the risks associated with the use of urban parks such as bicycle accidents, a runner having a heart attack, sunburn, sunstroke, pollen allergies, air pollution exposure, safety concern (rape, robbery, assault . . .), etc., should be also considered. However, due to the lack of data to estimate these risks, we have not included them in the assessment (Figure 3). Nevertheless, previous studies have reported that physical activity benefits could outweigh the risks related to—for example—air pollution or traffic accident exposures [60–62].

Another limitation was the necessity to make assumptions (summarised in Supplementary Material—Table S3). Acknowledging that there might be some displacement of physical activity from spaces existing before the urban riverside park (e.g., gyms, parks, beach, etc.), we designed two scenarios assuming different proportion of new physical activity performed in the riverside Park. For Scenario 1, we assumed that 100% of the physical activity performed in the park was new. In Scenario 2, we assumed that only 50% of the physical activity performed in the park was new. We created these scenarios because of the lack of specific data on the user physical activity behavior before the intervention. Of note, a previous study in Barcelona on urban cyclists [63] suggested that physical activity related to bicycle commuting performed using new bicycle infrastructure represented an additional physical activity, rather than a substitution of prior regular physical activity. This extra physical activity was the result of performing more moderate physical activity while travelling by bicycle, showing a positive dose-response relationship between bicycle commuting and physical activity duration. Moreover, physical activity practiced on the riverbanks of the Besòs River after the urban riverside regeneration might bring more health and well-being benefits than physical activity practiced in grey urban settings or indoors because it is being practiced in a natural environment, in green and blue spaces, where we expect to find lower levels of air pollution, temperature, and noise [18,64,65]. Another assumption that we made in this study was to consider the sample of survey respondents as representative of the park users (Supplementary Material—Table S3). Even though the surveys were conducted by the local authorities of Barcelona, a clear description of the methods used to recruit the participants for this survey was not available. Thus, the procedure employed to collect these data could include a potential selection bias, which might have affected the representativeness of the sample of this study.

Finally, although not of direct relevance to the current analysis, gentrification could be a negative long-term consequence of this urban riverside regeneration. Gentrification has been defined as the displacement of people from one neighborhood to another as a result of increased costs in the restored area (e.g., higher rents) [66,67]. Over time, the creation of the Besòs Riverside Park could impact local property values and increase the affluence of nearby neighborhoods. In turn, this could change the type of neighborhood amenities and services available, leading to an increased cost of living in the area, and stimulating the real estate speculation, resulting in health inequalities due to the displacement of the poorer residents [68]. In this case, residents forced to move out due to economic reasons would not benefit from the health effects estimated in this study. However, gentrification has no presumably occurred in the case of the Besòs Riverside Park, given that the pattern of the average rental price (€/month) in Sant Adrià de Besòs and Santa Coloma de Gramenet from 2005 to 2015 was similar than for Barcelona and other municipalities of the metropolitan area (data not shown) [69]. The implications of this possible gentrification effects were not included in this analysis, because it goes beyond the scope of this study. However, we acknowledge the importance of gentrification; and for this reason, we suggest that all urban regeneration projects should be accompanied with policies and regulations to impede or reduce the gentrification effects on existing inhabitants (e.g., safeguard affordable housing, protect senior homeowners, land use regulation, etc.).

4.3. Implications and Recommendations

The implementation of urban riverside regenerations, similar to the one evaluated in the present study, should be expanded in cities to promote the practice of physical activity among the population. As suggested in this study, such interventions might bring health and health-related economic benefits to the population. It is also important to improve the existing green or blue infrastructures by facilitating the accessibility, the aesthetics, and providing good maintenance to sustain and even increase their usability by attracting more users to these natural environments that already exist in the urban areas.

Currently there is a lack of evidence on the health implications of regeneration of urban natural spaces, so more research is needed in this area. More evidence on this area will help policy makers and stakeholders to improve urban planning, creating healthy urban environments and promoting health in all policies' approach. However, in order to create this scientific evidence, it will be necessary to have data available and accessible to characterize and define urban interventions, populations, user behaviors, and local health data. Moreover, since urban environmental interventions may benefit more socio-economic deprived populations [70], further research should focus on the assessment of health inequities in these groups. The design and development of these urban interventions must guarantee the equal use and enjoyment among all the population considering different age groups, gender, ethnicity, or socioeconomic status.

For the specific case of the Besòs Riverside Park, the incorporation of trees (that would create shade) along the riverbanks, and campaigns promoting different activities for all ages, might be initiatives that could increase the usability of the park between the citizens. Furthermore, investments in the increase of natural public spaces (both blue and green spaces) in other parts of the city will also help to promote health and well-being across the city population.

5. Conclusions

The number of people living in urban areas worldwide is increasing. Thus, nature-based urban planning solutions, such as urban riverside regeneration, should be considered as a relevant contributor to improving urban health and well-being, especially via the mechanism of increased physical activity.

Supplementary Materials: The following are available online at http://www.mdpi.com/1660-4601/16/3/462/s1, Figure S1. Exclusion criteria used to define the sample of survey respondents for analysis in this study, Figure S2.

Non-linear exposure-response function between physical activity in METs hour/week and relative risks (RR) for all-cause mortality, Figure S3. Formulae for the calculation of the relative risk (RR) used to estimate the health benefits for our study population, Table S1. Questions included in the survey conducted by Barcelona local authorities in 2014–2015, Table S2. Exposure-response function for each outcome, Table S3. List of assumptions considered for the assessment of health and health-related economic benefits of the urban riverside regeneration project, Table S4. Quartiles of basal levels of physical activity reported in the Barcelona Health Survey, Table S5. Direct health-care cost in euros for morbidity outcomes in Spain, Table S6. Descriptive analysis of the study population, Table S7. Sensitivity analysis using minimum visit duration to the park (i.e., 30 min/day) reported by walking commuter users. Results for Scenario 1 and Scenario 2, Table S8. Sensitivity analysis considering the minimum visit duration to the park (i.e., 30 min/day) reported by cyclists >65 years old. Results for Scenario 1 and Scenario 2.

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Supplementary Material

Paper II

Supplementary Material

Health Benefits of Physical Activity Related to An Urban Riverside Regeneration

Cristina Vert, Mark Nieuwenhuijsen, Mireia Gascon, James Grellier, Lora E. Fleming, Mathew P. White and David Rojas-Rueda

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Table 1. Questions included in the survey conducted by Barcelona local authorities in 2014-2015. These surveys were administered to Park users [1]. This is an adapted version of the original survey (in Catalan) and includes the key assumptions used for the model.

Questions *	Answers
1. Sex	○ Men ○ Women
2. Age	○ _______ years old
3. Where do you live?	○ Sant Adrià de Besòs ○ Santa Coloma de Gramenet ○ Badalona ○ Montcada i Reixac ○ Barcelona
4. Reason to come to the Besòs River:	○ Walk (for pleasure) ○ Sport–bicycle ○ To walk to/from work ○ To be healthy [a] ○ Sport–run ○ Others: _______(specify) [b]
5. Day when you usually come to the Park: (Multiple answer)	○ Weekday (Monday–Friday) ○ Saturday ○ Sunday/holiday
6. Frequency [c]:	○ More than 3 days/week ○ 1 day/week ○ 1 day/month ○ Occasionally
7. Duration of the visit to the Besòs River [d]:	○ Less than 1 hour ○ 1–2 hours ○ 2–4 hours ○ >4 hours

* The original survey included more questions. However, in this table we only report questions that have been used for this study. [a,b] "To be healthy" and "Others" are not physical activity categories. Thus, users who answered any of these two options were excluded of the study sample. [c] In order to use these values in the analysis, we assumed that: "more than 3 days/week"="5.5 days/week" [considering that the maximum expected days/week would be 7, and the minimum expected days/week would be 4. Thus, the mean of these values would be: 5.5 = (7+4)/2]; "1 day/week"="1.0 day/week"; "1 day/month"="0.25 days/week" (0.25 = 1 day/ 4 weeks); "occasionally"="0.0 days/week". We assumed these values being as conservative as possible. [d] In order to use these values in the analysis, we assumed: "less than 1 hour"="0.5 hours/day"; "1–2 hours"="1.0 hours/day"; "2–4 hours"="2.0 hours/day"; ">4.0 hours"="4 hours/day". We assumed these values being as conservative as possible.

Table 2. Exposure-response function for each outcome [2–4].

Health outcome	Risk estimate [RR (95% IC)]	Exposure	Age group
All-cause mortality	0.810 (0.760, 0.850)	11 MET hours/week	≥18 years
IHD	0.909 (0.857, 0.964)	10 MET hours/week	≥18 years
Ischemic stroke	0.910 (0.831, 1.000)	10 MET hours/week	≥65 years *
Type 2 diabetes	0.980 (0.967, 0.996)	10 MET hours/week	≥18 years
Colon cancer	0.978 (0.940, 1.016)	10 MET hours/week	≥18 years
Breast cancer	0.987 (0.971, 1.003)	10 MET hours/week	≥18 years
Dementia	0.720 (0.600, 0.860)	33 MET hours/week	≥65 years *

- Exposure-response functions for ischemic stroke and dementia were available for subjects ≥65 years old. The study population was divided by age groups (18 to 64 years old, and ≥65 years old), with the aim of assigning appropriate age-specific incidence rates and exposure-response functions for each health outcome.

Table 3. List of assumptions considered for the assessment of health and health-related economic benefits of the urban riverside regeneration project.

Assumption	Justification
• The sample of survey respondents is representative of the study population. The survey was conducted by Barcelona local authorities and used in this study to estimate health and health-related economic benefits of the urban riverside regeneration project.	• Data and description of the procedure employed by local authorities to conduct the surveys was not available. However, this is official data which is being used by local authorities to assess the usability of the Besòs Riverside Park. To our knowledge, this is the only official data available at this moment.
• Scenario 1: 100% of the physical activity practised in the Besòs Riverside Park is new and related to the study intervention. Scenario 2: 50% of the physical activity practised in the Besòs riverside park is new and related to the study intervention (considered in the analysis), the other 50% was previously conducted somewhere else (e.g. on the beach, in a park, in the gym, etc) (not considered in the analysis).	• Data on the physical activity behaviour of the users of the Besòs Riverside Park before the intervention was not available. However, park infrastructure, including access to the riverbanks did not exist previously and the people could not use the area before the intervention completion.
• Base levels of physical activity of the study population are similar than those reported for the whole population of Barcelona [5,8]	• Data on the base levels of physical activity of the specific study population was not available. Nevertheless, this data was available at city level and it was expected to be similar among the Barcelona population and the study population.
• Survey data on frequency of the visits to the Park (Supplementary Material –Table S1), we assumed: A) "more than 3 days/week"="5.5 days/week" B) "1 day/month"="0.25 days/week"	• Based on a conservationist approach: A) Maximum potential value = 7 days/week. Minimum potential value = 4 days/week. Thus, the mean of these values is: 5.5 = (7 + 4)/2. B) 0.25 = 1 day/ 4 weeks.
• Survey data on duration of the visits to the Park (Supplementary Material –Table S1), we assumed: C) "less than 1 hour"="0.5 hours/day" D) "1–2 hours"="1.0 hours/day" E) "2–4 hours"="2.0 hours/day" F) ">4.0 hours"="4 hours/day"	• Based on a conservationist approach: A) Maximum potential value=59 minutes. Minimum potential value=1 minute. Thus: 30 = (1 + 59)/2. And 30 minutes=0.5 hours. B) Most conservative value. C) Most conservative value. D) Most conservative value.
• For Scenario 1, the estimated number of visits to the Park per day is 1 for all the Park users, except for the walking commuters, who need to go to and from work. Thus, for this group of users the number of visits per day is 2.	• Most conservative value.
• Non-linear exposure-response function between physical activity and health outcomes	• There is epidemiological evidence that suggest the exposure-response relationship between physical activity and health outcomes is non-linear [4].
• Data from 2014-2015 surveys (number of users, duration, frequency and type of physical activity) is assumed to be constant though the time	• Health benefits of physical activity do not emerge instantaneously and require regular practise. Data used for this study was collected 15 years after the completion of the riverside park, which means that the users who were using the infrastructure at this moment, may be users who have been using it for some time and that might continue using it in the future.

Table 4. Quartiles of basal levels of physical activity reported in the Barcelona Health Survey [5], a population-based randomized sample studying the health status of Barcelona residents. Levels of physical activity are reported in quartiles, Q1 being the lowest level of physical activity reported for the Barcelona population, and Q4 the highest level of physical activity.

Quartile	MET hour/week
Q1	0.4
Q2	8.5
Q3	22.5
Q4	42.4

MET: Metabolic equivalent of task.

Table 5. Direct health-care cost in euros for morbidity outcomes in Spain [6,7].

	Cost per case (euros)
IHD	1,123
Stroke	2,214
DM2	2,782
Colon cancer	3,031
Brest cancer	1,095
Dementia	5,830

Table 6. Descriptive analysis of the study population.

	Total population: ≥18 years old (N = 5,753)	**≥18 and ≤ 64 years old** (N = 2,848)	**≥65 years old** (N = 2,932)
Age [median (min-max)]	48 (18–85)	42 (18–64)	70 (65–85)
Sex (%)			
Men	65	61	78
Women	35	39	22
Main activity conducted in the Besòs Riverside Park (%)			
Walking for leisure	38	55	21
Cycling	49	19	78
Running	12	24	1
Walking for commuting	1	2	0

Table 7. Sensitivity analysis using the minimum visit duration to the Park (i.e. 30 min/day) reported by walking commuter users. Results for Scenario 1 and Scenario 2.

	Scenario 1			Scenario 2		
	DALYs/year (95% CI)	**Direct Costs (euros/year)** (95% CI)	**VSL (euros/year)** (95% CI)	**DALYs/year** (95% CI)	**Direct Costs (euros/year)** (95% CI)	**VSL (euros/year)** (95% CI)
Cycling	**−7.9** (−14.6; −2.4)	**−25,284** (−46,826; −9,108)	**−15,629,701** (−21,916,593; −11,401,939)	**−5.3** (−9.7; −1.7)	**−16,818** (−30,648; −6,149)	**−10,426,408** (−14,505,355; −7,651,506)
Walking for leisure	**−2.4** (−4.3; −0.7)	**−4,487** (−8,154; −1,608)	**−7,304,560** (−10,144,657; −5,367,509)	**−1.6** (−2.8; −0.5)	**−2,920** (−5,236; −1,059)	**−4,753,055** (−6,557,344; −3,510,218)
Running	**−0.8** (−1.4; −0.2)	**−146** (−264; −28)	**−460,256** (−643,971; −336,315)	**−0.5** (−0.9; −0.1)	**−99** (−178; −19)	**−305,284** (−423,907; −224,357)
Walking for commuting	**0.0** (−0.1; 0.0)	**−10** (−17; −2)	**−29,541** (−41,092; −21,682)	**0.0** (−0.1; 0.0)	**−6** (−11; −1)	**−19,300** (−26,663; −14,239)
TOTAL	**−11.1** (−20.4; −3.4)	**−29,926** (−55,262; −10,746)	**−23,453,984** (−32,746,312; −17,127,445)	**−7.4** (−13.5; −2.3)	**−19,843** (−36,074; −7,229)	**−15,504,047** (−21,513,268; −11,400,319)

DALYs: Disability Adjusted Life Years; VSL: value of statistical life.

Table 8. Sensitivity analysis considering the minimum visit duration to the Park (i.e. 30 min/day) reported by cyclists >65 years old. Results for Scenario 1 and Scenario 2.

	Scenario 1			Scenario 2		
	DALYs/year (95% CI)	**Direct Costs (euros/year)** (95% CI)	**VSL (euros/year)** (95% CI)	**DALYs/year** (95% CI)	**Direct Costs (euros/year)** (95% CI)	**VSL (euros/year)** (95% CI)
Cycling	**−6.3** (−11.4; −1.9)	**−16,256** (−29,574; −5,912)	**−15,629,701** (−21,916,593; −11,401,939)	**−4.2** (−7.5; −1.3)	**−10,591** (−19,006; −3,898)	**−10,426,408** (−14,505,355; −7,651,506)
Walking for leisure	**−2.4** (−4.3; −0.7)	**−4,487** (−8,154; −1,608)	**−7,304,560** (−10,144,657; −5,367,509)	**−1.6** (−2.8; −0.5)	**−2,920** (−5,236; −1,059)	**−4,753,055** (−6,557,344; −3,510,218)
Running	**−0.8** (−1.4; −0.2)	**−146** (−264; −28)	**−460,256** (−643,971; −336,315)	**−0.5** (−0.9; −0.1)	**−99** (−178; −19)	**−305,284** (−423,907; −224,357)
Walking for commuting	**−0.1** (−0.2; 0.0)	**−18** (−33; −1)	**−58,213** (−82,133; −16,786)	**−0.1** (−0.1; 0.0)	**−13** (−23; −2)	**−39,448** (−55,172; −28,834)
TOTAL	**−9.5** (−17.3; −2.8)	**−20,907** (−38,026; −7,550)	**−23,452,730** (−32,787,354; −17,122,548)	**−6.3** (−11.4; −1.9)	**−13,622** (−24,443; −4,979)	**−15,524,195** (−21,541,777; −11,414,915)

DALYs: Disability Adjusted Life Years; VSL: value of statistical life.

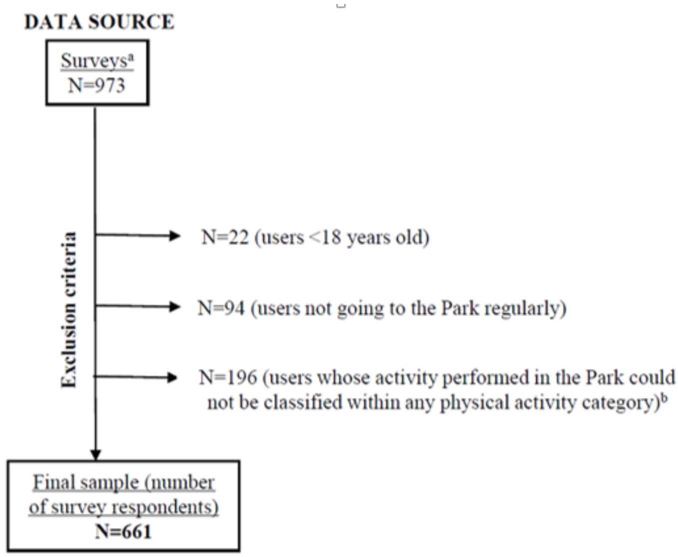

Figure 1. Exclusion criteria used to define the sample of survey respondents for analysis in this study. [a] Survey administered to Park users in 2014–2015 by Barcelona local authorities [1]. [b] Users who responded "to be healthy" or "others" as the "reason to come to the Besòs River" in the survey (see Supplementary Material – Table S1), were excluded of the sample of this study. This was because these activities could not be classified in a physical activity category according to the physical activity classification described by Ainsworth et al. 2011 [9]. This classification provides the energy cost of a wide variety of physical activities (e.g. dancing, walking, cycling, doing home activities like mopping or cleaning windows, etc.), which can be compared with other epidemiological studies providing data on self-reported physical activity.

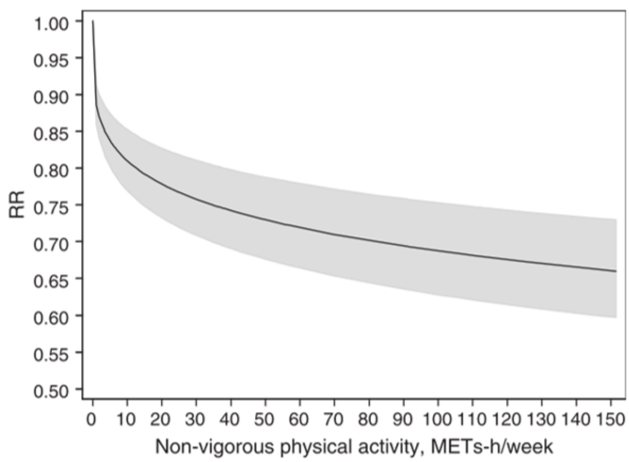

Figure S2. Non-linear exposure-response function between physical activity in METs hour/week and relative risks (RR) for all-cause mortality. Data obtained from a meta-analysis [4] including 22 studies. Shaded areas represent 95% confidence intervals.

$$RR\ for\ 1\ MET\ \frac{min}{week} = A^{(\frac{1}{B^{(y)}})}$$

$$RR\ basal = (RR\ for\ 1\ MET\ \frac{min}{week})^{C^{(y)}}$$

$$RR\ scenario = (RR\ for\ 1\ MET\ \frac{min}{week})^{D^{(y)}}$$

A = RR reference value. Risk estimate from exposure-response function obtained from meta-analysis [2–4]. See Supplementary Material – Table S2.
B = METs minutes/week reference value. Physical activity value from exposure-response function obtained from meta-analysis. See Supplementary Material – Table S2.
C = METs minutes/week basal value. Base levels of physical activity [5,8].
D = METs minutes/week basal + Scenario value. Base levels of physical activity [5,8] + estimated physical activity levels of the study population (Table 1).
Y = power transformation of 0.25 [4].

Figure 3. Formulae for the calculation of the relative risk (RR) used to estimate the health benefits for our study population.

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5.3 Paper III

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Physical and mental health effects of repeated short walks in a blue space environment: a randomised crossover study

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Physical and mental health effects of repeated short walks in a blue space environment: a randomised crossover study

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Abstract

Introduction: Blue spaces may benefit mental health and promote physical activity, although the evidence is still scarce. And benefits on physical health are less consistent. The objective of this randomized crossover study was to assess psychological and cardiovascular responses to blue spaces' exposure.

Methods: A sample of 59 healthy adult office workers was randomly assigned to a different environment (i.e. blue space, urban space, and control site) on 4 days each week, for 3 weeks. For 20 minutes per day, they either walked along a blue or an urban space or rested at a control site. Before, during and/or after the exposure, we measured self-reported well-being and mood, blood pressure, and heart rate variability parameters. For well-being, we also assessed the duration of these potential effects over time (at least 4 hours after exposure).

Results: We found significantly improved well-being and mood responses immediately after walking in the blue space compared with walking in the urban space or when resting in the control site. Cardiovascular responses showed increased activity of the sympathetic nervous system, both during and after walking along the blue and urban spaces. However, cardiovascular responses measured after the walks, showed no statistically significant differences between the blue and the urban space environments.

Conclusions: Short walks in blue spaces can benefit both well-being and mood. However, we did not observe a positive effect of blue spaces for any of the cardiovascular outcomes assessed in this study.

Keywords: blue spaces; well-being; mood; cardiovascular health; physical activity.

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Highlights

- Blue spaces are suggested to benefit mental health and promote physical activity.
- Evidence for physical health is less consistent.
- We conducted a randomised crossover study to evaluate health effects of blue spaces.
- We found significantly improved well-being/mood after short walks in a blue space.
- No effects were found for cardiovascular outcomes.

1. Introduction

Blue spaces are considered "outdoor environments – either natural or manmade – that prominently feature water and are accessible to humans" (Grellier et al., 2017). A recent systematic review based on 35 studies reported that blue space exposure benefits mental health and well-being and improves physical activity levels, while the evidence for benefits on general health, obesity, cardiovascular and related outcomes was less consistent (Gascon et al., 2017). More recent studies have added to this evidence showing self-reported general and mental health (J. Garrett et al., 2019; Hooyberg et al., 2020), physical activity, social interaction, and psychological benefits of blue spaces (de Bell et al., 2017), and the association between blue spaces exposure and health outcomes on older adults (J. K. Garrett et al., 2019). But still, there are few studies on blue spaces health benefits and the methodological heterogeneity across them warrants further studies on this topic (Gascon et al., 2017).

Besides the physical environment, physical activity is also a key determinant of human's health (World Health Organization, 2018a). A physically active lifestyle contributes to the prevention of non-communicable diseases such as stroke, diabetes, hypertension, overweight and obesity (World Health Organization, 2018a). It also improves mental health, quality of life and well-being (World Health Organization, 2018b). Walking is a cost-effective form of physical activity, which might appeal to a significant part of the population (Brown et al., 2014; Marselle et al., 2013; National Institute for Health and Clinical Excellence, 2012; WHO, 2014). Moreover, some studies have suggested that conducting physical activity in natural environments brings additional benefits for mental health and well-being (e.g. improves restoration, decreases anger, depression and tension, etc.) compared with conducting physical activity indoors (Bowler et al., 2010; Lahart et al., 2019; Mitchell, 2013; Thompson Coon et al., 2011) or non-natural spaces (Bowler et al., 2010; Mitchell, 2013). However, the evidence is still not conclusive (Lahart et al., 2019; Mitchell, 2013; Thompson Coon et al., 2011).

The aim of this study was to assess psychological and cardiovascular responses of the exposure to blue spaces, compared to urban spaces, and with a control site. Thus, the objectives were: (i) to evaluate changes in well-being and mood responses, blood pressure (BP), and heart rate variability (HRV) after 20 minute walks in a blue space compared with 20 minute walks in an urban space and with resting at a control site; and,

(ii) to assess whether well-being/mood effects were sustained for (at least) 4 hours after the exposure.

2. Methods

2.1. Study design and participants

We applied a randomized crossover design, with participants serving as their own controls. Participants (n=59) were office workers at the Barcelona Biomedical Research Park (PRBB), a research hub at the seafront of Barcelona (Catalonia, Spain). The study was advertised to all members of the PRBB via an internal newsletter sent by email, and posters placed on different parts of the PRBB building.

Inclusion criteria were: working at the PRBB building; available during the whole study period; aged between 18 and 65 years old; non-smokers; not pregnant; not suffering any chronic diseases including high BP (i.e., systolic BP > 139 mmHg and diastolic BP > 89 mmHg) (Pickering et al., 2005), pulmonary diseases, or cardiovascular diseases; not taking medication for hypertension, depression, anxiety, medication for sleep, or any other medication related with any of the chronic diseases listed above; and able to walk for 20 minutes at a constant moderate pace. Before their enrolment in the study (Time 0 – T0), participants attended an informative meeting to receive all the information regarding the aim and the procedure of the study, signed an informed consent, and answered the background questionnaire (Figure 1). Sixty participants were included in the study sample, but one dropped out in the first week due to personal reasons. Thus, 59 participants were finally included.

Every day, measurements and questionnaires were conducted in the study room at Time 1 (T1: before exposure) and Time 3 (T3: immediately after exposure). The time spent in the different environments corresponds to Time 2 (T2). For the short-term follow-up (Time 4 - T4) we designed an online questionnaire that participants answered 4 hours after the exposure (Figure 1). To standardise the effects on health responses, during T1, T2 and T3 participants were asked to refrain from talking to each other, using their phone or headphones, reading, eating or drinking anything but water. Moreover, participants were asked to abstain from consuming alcohol at least 12 hours before the measurements (T1), caffeine or food at least 1 hour before (T1) (Gidlow et al., 2016; Grazuleviciene et al., 2016), and practising vigorous physical activity (e.g. running, walking, swimming or cycling fast, competitive sports, etc.) during the morning before T1. No eating, drinking or physical activity restrictions were defined from T3 to T4.

For study organization reasons and to avoid extreme temperatures on summer or winter, the study was conducted in two different study periods (spring and autumn) of 3 non-necessarily consecutive weeks each (1^{st} period: April – May 2017; 2^{nd} period: September – October 2017), with 29 and 30 participants in each study period respectively. Also, participants were distributed into two turns, the first starting at 10 am and the second at 11.30 am. The study was scheduled on the same weeks for all the participants, with some exceptions when participants occasionally could not attend on the scheduled week. In this case, they were rescheduled for another week. Weather conditions were similar for both study periods (1^{st} period: average temperature=17.0ºC; and average relative humidity (RH)=75.2%. 2^{nd} period: average temperature=16.8ºC; and average RH=66.5%). Upon completion of the study, participants were paid 150 euros. The study was approved by the Clinical Research Ethics Committee of the Parc de Salut MAR.

2.2. Exposure environments

For each study week, each participant was randomly assigned to a different environment for the whole week (i.e. blue, urban, or control site). Thus, all participants were exposed to all environments upon completion of the study. Participants did not know which environment they would be exposed to until the first day of each study week.

We designed a route for both urban and blue environments (Figures 2 and 3). The route on the blue space environment was along the seafront to a breakwater on the beach (Figure 2). The route on the urban space environment was along the sidewalks of nearby PRBB streets (Figure 3). The presence of trees or other green or blue elements along the urban route were avoided as much as possible when designing the route. The starting point of both routes was at the PRBB building, and their length was approximately the same (1.6 km). The control site was in a room at the PRBB (Figure S1 – Supplementary Material). Details of each environment are described in Table S1 (Supplementary Material). We instructed participants to either walk on their own for 20 minutes along the blue or urban route, or to rest for 20 minutes at the control site (Figure S1 – Supplementary Material).

2.3. Health measures

2.3.1. Well-being and mood

Every day, participants completed a set of questionnaires to assess their well-being and mood before (T1) and after (T3 and T4) the exposure. Participants' well-being was also assessed one month upon the completion of the study (Time 5 – T5) (Figure 1). All the questionnaires were completed individually in the study room using tablets, except questionnaires at T4 and T5, which were completed online at home or at the office. Each of these questionnaires included a set of questions targeting specific outcomes. The wording of the questions was maintained to retain its purpose. Some of the questions were repeated across the questionnaires (Figure 1).

- *Subjective well-being (SWB):* SWB was assessed using two items from a questionnaire developed by the UK's Office of National Statistics (White et al., 2017). We asked the participants "Overall how happy did you feel yesterday?" and "Overall how anxious did you feel yesterday?". Responses ranged from 0 "Not at all" to 10 "Completely". Given large skews in the distribution of these variables and based on the median (median for happiness=7; median for anxiety=4), we dichotomised these variables.

- *WHO-5 Well-being:* We employed a set of questions adapted from the WHO-5 well-being index (Topp et al., 2015). In our study, we adapted the questions in order to refer to the participant's affective states during the time they were exposed to each environment. Under the statement "During the time that I have been exposed to the [blue/urban route or to the control environment]", participants were asked to answer the following questions: "I have felt cheerful and in good spirits"; "I have felt calm and relaxed"; "I have felt active and vigorous"; "I woke up feeling fresh and rested"; and "My daily life has been filled with things that interest me". Responses included the following options: 0 "At no time"; 1 "Some of the time"; 2 "Less than half the time"; 3 "More than half the time"; 4 "Most of the time"; and 5 "All of the time". As well as item-specific scores, we created summary scores ranging from 0 (worst quality of life) to 100 (best quality of life) (Topp et al., 2015).

- *Total Mood Disturbance (TMD):* We employed the Spanish short version of the Profile of Mood States (POMS) (Balaguer et al., 1993; Fuentes et al., 1995) to assess total mood disturbance (i.e. psychological distress). It included 29 adjectives, describing different moods, which were classified into 5 subscales: tension/anxiety (TA), depression (D), anger/hostility (AH), fatigue (F), and vigour (V) (Fuentes et al., 1995). Responses were rated on a five-point scale ranging from "Not at all" to "Very much". The total score for TMD was calculated using the following formula: [(TA) + (D) + (AH) + (F) – (V)], indicating the lower the score, the better the mood state. POMS is a well-established measure for which reliability and validity has been previously documented (Fuentes et al., 1995; Song et al., 2019).

- *Somatisation:* The lack of somatisation was assessed every afternoon during the study period. We used an adaptation of the four-dimensional symptom questionnaire (4DSQ) (Terluin et al., 2006), previously used in other studies, e.g. (Triguero-Mas et al., 2017a). We asked participants whether at the moment they were answering the questionnaire they were feeling: "dizziness"; "back/shoulders pain"; "headache"; "painful muscles"; "pain in the chest"; "nausea"; "pain in the abdomen or stomach area"; "ache in the back of the head"; or "fatigue". Responses ranged from 1 "Severely" to 5 "No". We created a sum score of all the items, ranging from 9 to 45. Higher scores indicate lower somatisation symptoms.

- *Vitality and mental health:* We used an adapted version of the SF-36 Health Survey Manual (Ware et al., 1993) to assess vitality and mental health at follow up. For vitality, we asked participants whether at the moment they were answering the questionnaire they were feeling (i) "full of pep and/or energy"; (ii) "worn out"; or (iii) "tired". For mental health, we asked participants whether at the moment they were answering the questionnaire they were feeling (iv) "nervous"; (v) "downhearted"; (vi) "calmed/relaxed"; or (vii) "happy". Possible answers ranged from 5 "No" to 1 "Very much". For three items (i, vi, and vii) answers were scored inversely. The final score was based on the sum of items score for each well-being measure (i.e. vitality and mental health), and transformed to a 0-100 scale according to guidelines (Ware et al., 1993). Higher scores indicated better well-being outcomes.

- *Sleep characteristics:* For assessing sleep characteristics we used a set of questions based on the Pittsburg sleep quality index (Buysse et al., 1988). Under the statement "Please describe how you slept last night" we asked participants the following questions: "I fall asleep easily"; "I felt restless and disturbed"; "I woke up earlier than usual"; "I sleep well"; "Number of hours I slept (hh:mm)". Participants answered "yes", “no”, or “I don’t know”, except for the last question in which they specified the number of hours and minutes they slept the previous night. For this last variable, answers were dichotomised into “<7 hours” and “≥7 hours”, considering that this is the adequate sleep duration for healthy adults (Hirshkowitz et al., 2015). For all the variables, we excluded observations whose answer was “I don’t know”.

- *General health:* To assess self-reported general health we used a single question from the SF-12 Physical and Mental Health Summary Scales (Ware et al., 1995). This was ‘How is your health in general?’, and participants could answer 1 “Very good”, 2 “Good”, 3 “Fair”, 4 “Bad”, or 5 “Very bad”. As previously done in other studies (J. K. Garrett et al., 2019), and due to the distribution of the variable, we dichotomised answers into “Good” (for Very good, and Good) and “Not good” (for Fair, Bad and Very bad). This question was previously used in other studies assessing health effects of green or blue spaces (J. K. Garrett et al., 2019; Wheeler et al., 2012).

- *Life satisfaction:* Life satisfaction was measured using one item from a scale developed by the UK’s Office of National Statistics (White et al., 2017). In this case, we asked participants “Overall how satisfied are you with life nowadays?”. Possible responses ranged from 0 “Not at all” to 10 “Completely”.

- *Eudaimonic well-being:* we asked “Overall to what extent do you feel that the things you do in your life are worthwhile?” to assess eudaimonic well-being (White et al., 2017). Possible responses ranged from 0 “Not at all” to 10 “Completely”.

2.3.2. Blood pressure and pulse rate

For this study, BP measurements [systolic BP (SBP), diastolic BP (DBP)] and pulse rate were taken at T1 and again at T3 in the study room by trained technicians using a calibrated digital BP monitor (Model M10-IT, OMRON Healthcare, UK) (Figure 1). Before each reading, participants sat down with feet flat on the floor, relaxed and quiet for at least 10 minutes with cuffs placed on their left arm leaning on the table. We target 3 reliable readings at each study episode (T1 and T3), with pauses of at least 2 minutes in between. We used the mean of the 3 readings for each study episode.

2.3.3. Heart Rate Variability

In this study, HRV was continuously measured from T1 to T3 including the exposure time, T2, using the wireless chest-based wearable device Zephyr BioHarness (Zephyr Technology Corporation, Annapolis, MD, US) (Medtronic, 2019). Raw data were obtained using the BioHarness Log Downloader 9500.0078.V1c (1.0.29.0), processed and cleaned using the R package RHRV (García Martínez et al., 2017). We assessed the presence of ectopic beats, and (both automatically and manually) removed artefacts using algorithms provided by the R package RHRV (García Martínez et al., 2017; Rodríguez-Liñares et al., 2011). Using these algorithms, we rejected values exceeding the cumulative mean threshold, and also those which were not within acceptable physiological values (Rodríguez-Liñares et al., 2011). After estimating the interpolated heart rate signal, we conducted both frequency-domain, and time-domain analysis for each study episode (T1, T2, and T3), estimating a mean value for each.

For the frequency-domain analysis (using the Fourier transformation) we used a time length of 5 minutes (300 seconds), which refers to a short-term length (Massaro and Pecchia, 2019). We obtained heart rate (HR), high frequency (HF; 0.15–0.40 Hz) power, low frequency (LF; 0.05–0.15 Hz) power and the ratio of LF to HF (LF/HF). For the time-domain analysis we used the standard deviation of NN intervals (SDNN), and the root mean square of successive NN interval differences (RMSSD).

2.4. Other measurements

Apart from the indicators mentioned above, we measured other health indicators which were assessed as potential covariables in the different models employed in this study. Participants' body mass index (BMI) was assessed at T0 and again upon the completion of the study, and the mean value between both measurements was calculated. Also, we continuously and quantitatively measured participants' physical activity and sleep quality using ActiGraph GT3X+, a portable device which subjects wore on their non-dominant wrist for 7 consecutive days each week of study participation (starting 3 days prior the start of the study and finishing the day participants completed the whole study week). We used ActiLife software version 6.11.9 for analysing this data (ActiGraph, 2019). We obtained average vector magnitude (VM) and steps to assess (i) weekly records of physical activity, and (ii) physical activity during the time of exposure (using 10-seconds time-window). Sleep quality was assessed using the variables "Total Sleep

Time" (total time scored as "asleep") and "Efficiency" (total sleep time divided by total time in bed, in %).

Also, at T3 and T4, participants rated the quality and self-perception of the route they had been exposed to. And at T5 we assessed participants' physical activity levels and visits to natural environments 1 month upon the end of the study (Figure 1).

2.5. Statistical analysis

Two different analysis scenarios were considered. For analysis scenario 1, the control resting exposure was used as reference value, and we compared this with the blue space and the urban space exposure. For analysis scenario 2, we compared the blue space exposure to the urban space exposure (used as a reference).

-*Well-being and mood:* The association between the environments and each of the well-being/mood outcomes were assessed using mixed-effects regression models with participants' ID used as random effects. Specifically, logistic models were used for dichotomous outcomes, reporting odds ratio (OR), and Poisson models were used for count outcomes, reporting incidence-rate ratios (IRR). In both cases, 95% Confidence Intervals (CI) were reported. The effect of different covariates (listed and described in Table S2 – Supplementary Material) in the models was assessed, and we finally adjusted our models by age, gender, the days of the week, and well-being/mood outcomes measured at T1 (when this data was available – see Figure 1). In order to assess whether well-being/mood effects were influenced by participants' health status, we stratified the analysis by good/not good general health according to the "General health" outcome assessed at T3. Also, due to potential differences between women and men in the association between blue space exposure and well-being/mood outcomes (Bell, 2016; Pérez-Tejera et al., 2018; Triguero-Mas et al., 2017a), we assessed interactions between gender and exposure in models with outcomes whose effects were statistically significant.

-*Blood pressure:* For BP, we used mixed-effects linear regression models for continuous variables, reporting coefficients with a 95% CI. We used participants' ID as random effects. The exposure environment and BP readings at T1 were included as fixed effects. These models were adjusted by age, gender, BMI, and the days of the week.

- *Heart Rate Variability:* These outcomes were measured during T1, T2 and T3 (only domain evaluated during T2). We fit mixed-effects linear regression models with random intercepts for each participant, accounting for an interaction between exposure environment (i.e., control, blue and urban) and study episodes (i.e., T1, T2, and T3) as fixed-effects. Models were adjusted by age, gender, BMI, and the days of the week. To normalize the residuals distribution, HRV parameters were natural log-transformed (Goldberger and Stein, 2019).

Since we acknowledge the relevance of physical activity on BP and HRV results, we conducted sensitivity analysis adjusting BP and HRV models by physical activity quantitatively measured both, weekly and at T2. Given the high correlation between VM and steps (corr.=0.7 for weekly measurements, and corr.=0.8 for T2 measurements), we adjusted our models only by VM.

The statistical analysis was conducted using STATA version 14, and RStudio version 3.5.3. For all the analysis a p-value ≤0.05 was considered statistically significant.

3. Results

Fifty-nine healthy adult participants completed the 3-week long study. Participants' characteristics are described in Table 1. Participants rated the blue route significantly better than the urban route, highlighting its better quality, the safety, the lack of garbage and vandalism, and reporting to feel more satisfied when walking along it (Table S3 – Supplementary Material). Perceived air pollution was the main cause of discomfort along the urban route, followed by noise (85% and 75% of the participants rated it badly, respectively), while all ratings of discomfort were lower along the blue route (Table S3 – Supplementary Material).

3.1. Well-being and mood effects

The analysis of well-being/mood outcomes (described in Table 2) showed some differences among the different environments, suggesting better mood and well-being scores when participants were exposed to the blue environment, compared with the urban and control environments (Table 3). The most statistically significant associations were observed for "WHO-5 well-being" and TMD, showing consistency between analysis scenarios 1 and 2 (Table 3). Statistically significant associations were also observed for "Vitality" and "Mental health", although in this case IRR were very close to 1 (Table 3). The only exception was for "sleep duration", which was suggested to be statistically significant higher – and closer to the adequate time sleep for healthy adults – for the urban exposure, compared with the control site. Adjusted models did not differ from the crude models (data not shown).

- *Subjective well-being (SWB):* For SWB we did not observe statistically significant associations (Table 3).

- *WHO-5 Well-being:* For both analysis scenarios, IRR for "Total Well-being Score" was increased when participants were exposed to blue environment (Table 3), suggesting participants' better subjective well-being when they were exposed to this environment [for the blue environment, IRR=1.32 (1.25, 1.38) and IRR=1.34 (1.27, 1.40) in analysis scenario 1 and 2, respectively] compared with the control and urban environments (Table 3).

- *Total Mood Disturbance (TMD):* For both analysis scenarios, IRR for negative TMD sub-scales (TA, D, AH, and F) were significantly lower after walking along the blue route compared with the control and the urban environments [e.g. for the blue environment, IRR=0.36 (95% CI; 0.28, 0.47) for AH in analysis scenario 2]; while IRR for V (i.e. positive TMD sub-scale) was significantly higher [e.g. IRR=1.61 (95% CI; 1.50, 1.73) for V in the blue environment in analysis scenario 1] (Table 3). We also observed a statistically significant higher IRR for AH after walking along the urban route compared with the control [IRR=1.32 (95% CI; 1.09, 1.60)] (analysis scenario 1) (Table 3). We found a decreased IRR for the total score of TMD for both analysis scenarios, suggesting lower TMD when participants were exposed to the blue and urban environments compared with the control, and when they were exposed to the blue environment compared with the urban environment (Table 3).

- *Somatisation:* We did not observe statistically significant associations (Table 3) for somatisation.

- *Vitality and mental health:* "Vitality" and "mental health" measured at the blue and urban environments showed a statistically significant increased IRR (95% CI) for both analysis scenarios, although estimates were very close to 1 [e.g. IRR=1.07 (95% CI; 1.04, 1.09) for "Vitality" in the blue environment in analysis scenario 2] (Table 3).

“Somatisation”, “vitality” and “mental health” were measured at T4. These results suggest no consistency of the persistence over time of the well-being effects associated with blue spaces’ exposure.

- *Sleep characteristics*: We observed a lower OR for sleeping less than 7 hours/day (vs. sleeping at least 7 hours/day) when participants were exposed to the urban environment compared with the control, although no statistically significant associations were found for any of the other variables describing sleep characteristics (Table 3).

- *General health, life satisfaction, and eudaimonic well-being:* We did not observe statistically significant associations for any of these outcomes (Table 3).

For the outcomes that showed statistically significant associations (i.e. “WHO-5 well-being”, TMD and “Vitality” and “mental health”), we stratified the models by “General health” (assessed within a questionnaire at T3). For “WHO-5 well-being”, “Vitality” and “mental health” we observed better scores among non-healthy participants compared with healthy participants (Table S4 – Supplementary Material). This was not observed for TMD (Table S4 – Supplementary Material). No statistically significant interactions were observed between gender and the exposure environments for TMD, neither for “Vitality” and “Mental health” (data not shown). For “WHO-5 well-being”, we observed a statistically significant interaction between gender and the exposure environment, for “Total Well-being score” in analysis scenario 1 (p-value=0.02) (data not shown). In this case, the effect of blue spaces exposure appeared to be stronger for women than for men (Table S5 – Supplementary Material).

3.2. Blood pressure and pulse rate

The descriptive analysis of BP and pulse rate, with pairwise comparisons between T1 and T3 with Bonferroni corrections, showed only statistically significant differences of SBP and pulse rate in the control site (Table S6 – Supplementary Material).

In the same line, we found statistically significant increased SBP and pulse rate in the blue and urban environments compared with the control site (analysis scenario 1) [e.g. SBP for subjects exposed to blue environment: coef. =1.16 (95% CI: 0.26, 2.06)] (Table 4). However, no statistically significant associations were observed in analysis scenario 2 (Table 4). Results for the adjusted models did not differ from those of the crude models (Table S7 – Supplementary Material).

Results from the sensitivity analysis, with models adjusted by physical activity levels, showed no statistically significant associations for SBP, DBP, and neither pulse rate for any of the two different analysis scenarios (Table S8 – Supplementary Material).

Physical activity levels, quantitatively assessed with VM, showed no statistically significant differences between exposure environments (Table S9 – Supplementary Material).

3.3. Heart Rate Variability

The descriptive analysis of HRV variables, with pairwise comparisons with Bonferroni corrections, can be found at the Supplementary Material (Table S10 – Supplementary Material). The description of logarithmic HRV variables, by exposure environment and study period, are also graphically represented (Figure 4).

We found statistically significant interaction between exposure environments and study period in analysis scenario 1, and in analysis scenario 2, in this case only for LF and HF (Table S11 – Supplementary Material). In the analysis of association (Table 5), we found statistically significant increased HR and LF/HF; and statistically significant decreased LF, HF, SDNN, and RMSSD when participants were exposed to the blue and urban environments, compared with the control (analysis scenario 1). This is an indicator of a stimulation of the sympathetic nervous system (SNS), related with increased activity levels (European Society of Cardiology, 1996; García Martínez et al., 2017; Laeremans et al., 2018; Shaffer and Ginsberg, 2017; Song et al., 2019, 2015; Stigsdotter et al., 2017; Valenza et al., 2018). We also observed increased LF/HF, and decreased LF, HF, SDNN, and RMSSD, when we compared estimates of the blue exposure with those in the urban exposure (analysis scenario 2), although in this case it was only statistically significant at T2 (during exposure) and the association was weaker than in analysis scenario 1 (Table 5). No statistically significant associations were observed in analysis scenario 2 at T3 (after exposure), when all the values were very close to zero (Table 5). Thus, suggesting no differences on HRV parameters, between the urban and the blue environments at T3. Crude models showed very similar results (Table S12 – Supplementary Material).

In the sensitivity analysis (Table S13 – Supplementary Material), when the model was adjusted by VM at T2, we found a weaker effect of the exposure environments and study period on HRV parameters in analysis scenario 1. However, the direction of the association was consistent with the main model (Table 5). In analysis scenario 2 (Table S13 – Supplementary Material), the sensitivity analysis showed no differences with the main model. Finally, when the model was adjusted by weekly VM (as a proxy of the baseline physical activity levels of the study population), the estimates of the sensitivity analysis (Table S13 – Supplementary Material) did not differ from those of the main model (Table 5).

4. Discussion

4.1. Main findings

In this study we observed better well-being and mood responses shortly after walking 20 minutes in a blue space versus walking in an urban space (analysis scenario 2) or resting in a control site (analysis scenario 1). Nevertheless, there was no evidence that BP and pulse rate decreased in the blue space exposure, compared with the urban space (analysis scenario 2) or the control site (analysis scenario 1). Also, cardiovascular responses showed unexpected findings by suggesting an increased activity of the SNS not only during the time participants walked in either the blue or the urban space compared with resting in the control site, but also after that (analysis scenario 1), when we would expect an increased dominance of the parasympathetic nervous system (PNS) (Goldberger and Stein, 2019). Similar effects on cardiovascular outcomes were observed during the time participants walked in the blue space, compared to the urban space (analysis scenario 2), although the association was weaker in this case. Results of analysis scenario 1 highlight the importance of moderate physical activity on cardiovascular health, regardless of the environment in which it is being practised.

Psychological responses seemed to be not only influenced by physical activity, but also by the type of environment, being better when participants were exposed to blue space. Furthermore, our results suggest better psychological responses among participants reporting bad general health status, and – for some outcomes – also among women. Positive effects on mental health have already been reported by other experimental studies whose participants were exposed to – either natural or artificial – nature views while being sedentary (Bielinis et al., 2018; Gilchrist et al., 2015; Mangonea et al., 2017). Well-being benefits as a consequence of being in contact with nature have been broadly described (Bratman et al., 2019; Frumkin et al., 2017) and might be explained by the biophilia hypothesis (Wilson, 1984), suggesting human's affinity to nature and its positive well-being consequences when this is accomplished (Nieuwenhuijsen et al., 2017; Yeager et al., 2019).

Physical activity is related with an activation of the SNS activity, and a deactivation of the PNS activity (Goldberger and Stein, 2019). This situation is characterized by an increase of HR and LF/HF, and a decrease of HF and LF (highly correlated with RMSSD and SDNN, respectively) (Castaldo et al., 2015; García Martínez et al., 2017; Shaffer and Ginsberg, 2017). This expected situation during physical activity periods is observed for HRV parameters at T2. However, even though our results suggest a potential reactivation of the PNS [responsible for recovering the normal cardiovascular situation (García Martínez et al., 2017; Massaro and Pecchia, 2019)] at T3, the estimates still do not indicate the complete rebalance of the PNS and SNS activities. We hypothesized that participants would be more relaxed after walking in a blue space than in an urban space, as suggested by other similarly designed studies (e.g., Lee et al., 2011; Song et al., 2019; Triguero-Mas et al., 2017b). However, this was not observed in our study. On the same line, BP and pulse rate were supposed to increase due to physical activity and decrease on the recovery (T3), showing better results for the blue space than for urban space. In this study, BP and pulse rate were higher after the exposure (T3), being statistically significant for SBP and pulse rate in analysis scenario 1 (Table 4). We did not find a decreased BP or pulse rate after the exposure in the blue space, neither in the urban space.

4.2. Strengths and limitations

In our study we did not observe positive cardiovascular effects of being exposed to a blue space, as other similarly designed studies with green spaces' exposure suggested (Lee et al., 2011; Song et al., 2019, 2015, 2014, 2013; Triguero-Mas et al., 2017b). We acknowledge some study limitations that might explain our results. The post-exposure assessment was shortly after the exposure, which included moderate physical activity when participants were exposed to the blue and urban environment. Physical activity, which requires energy expenditure, increases the SNS activity and decreases the PNS activity (Castaldo et al., 2015; García Martínez et al., 2017; Goldberger and Stein, 2019). Subsequently, the SNS and PNS activity would rebalance and an increased PNS activity would suggest better health and a greater state of relaxation. However, post-exposure parameters of this study might be assessed too close to the exposure period, not having enough time to recover the PNS and SNS activities from the physical activity stimulus. A longer time period between the exposure and the post-exposure assessment, such as 20 minutes (instead of 10 minutes as in our study), might be required to observe cardiovascular effects produced by the exposure (urban or blue space environment) and not by physical activity (Torrente et al., 2017; Triguero-Mas et al., 2017b). Also, in our study we evaluated acute effects of short walks along blue spaces. A continuous long-lasting exposure to blue spaces, being or not moderately active, might result in positive effects on cardiovascular health that cannot be identified with our study design because blue spaces' exposure may lead to longer lasting cardiovascular effects than exposure to urban spaces. Based on previous literature, we defined an exposure duration of 20 minutes in order to facilitate participants' engagement in the study, given that the study was conducted during working hours. Even though other similar studies observed positive health effects even after 15 minutes walks on green spaces (Bielinis et al., 2018; Song et al., 2019, 2015, 2013), we acknowledge that our results might be underestimations and that we might have observed greater health benefits with a longer exposure period. The exposure time-length and the intensity and type of physical activity conducted by the participants – who reported to be very active (see Table 1) – might be insufficient to promote changes in healthy adults' baseline BP or HRV with normal ranges. Besides this, outcomes selected to assess changes on cardiovascular health between environments, might not be sensitive enough for this purpose. Beyond physical activity, it is also well-known that air pollution might have an effect on cardiovascular health (Nieuwenhuijsen, 2018). In our analysis we did not find evidence for adjusting our BP and HRV models by air pollution, thus air pollution was not included as a covariable. However, air pollution measurements available for this study correspond to those measured in a station next to PRBB. Air pollution measurements specifically measured in the urban and in the blue route might better represent air pollution levels in each exposure environments but could not be used because this data was not available. Apart from that, in the current study we used a study sample whose characteristics might have underestimated the expected health effects. As shown in Table 1, 88% of the participants reported to have views to blue spaces from their workplace. This is no surprise given that the PRBB is in front of the sea. We hypothesize that greater effects on well-being and mood would be observed among participants who are not usually exposed to blue spaces. Also, participants of this study were healthy adults, physically active and highly educated, threatening the generalization of the study results. Cardiovascular effects of short walks on blue spaces might be observed using a similar study design with hypertensive, obese, and/or older participants.

Strengths of this study include the randomized cross-over design, that well-being/mood and BP models were adjusted by baseline measures (except for some mood and well-being outcomes that were not measured at baseline), that we accounted for an interaction between exposure environment and study episodes in the HRV models, and that the blue environment could be compared not only with urban environment, but also with a control site. Thus, each participant served as their own control, reducing the risk of bias. Also, we used different (and most of them validated) questions to identify a wide range of changes on well-being and mood, not only focusing on a specific outcome. Furthermore, our results are consistent with those found in other similarly designed studies, reporting better well-being and mental health outcomes after walking along natural environments (Bielinis et al., 2018; Bratman et al., 2015; Brown et al., 2014; Gidlow et al., 2016; Koselka et al., 2019; Song et al., 2019; Triguero-Mas et al., 2017a). However, most of these other studies compared urban versus green spaces, while we evaluated exposure to blue spaces, rarely done before (for exceptions see Gidlow et al., 2016; Triguero-Mas et al., 2017a). Finally, this is, to our knowledge, one of the very few studies evaluating the effects of blue spaces exposure on people's health that uses repeated acute exposures instead of single exposures (for exceptions see Brown et al., 2014; Koselka et al., 2019), and our unexpected findings on cardiovascular responses are consistent with another study using repeated acute exposures (Brown et al., 2014).

4.3. Future research

Despite our null results for cardiovascular effects of blue spaces exposure, it is key to keep considering this outcome in further studies given that cardiovascular diseases are still a leading cause of mortality worldwide (Nieuwenhuijsen, 2018) and because previous research has found favorable changes in HRV indicators in blue environments (Triguero-Mas et al., 2017b). Nature's contact benefits our physiological and psychological health (Thompson et al., 2016) and this is even more relevant in the urbanization context we are living nowadays (Bratman et al., 2019). People's nature affinity has also been observed in this study: most of the participants positively rated the experience of walking along the blue space, and we observed positive effects for well-being and mood.

The evaluation of health benefits associated to blue space's exposure has gained more attention recently. However, there are still some knowledge gaps that require more research (Gascon et al., 2017). For example, potentially differing health effects depending on the type of blue space people are exposed to. While we observed positive well-being and mood effects on participants when they were exposed to the blue environment, in our case an urban beach, it is not clear whether these effects would be magnified or reduced if the blue space had been a river, a lake, or a fountain instead of an urban beach. The wildness and other characteristics (such as type, quality or context) of the selected site could influence the magnitude of the health effects observed in this study (Cheesbrough et al., 2019; Wheeler et al., 2015).

5. Conclusions

Compared to walking along an urban space environment, short walks in a blue space environment (urban beach) can benefit both well-being and mood. However, we did not observe differences regarding cardiovascular outcomes.

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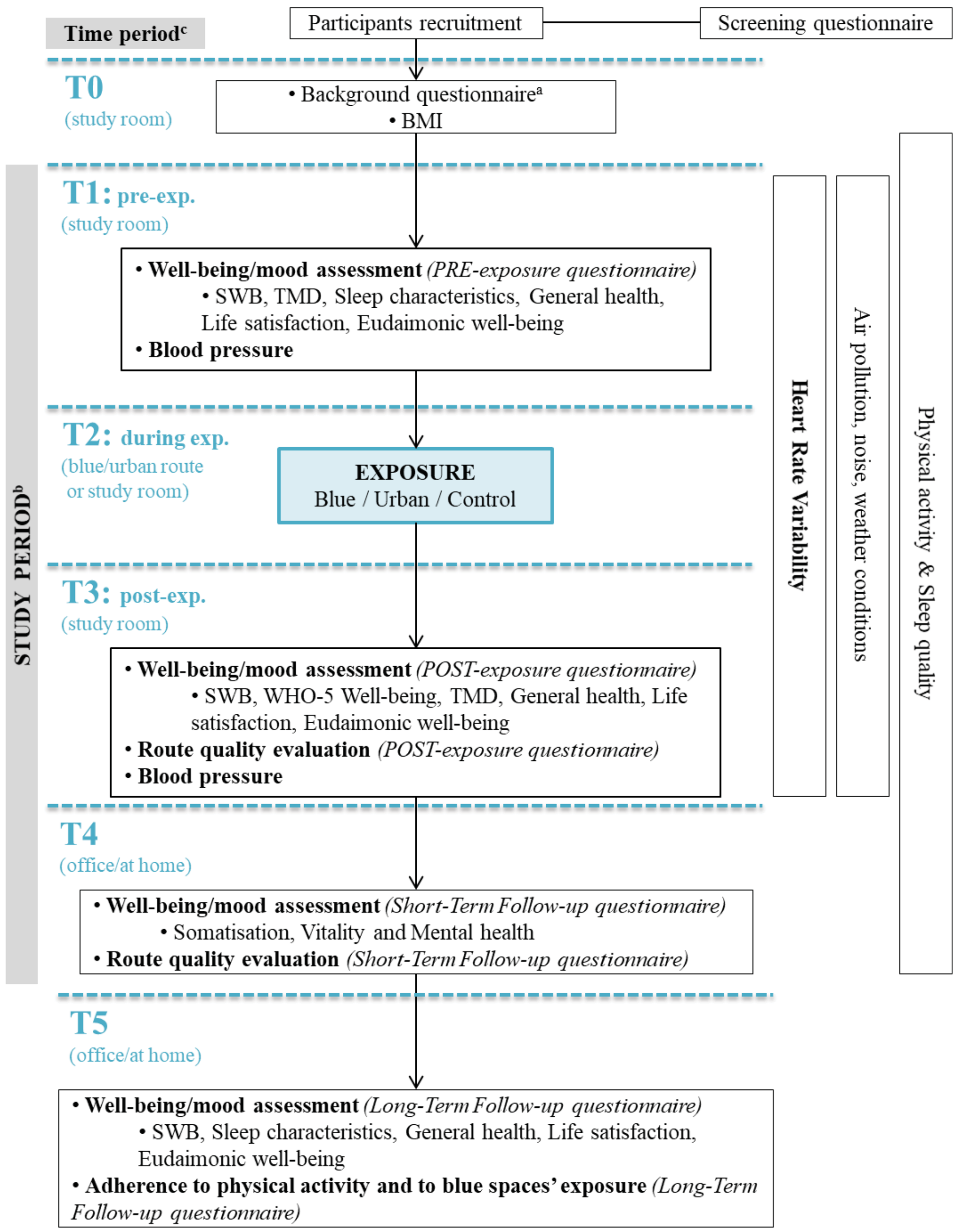
Tables and Figures

Figure 1. Flowchart of the study procedure.



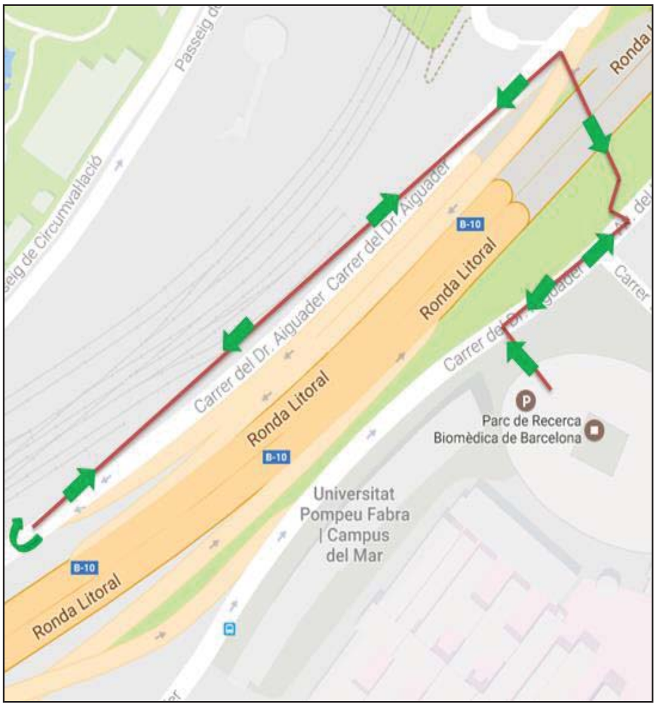
[a]Background questionnaire includes questions about participants' socioeconomic characteristics, natural spaces' exposure and use, and physical activity.
[b]The 1st turn was from 10 am to 11 am, and the 2nd turn was from 11.30 am to 12.30 am. The short-term follow-up questionnaire was sent to participants every day of the study period at 4 pm approximately, thus at least 3.5h after study participation.
[c]Time period refers to the moment when the different variables were measured. Time=0 (T0): baseline; Time=1 (T1): pre-exposure; Time=2 (T2): during exposure; Time=3 (T3): post-exposure; Time=4 (T4): short-term follow-up; Time=5 (T5): long-term follow-up.

Figure 2. Blue route: **(a)** Route followed by the participants when they were randomly assigned to the blue space exposure (Google Maps) **(b)** Image of a section of the blue route, at the breakwater in the beach (*Espigó del Gas*). Photo taken by: Cristina Vert, October 2019.

(a)

(b)

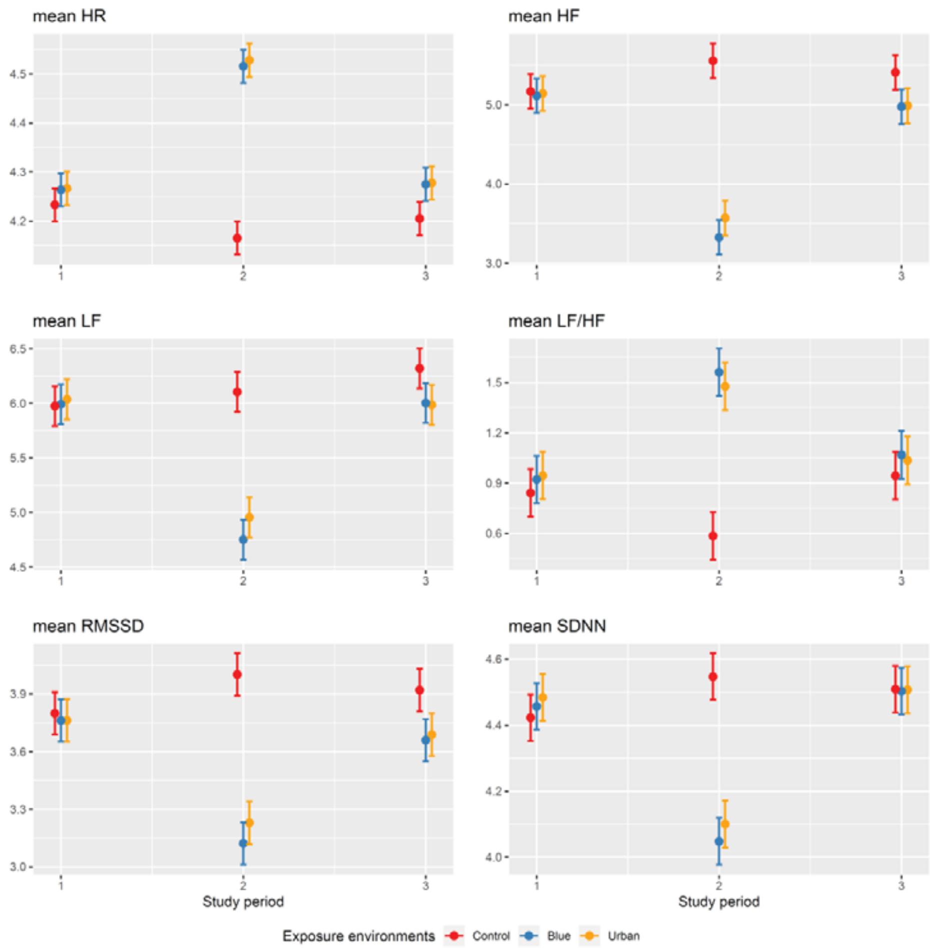
Figure 3. Urban route: **(a)** Route followed by the participants when they were randomly assigned to the urban space exposure (Google Maps) **(b)** Image of a section of the urban route, on the sidewalk next to the road. Photo taken by: Cristina Vert, October 2016.



(a)

(b)

Figure 4. Mean logarithmic HRV variables*, by exposure environment and study period (i.e., T1, T2, T3).



HRV variables: heart rate (HR), low frequency power (LF), high frequency power (HF), and the ratio of LF to HF (LF/HF); and (ii) time domain measurements: standard deviation of NN interval (SDNN), and the root mean square of successive NN interval differences (RMSSD).

Table 1. Participants characteristics (n=59).

Parameter	Category	n (%)
Gender	Women	41 (69.5)
Age [mean (min; max)]		29 (19;49)
Education	University degree	56 (94.9)
Perceived household income	Feeling comfortable	30 (50.9)
Marital status	Married, couple or civil union	21 (35.6)
Residential access natural spaces (blue and/or green)	Yes	10 (17.0)
Views blue spaces at work	Yes	52 (88.1)
Access private open space	Yes	37 (62.7)
Blue space exposure during childhood	Yes	49 (83.1)
Meeting physical activity WHO guidelines[a]	Yes	53 (89.8)
BMI (kg/m^2) [mean (min; max)]		22.6 (17.1; 35.1[b])

[a]WHO guidelines recommend to the adult population to do at least 150 minutes of moderate-intensity physical activity, or 75 minutes of vigorous-intensity physical activity throughout the week, or an equivalent combination of moderate- and vigorous-intensity activity (World Health Organization, 2018a). In this case, this variable refers to the self-reported physical activity conducted during the last 7 days (assessed with the Background questionnaire, at T0, and considered as the baseline measure of self-reported physical activity).

BMI: body mass index. SBP: Systolic blood pressure. DBP: Diastolic blood pressure.

[b]Although the maximum value of BMI was 35.5 kg/m^2, among the whole study sample there was only one subject with BMI>30 kg/m^2 (corresponding to Obesity Class I according to WHO (WHO Regional Office for Europe, 2019)). And six subjects had a BMI between 25 and 29.9 kg/m^2 (corresponding to Pre-obesity according to WHO (WHO Regional Office for Europe, 2019)). A sensitivity analysis excluding subjects whose BMI>25 kg/m^2 was conducted, showing similar results than those reported in Table 3 (data not shown).

Table 2. Descriptive statistics of well-being and mood variables.

	Exposure			
	Control	**Blue**	**Urban**	**p-value**
Subjective well-being (SWB) [%]				
PRE Exposure (T1)				
Yesterday I felt happy	61.0	52.5	59.3	0.62
Yesterday I felt anxious	23.7	27.1	27.1	0.89
POST exposure (T3)				
Yesterday I felt happy	47.5	48.3	44.1	0.89
Yesterday I felt anxious	49.2	37.9	42.4	0.47
WHO-5 Well-being [%]				
I have felt cheerful and in good spirits (yes)	29.0	44.9	26.2	<0.01*
I have felt calm and relaxed (yes)	35.9	42.7	21.4	<0.01*
I have felt active and vigorous (yes)	15.2	52.2	32.6	<0.01*
I woke up feeling fresh and rested (yes)	31.5	37.0	31.5	0.63
My daily life has been filled with things that interest me (yes)	32.4	36.0	31.5	0.52
Total Well-being Score [a] [mean (std.dev.)]	47.9 (18.3)	63.2 (15.7)	47.1 (19.7)	<0.01*
Total Mood Disturbance (TMD) [mean (std.dev.)]				
PRE Exposure (T1)				
Tension/Anxiety[b] (TA)	4.4 (3.2)	4 (2.4)	4.4 (3.8)	0.56
Depression[b] (D)	0.9 (2.2)	0.8 (2.2)	1 (2.8)	0.73
Anger/Hostility[b] (AH)	1 (2.3)	0.8 (2.3)	1.4 (3.3)	0.16
Fatigue[c] (F)	1.5 (2.3)	1.4 (2.3)	1.9 (3)	0.93
Vigour[b] (V)	9.6 (5.4)	9.9 (5.6)	9.6 (5.2)	0.94
Total score POMS[d]	98.3 (10.4)	97.3 (9.6)	99.1 (12.2)	0.57
POST exposure (T3)				
Tension/Anxiety[b] (TA)	4.4 (2.6)	3.9 (2)	4.6 (3)	0.23
Depression[b] (D)	1 (2.2)	0.7 (2.2)	0.7 (1.9)	0.09
Anger/Hostility[b] (AH)	1.1 (2.7)	0.5 (1.5)	1.4 (2.7)	<0.01*
Fatigue[c] (F)	1.9 (2.3)	1 (1.6)	1.6 (2.5)	<0.01*

Vigour[b] (V)	7 (5)	11.3 (5.7)	10 (5)	<0.01*
Total score POMS[d]	101.4 (9.7)	94.8 (8.7)	98.4 (10.1)	<0.01*
No somatisation index[e] [mean (std.dev.)]	40.4 (2.6)	40.7 (2.5)	40.2 (3.5)	0.35
Vitality and mental health (SF36) [mean (std.dev.)]				
Vitality[f]	62.9 (18.5)	67.9 (18.4)	63.2 (19.3)	0.02*
Mental health[f]	64.7 (19.2)	69.1 (18.3)	65.6 (19.1)	0.04*
Sleep characteristics[g] (last night) (T1) [%]				
Sleep latency ("Fall asleep easily")	84.4	85.7	76.8	0.03
Sleep disturbance ("Restless and disturbed")	24.1	25.6	25.4	0.93
"Wake up earlier than usual"	21.4	29.2	25.0	0.17
Sleep quality ("Sleep well")	79.5	79.8	78.5	0.94
Sleep duration ("Short time sleeping (<7h)")	33.0	35.9	34.7	0.82
General health (good) [%]				
PRE exposure (T1)	93.22	91.53	91.53	0.93
POST exposure (T3)	86.44	91.38	93.22	0.44
Life satisfaction [mean (std.dev.)]				
PRE exposure (T1)	7.4 (1.4)	7.3 (1.4)	7.2 (1.4)	0.56
POST exposure (T3)	7.4 (1.3)	7.3 (1.4)	7.2 (1.6)	0.94
Eudaimonic well-being [mean (std.dev.)]				
PRE exposure (T1)	7.1 (1.6)	7.2 (1.4)	7.2 (1.6)	0.92
POST exposure (T3)	7.2 (1.4)	7.3 (1.5)	6.9 (1.7)	0.40

To assess statistically significant outcomes' differences between exposures, we conducted Kruskal-Wallis tests for continuous dependent variables, and chi-square or Fisher's exact tests for categorical dependent variables. We used a 0.05 level of significance (with an * showing statistically significant results).

[a]Score ranging from 0 to 100, illustrating the worst and best scenario, respectively.

[b]Score ranging from 0 "Not at all" to 24 "Very much".

[c]Score ranging from 0 "Not at all" to 20 "Very much".

[d]Lower score indicates better mental health.

[e]Minimal potential score was 9 (representing the highest somatisation index), and maximum potential score was 45 (representing the lowest somatisation index).
[f]Score ranging from 0 (representing low vitality and mental health) to 100 (representing high vitality and mental health).
[g]Sleep characteristics categories have been defined according to The Pittsburgh Sleep Quality Index (PSQI) (Buysse et al.. 1988).

Table 3. Association between environments of exposures (i.e. control, blue, urban) and well-being and mood (analysis scenario 1 and 2)[a]

	Exposure (analysis scenario 1)			Exposure (analysis scenario 2)	
	Control	**Blue**	**Urban**	**Urban**	**Blue**
	ref.	IRR[b] (95% CI)	IRR[b] (95% CI)	ref.	IRR[b] (95% CI)
Subjective well-being (SWB)					
Yesterday I felt happy	ref.	1.20 (0.52, 2.73)	0.93 (0.41, 2.13)	ref.	1.38 (0.62, 3.06)
Yesterday I felt anxious	ref.	0.55 (0.23, 1.29)	0.67 (0.28, 1.58)	ref.	0.78 (0.28, 2.16)
WHO-5 Well-being					
I have felt cheerful and in good spirits	ref.	1.45 (1.18, 1.80)*	1.00 (0.79, 1.25)	ref.	1.50 (1.22, 1.86)*
I have felt calm and relaxed	ref.	1.11 (0.91, 1.35)	0.70 (0.56, 0.88)*	ref.	1.62 (1.31, 2.01)*
I have felt active and vigorous	ref.	2.46 (1.90, 3.19)*	1.83 (1.39, 2.40)*	ref.	1.38 (1.11, 1.71)*
I woke up feeling fresh and rested	ref.	1.04 (0.82, 1.33)	0.92 (0.71, 1.17)	ref.	1.15 (0.89, 1.47)
My daily life has been filled with things that interest me	ref.	1.09 (0.87, 1.35)	1.01 (0.81, 1.26)	ref.	1.07 (0.82, 1.40)
Total Well-being Score	ref.	1.32 (1.25, 1.38)*	0.99 (0.94, 1.05)	ref.	1.34 (1.27, 1.40)*
Total Mood Disturbance (TMD)					
Tension/Anxiety (TA)	ref.	0.95 (0.86, 1.06)	1.07 (0.97, 1.19)	ref.	0.88 (0.80, 0.98)*
Depression (D)	ref.	0.72 (0.57, 0.91)*	0.82 (0.66, 1.04)	ref.	0.85 (0.66, 1.08)
Anger/Hostility (AH)	ref.	0.51 (0.40, 0.66)*	1.32 (1.09, 1.60)*	ref.	0.36 (0.28, 0.47)*
Fatigue (F)	ref.	0.55 (0.46, 0.66)*	0.80 (0.68, 0.94)*	ref.	0.68 (0.56, 0.82)*
Vigour (V)	ref.	1.61 (1.50, 1.73)*	1.44 (1.34, 1.55)*	ref.	1.12 (1.05, 1.20)*
Total score POMS	ref.	0.94 (0.92, 0.96)*	0.97 (0.95, 0.99)*	ref.	0.97 (0.95, 0.99)*
No somatisation index	ref.	1.01 (0.97, 1.04)	1.00 (0.97, 1.03)	ref.	1.02 (0.86, 1.20)
Vitality and mental health (SF36)					
Vitality	ref.	1.08 (1.06, 1.11)*	1.01 (0.99, 1.04)	ref.	1.07 (1.04, 1.09)*
Mental health	ref.	1.08 (1.05, 1.10)*	1.02 (1.00, 1.05)	ref.	1.05 (1.03, 1.08)*
Sleep characteristics[f] (last night)					
Sleep latency (“Fall asleep easily”)	ref.	2.35 (0.83, 6.65)	0.87 (0.36, 2.11)	ref.	2.61 (0.93, 7.32)
Sleep disturbance (“Restless and disturbed”)	ref.	0.68 (0.29, 1.58)	0.73 (0.32, 1.70)	ref.	0.91 (0.39, 2.14)

"Wake up earlier than usual"	ref.	1.10 (0.47, 2.59)	0.65 (0.26, 1.62)	ref.	1.62 (0.67, 3.91)
Sleep quality ("Sleep well")	ref.	1.71 (0.71, 4.13)	1.15 (0.50, 2.66)	ref.	1.50 (0.62, 3.63)
Sleep duration ("Short time sleeping (<7h)")	ref.	0.65 (0.26, 1.63)	0.34 (0.13, 0.92)*	ref.	1.83 (0.68, 4.96)
General health (good)	ref.	4.49 (0.51, 39.24)	9.17 (0.79, 107.11)	ref.	0.56 (0.07, 4.60)
Life satisfaction	ref.	1.20 (0.34, 4.26)	1.28 (0.35, 4.63)	ref.	0.90 (0.29, 2.76)
Eudaimonic well-being	ref.	1.51 (0.51, 4.47)	0.73 (0.24, 2.20)	ref.	2.18 (0.68, 6.70)

*p-value≤0.05

[a]All the models were adjusted by age, gender, day of the week, and well-being/mood measured at T1 (when this data was available – see Figure 1). Except for *"SWB"*, *"General health"*, *"Life satisfaction"*, and *"Eudaimonic well-being"*, that could not be adjusted by day of the week, because these variables were measured only on the first and last day of each study week, but not the whole days of the study week.

[b]IRR=Incidence Rate Ratio. For dichotomous dependent variables we conducted logistic regression models, reporting odds ratio (OR) instead of IRR. Dichotomous dependent variables were: "*Subjective well-being*", "*Sleep characteristics*", "*General health (good)*", and "*Life satisfaction*".

Table 4. Association between exposure environments (i.e. control, blue, urban) and BP (measured at T3)[a]. BP variables included systolic blood pressure (SBP), diastolic blood pressure (DBP), and pulse rate.

	Analysis scenario 1			Analysis scenario 2	
	Control	**Blue**	**Urban**	**Urban**	**Blue**
		Coef. (95% CI)	Coef. (95% CI)		Coef. (95% CI)
SBP	ref.	1.16 (0.45, 1.87)*	1.27 (0.57, 1.98)*	ref.	-0.09 (-0.82, 0.65)
DBP	ref.	0.39 (-0.09, 0.88)	0.20 (-0.28, 0.67)	ref.	0.22 (-0.27, 0.70)
Pulse rate	ref.	2.08 (1.48, 2.67)*	1.87 (1.27, 2.46)*	ref.	0.21 (-0.39, 0.81)

[a]Models adjusted by: age, gender, body mass index (BMI), days of the week, and BP measured at T1.
*Statistically significant (p-value≤0.05)

Table 5. Association between exposure environments (i.e. control, blue, urban) and logarithmic HRV variables. HRV variables included (i) frequency domain measurements: heart rate (HR), low frequency power (LF), high frequency power (HF), and the ratio of LF to HF (LF/HF); and (ii) time domain measurements: standard deviation of NN interval (SDNN), and the root mean square of successive NN interval differences (RMSSD).

		Analysis scenario 1			Analysis scenario 2	
		Control	**Blue**	**Urban**	**Urban**	**Blue**
	Time period[a]		Coef. (95% CI)	Coef. (95% CI)		Coef. (95% CI)
Ln(HR)	T1	ref.	0.021 (0.006, 0.037)*	0.025 (0.010, 0.041)*	ref.	-0.004 (-0.021, 0.013)
	T2	ref.	0.363 (0.347, 0.379)*	0.369 (0.353, 0.384)*	ref.	-0.005 (-0.022, 0.011)
	T3	ref.	0.072 (0.056, 0.088)*	0.077 (0.061, 0.093)*	ref.	-0.005 (-0.021, 0.012)
Ln(LF)	T1	ref.	-0.009 (-0.112, 0.094)	-0.009 (-0.111, 0.095)	ref.	-0.007 (-0.117, 0.103)
	T2	ref.	-1.390 (-1.493, 1.288)*	-1.230 (-1.333, -1.127)*	ref.	-0.167 (-0.277, -0.057)*
	T3	ref.	-0.295 (-0.398, -0.193)*	-0.341 (-0.445, -0.238)*	ref.	0.039 (-0.070, 0.149)
Ln(HF)	T1	ref.	-0.047 (-0.177, 0.083)	-0.057 (-0.188, 0.074)	ref.	0.003 (-0.136, 0.142)
	T2	ref.	-2.276 (-2.406, -2.146)*	-2.059 (-2.190, -1.929)*	ref.	-0.224 (-0.363, -0.085)*
	T3	ref.	-0.415 (-0.545, -0.285)*	-0.425 (-0.555, -0.294)*	ref.	0.003 (-0.136, 0.141)
Ln(LF/HF)	T1	ref.	0.045 (-0.042, 0.132)	0.056 (-0.031, 0.144)	ref.	-0.012 (-0.104, 0.080)
	T2	ref.	0.980 (0.892, 1.067)*	0.884 (0.796, 0.971)*	ref.	0.095 (0.003, 0.187)*
	T3	ref.	0.125 (0.038, 0.212)*	0.088 (0.001, 0.176)*	ref.	0.036 (-0.056, 0.128)
Ln(SDNN)	T1	ref.	0.042 (-0.010, 0.095)	0.065 (0.012, 0.118)*	ref.	-0.027 (-0.084, 0.029)
	T2	ref.	-0.537 (-0.589, -0.484)*	-0.480 (-0.533, -0.427)*	ref.	-0.061 (-0.118, -0.004)*
	T3	ref.	0.001 (-0.051, 0.054)	0.001 (-0.051, 0.054)		-0.004 (-0.061, 0.052)
Ln(RMSSD)	T1	ref.	-0.028 (-0.099, 0.043)	-0.038 (-0.110, 0.033)	ref.	0.005 (-0.072, 0.082)
	T2	ref.	-0.927 (-0.999, -0.856)*	-0.843 (-0.914, -0.771)*	ref.	-0.090 (-1.167, -0.013)*
	T3	ref.	-0.259 (-0.330, -0.188)*	-0.232 (-0.304, -0.160)*	ref.	-0.032 (-0.109, 0.045)

[a]Time period refers to the moment when the HRV parameters were measured. Time=1 (T1): pre-exposure; Time=2 (T2): during exposure; Time=3 (T3): post-exposure (see Figure 1)
Models adjusted by: age, gender, body mass index (BMI), and days of the week (see Table S2 – Supplementary Material).
*Statistically significant (p-value≤0.05)

Supplementary Material

Paper III

Supplementary Material

Physical and mental health effects of repeated short walks in a blue space environment: a randomised crossover study

Cristina Vert, Mireia Gascon, Otavio Ranzani, Sandra Márquez, Margarita Triguero-Mas, Glòria Carrasco-Turigas, Lourdes Arjona, Sarah Koch, Maria Llopis, David Donaire-Gonzalez, Lewis R. Elliott, Mark Nieuwenhuijsen

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Figure S1. Control site. Participants sit on the deckchair during 20 minutes per day the week they were randomly assigned to the control exposure (i.e. the study room). Photo taken by: Cristina Vert, October 2017.

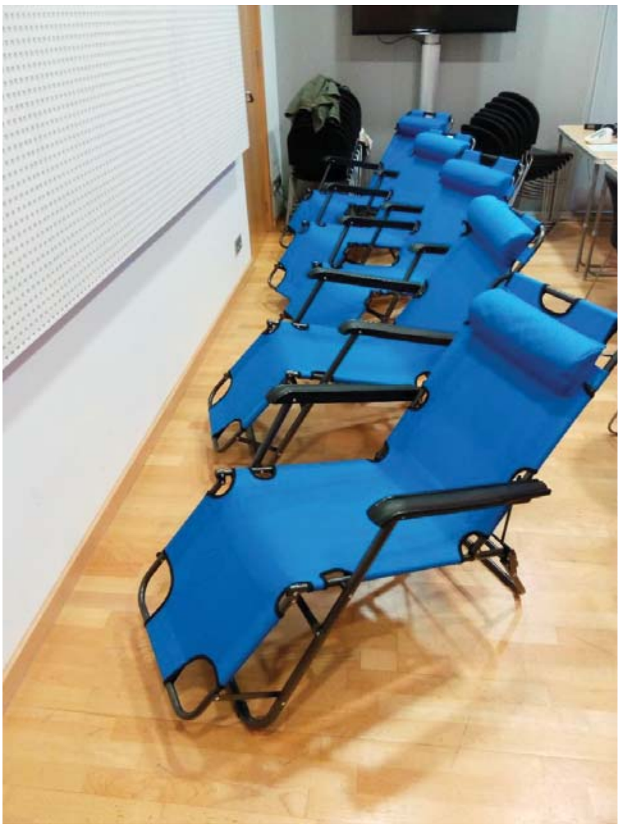

Table S1. Detailed description of the environments of exposure.

Exposure environments	Description
Blue Space	Participants walked from PRBB building (*Carrer del Dr. Aiguader, 88, 08003 Barcelona*) to the beach (*Platja del Somorrostro*) along the seaside walking path upstairs. In about 600 meters, they turned to the left and went downstairs to the breakwater called *Espigó de Gas*. Participants went back to study room following the same route. Route took 20 minutes.
Urban space	Participants walked from PRBB building (*Carrer del Dr. Aiguader, 88, 08003 Barcelona*) to go across an urban park (*Parc de les Cascades*), and turn to the left to walk along the sidewalk next to a road with a lane for buses and taxis, and another lane for other motorized vehicles (*Carrer del Dr. Aiguader)*. In the sidewalk there is also a bicycle lane. Participants went back to the study room following the same route. Route took 20 minutes.
Control	Participants rested for 20 minutes in the study room, at PRBB, on comfortable deck chairs so they were able to relax. They were asked not to use their mobile phones, talk to each other, work or read. They were always supervised by at least one researcher.

Table S2. Description of the co-variables.

Variable	**Description**
Age*	Range from 19 to 49 years old.
Gender*	Women and men.
Education level*	Participants' own educational level according to whether they had completed primary education, secondary education, or higher education.
Income level*	Participants' own perception according to whether they felt comfortable or not regarding their household income.
Civil status*	Participants' civil status
Residential access natural spaces*	Access to green and/or blue space within 10-15 minutes' walk from participants' home.
Views blue spaces at work*	Blue spaces views from either participants' office, when commuting, and during lunch-time (labour days).
Residential access private open space*	Participants' access to a private open space (e.g. terrace, garden, vegetable garden...).
Exposure blue spaces during childhood*	Participants' usual exposure to blue spaces during childhood.
Meeting physical activity guidelines*	According to participants' physical activity (PA) levels (measured in METs), compliance or not of WHO PA guidelines: WHO guidelines recommend to the adult population to do at least 150 minutes of moderate-intensity physical activity, or 75 minutes of vigorous-intensity physical activity throughout the week, or an equivalent combination of moderate- and vigorous-intensity activity (World Health Organization 2018).
Temperature	Average background temperature (ºC) for each study week. It was measures in the *Zoo* station (41.386261, 2.190526) by the *Servei Meteorològic de Catalunya* (Generalitat de Catalunya).
Relative humidity	Average background relative humidity (%) for each study week. It was measures in the *Zoo* station (41.386261, 2.190526) by the *Servei Meteorològic de Catalunya* (Generalitat de

	Catalunya).
BMI**	Body mass index assessed with the average height and weight measured at the beginning and the end of the study period.
Order	All the possible order of exposure to the different exposure environments (blue, urban, control).
Air pollution	Average NO_2 (mg/m^3) and average O_3 (mg/m^3) for each study week. It was measured in the *Ciutadella* station (41.3885, 2.1871) by Barcelona local authorities.
Season	Any of the two different study periods of 3 non-necessarily consecutive weeks each (1st period: April – May 2017; 2nd period: September – October 2017).
Turn	Any of the two different turns when participants could participate in the study: 1st turn (10.00am) or 2nd turn (11.30am).
Days of the week	Days of the study week, from Monday to Thursday. Some study weeks also included Friday as an exception. This occurred when a participant could not attend someday from Monday to Thursday, then he/she was rescheduled on Friday of the same week.

*These variables were collected with the Background questionnaire (T0).

**Mean BMI was calculated with the participants' height and weight measured at T0 and again upon the completion of the study. It was measured in the study room by trained researchers.

Table S3. Assessment of the quality of the route, for the blue and the urban environments (N=59).

Assessment variables	**Exposure**		
	Blue	**Urban**	**p-value***
Felt uncomfortable because of:			
Air pollution (%)	27	85	<0.01
Noise (%)	15	75	<0.01
People (%)	41	44	<0.01
Quality of the route			
Bad (%)	0	29	
Regular (%)	7	40	<0.01
Good (%)	93	31	
Felt satisfied walking along the route (%)	95	40	<0.01
Felt safe (i.e. no danger) walking along the route (%)	95	74	<0.01
There was no rubbish/vandalism along the route (%)	79	62	0.04

*pvalues were estimated using chi-square or Fisher's exact test.

Table S4. Association between environments of exposures (i.e. control, blue, urban) and "WHO-5 well-being", TMD, and vitality and mental health, stratified by "General health" (good/not good)[a].

S4.1. Analysis scenario 1 (ref.=control).

	General health = "Good"			General health = "Not good"		
	Control	**Blue**	**Urban**	**Control**	**Blue**	**Urban**
	ref.	IRR[b] (95% CI)	IRR[b] (95% CI)	ref.	IRR[b] (95% CI)	IRR[b] (95% CI)
WHO-5 well-being						
Total Well-being Score	ref.	1.29 (1.23, 1.36)*	0.97 (0.92, 1.02)	ref.	1.62 (1.32, 1.99)*	1.20 (0.95, 1.51)
Total Mood Disturbance (TMD)						
Total score POMS	ref.	0.95 (0.91, 0.99)*	0.97 (0.93, 1.00)	ref.	0.91 (0.81, 1.02)	0.98 (0.87, 1.10)
Vitality and mental health (SF36)						
Vitality	ref.	1.07 (1.02, 1.12)*	1.01 (0.96, 1.06)	ref.	1.28 (1.09, 1.49)*	1.06 (0.90, 1.26)
Mental health	ref.	1.08 (1.03, 1.13)*	1.03 (0.98, 1.07)	ref.	1.05 (0.89, 1.25)	0.94 (0.78, 1.14)

S4.2. Analysis scenario 2 (ref.=urban).

	General health = "Good"		General health = "Not good"	
	Urban	**Blue**	**Urban**	**Blue**
	ref.	IRR[b] (95% CI)	ref.	IRR[b] (95% CI)
WHO-5 well-being				
Total Well-being Score	ref.	1.34 (1.27, 1.41)*	ref.	1.49 (1.17, 1.88)*
Total Mood Disturbance (TMD)				
Total score POMS	ref.	0.98 (0.94, 1.02)	ref.	0.95 (0.82, 1.07)
Vitality and mental health (SF36)				
Vitality	ref.	1.06 (1.01, 1.11)*	ref.	1.27 (1.04, 1.54)*
Mental health	ref.	1.05 (1.00, 1.10)*	ref.	1.17 (0.93, 1.45)

[a]For this analysis we only used "General health" assessed at T3 (and not at T1) because this is a trait measure and barely changed from T1 to T3.

Table S5. Association between exposure environments (i.e. control, blue, or urban space) and Total Well-being Score, stratified by gender (analysis scenario 1)[a,b]

	Exposure				
	Control	Blue		Urban	
	ref.	IRR (95% CI)		IRR (95% CI)	
		Women	Men	Women	Men
Positive quality-of-life currently					
Total Well-being Score	ref.	1.35 (1.27, 1.43)*	1.25 (1.15, 1.37)*	1.03 (0.97, 1.10)	0.88 (0.80, 0.97)*

[a]Analysis scenario 2 is not shown because likelihood-ratio test did not indicate significant interaction for any variable for this analysis scenario.
[b]Models were adjusted by age, and days of the week.

Table S6. Descriptive analysis of SBP (mmHg), DBP (mmHg), and Pulse rate (bpm) [median (IQR)] by exposure environments (i.e. control, blue and urban space). Within each environment, we used the Wilcoxon signed rank sum test with Bonferroni-adjustment for multiple comparisons to assess whether the distribution of BP measured at T1 (ref. value) was significantly different (p-value ≤0.05*) than BP measured at T3.

	Time period[b]	**Control**	Difference T3-T1[a]	**Blue**	Difference T3-T1 [a]	**Urban**	Difference T3-T1 [a]
SBP (mmHg)	**T1**	97 (92.1, 106.5)	0.4*	99.5 (91.7, 105.8)	-0.6	99.1 (92.6, 105.3)	-1.3
[median (IQR)]	**T3**	97.4 (91.7, 103.8)		98.9 (91.2, 107.3)		97.8 (92.1, 105.8)	
DBP (mmHg)	**T1**	65.1 (61.2, 70.0)	0.2	65.6 (62.0, 71.0)	0.8	65.1 (61.9, 71.3)	1.1
[median (IQR)]	**T3**	65.3 (61.3, 69.0)		66.4 (62.2, 70.4)		66.2 (61.9, 74.2)	
Pulse rate (bpm)	**T1**	66.2 (58.5, 71.9)	-2.1*	67.2 (58.8, 73.9)	0.5	66.3 (61.1, 74.2)	-0.7
[median (IQR)]	**T3**	64.1 (57.9, 69.3)		67.7 (59.4, 74.8)		65.6 (60.8, 73.8)	

[a]Difference between T3 and T1 measurements of SBP, DBP, and pulse rate.
[b]Time period refers to the moment when BP and pulse rate were measured. Time=1 (T1): pre-exposure; Time=3 (T3): post-exposure (see Figure 1).

Table S7. Association between exposure environments (i.e. control, blue, urban) and blood pressure and pulse rate. **Crude model.**

	Analysis scenario 1			**Analysis scenario 2**	
	Control	**Blue**	**Urban**	**Urban**	**Blue**
		Coef. (95% CI)	Coef. (95% CI)		Coef. (95% CI)
SBP	ref.	1.08 (1.19, 1.97)*	1.11 (0.22, 2.00)*	ref.	-0.01 (-1.04, 1.02)
DBP	ref.	0.26 (-0.28, 0.80)	0.07 (-0.46, 0.61)	ref.	0.20 (-0.32, 0.71)
Pulse rate	ref.	2.06 (1.30, 2.81)*	1.79 (1.04, 2.55)*	ref.	0.28 (-0.38, 0.93)

Crude analysis (only adjusted by BP measured at T1)
*Statistically significant (p-value≤0.05)
SBP: Systolic blood pressure. DBP: Diastolic blood pressure

Table S8. Association between exposure environments (i.e. control, blue, urban) and BP (measured at T3)[a]. BP variables included systolic blood pressure (SBP), diastolic blood pressure (DBP), and pulse rate. **Models adjusted by physical activity** [(A) Mean VM[b] recorded at T2, i.e. during the exposure; and (B) Weekly mean VM[b]].

	Analysis scenario 1			Analysis scenario 2	
	Control	**Blue**	**Urban**	**Urban**	**Blue**
		Coef. (95% CI)	Coef. (95% CI)		Coef. (95% CI)
A) Adjusted by VM at T2					
SBP	ref.	1.41 (-0.32, 3.14)	1.39 (-0.35, 3.14)	ref.	0.04 (-0.74, 0.82)
DBP	ref.	-0.04 (-1.19, 1.11)	-0.33 (-1.48, 0.82)	ref.	0.29 (-0.22, 0.80)
Pulse rate	ref.	1.27 (-0.19, 2.72)	0.90 (-0.56, 2.36)	ref.	0.40 (-0.23, 1.02)
B) Adjusted by weekly VM					
SBP	ref.	1.12 (0.40, 1.84)*	1.11 (0.37, 1.84)*	ref.	0.02 (-0.75, 0.78)
DBP	ref.	0.53 (0.05, 1.00)	0.20 (-0.28, 0.69)	ref.	0.30 (-0.18, 0.79)
Pulse rate	ref.	2.20 (1.59, 2.80)*	1.77 (1.16, 2.38)*	ref.	0.39 (-0.23, 1.01)

[a]Models adjusted by: age, gender, body mass index (BMI), the days of the week, blood pressure measured at T1, and physical activity (VM at T2, and weekly VM).
[b]VM: vector magnitude.
*Statistically significant (p-value≤0.05)

Table S9. Descriptive analysis of physical activity levels [mean (sd)] quantitatively measured at T2, and during the whole study week.

Physical activity levels	Exposure environments			p-value
	Control	**Blue**	**Urban**	
VM at T2 (counts/min)	-	941.48 (180.51)	938.92 (177.98)	0.90
Weekly VM (counts/min)	518.99 (161.84)	534.75 (173.19)	523.05 (523.05)	0.69

We used Kruskall Wallis test (with a statistically significant p-value≤0.05) to assess differences in the means of physical activity levels between exposure environments.

Table S10. Descriptive analysis of HRV variables [median (IQR)] by exposure environments (i.e. control, blue and urban space). Within each environment, we used the Wilcoxon signed rank sum test with Bonferroni-adjustment for multiple comparisons to assess whether the distribution of HRV variables measured at T1 (ref. value) was significantly different (p-value ≤0.05*) than for HRV variables measured at T2 and measured at T3.

	Time period[a]	**Control**	Difference T2-T1 and T3-T1	**Blue**	Difference T2-T1 and T3-T1	**Urban**	Difference T2-T1 and T3-T1
Frequency-domain							
HR (bpm) [median (IQR)]	T1	69.5 (61.3, 77.9)		71.8 (63.8, 79.7)		73.2 (65.2, 79.9)	
	T2	65.7 (58.2, 72.4)	-3.8*	93.6 (85.8, 102.2)	21.8*	93.9 (83.2, 103.7)	20.7*
	T3	69.0 (60.8, 74.3)	-0.5*	74.2 (66.3, 81.6)	2.4	73.1 (64.7, 81.4)	-0.1
LF (ms^2) [median (IQR)]	T1	428.8 (226.4, 786.8)		418.5 (261.2, 630.2)		420.3 (229.5, 701.0)	
	T2	430.0 (270.6, 744.7)	-345.2	124.2 (72.4, 234.7)	-294.3*	173.6 (80.2, 337.9)	-246.7*
	T3	513.6 (320.8, 1026.5)	84.8*	411.0 (252.7, 676.0)	-7.5	443.2, 215.0, 621.7)	22.9
HF (ms^2) [median (IQR)]	T1	180.0 (86.3, 383.6)		187.4 (74.1, 350.7)		177.6 (81.6, 371.7)	
	T2	231.2 (115.9, 586.2)	51.2*	31.9 (18.5, 73.0)	-155.5*	50.0 (19.5, 100.4)	-127.6*
	T3	217.9 (110.6, 474.3)	37.9*	159.9 (70.2, 301.0)	-27.5*	145.9 (86.4, 353.9)	-31.7
LF/HF (%) [median (IQR)]	T1	2.35 (1.7, 4.0)		2.6 (1.8, 4.2)		2.7 (2.1, 4.4)	
	T2	1.90 (1.3, 2.9)	-0.45*	4.8 (3.4, 6.3)	2.2*	4.5 (3.1, 6.4)	1.8*
	T3	2.80 (1.8, 4.3)	0,45	2.9 (2.0, 4.7)	0.3*	3.1 (1.9, 5.2)	0.4*
Time-domain							
SNDD (ms) [median (IQR)]	T1	83.1 (67.6, 105.7)		88.6 (68.2, 106.6)		91.8 (70.6, 106.2)	
	T2	93.8 (73.4, 122.7)	10,7*	57.9 (46.3, 74.3)	-30.7*	62.1 (47.8, 85.3)	-29.7*
	T3	92.1 (73.5, 114.7)	9*	90.4 (74.1, 115.9)	1.8	92.2 (73.8, 118.3)	0.4
RMSSD (ms) [median (IQR)]	T1	45.9 (29.5, 64.0)		43.5 (29.1, 59.3)		44.1 (28.8, 60.6)	
	T2	53.1 (35.6, 82.5)	7.2*	23.9 (15.9, 35.1)	-19.6*	27.7 (17.1, 44.6)	-16.4*
	T3	47.4 (33.5, 71.0)	1.5*	39.5 (30.4, 50.9)	-4*	41.5 (28.5, 55.4)	-2.6

[a]Time period refers to the moment when the HRV parameters were measured. Time=1 (T1): pre-exposure; Time=2 (T2): during exposure; Time=3 (T3): post-exposure (see Figure 1)

Table S11. Interactions p-values between exposure environment and study period. P-value of the likelihood ratio test comparing the model with and without the interaction term.

HRV parameters	**p-value**	
	Analysis scenario 1	Analysis scenario 2
HR	<0.001	0.993
LF	<0.001	0.023
HF	<0.001	0.031
LF/HF	<0.001	0.265
SDNN	<0.001	0.371
RMSSD	<0.001	0.225

Table S12. Association between exposure environments (i.e. control, blue, urban) and logarithmic HRV variables. HRV variables included (i) frequency domain measurements: heart rate (HR), low frequency power (LF), high frequency power (HF), and the ratio of LF to HF (LF/HF); and (ii) time domain measurements: standard deviation of NN interval (SDNN), and the root mean square of successive NN interval differences (RMSSD). **Crude model.**

		Analysis scenario 1			Analysis scenario 2	
		Control	**Blue**	**Urban**	**Urban**	**Blue**
	Time period[a]		Coef. (95% CI)	Coef. (95% CI)		Coef. (95% CI)
Ln(HR)	T1	ref.	0.019 (0.003, 0.034)*	0.022 (0.007, 0.038)*	ref.	-0.002 (-0.018, 0.014)
	T2	ref.	0.360 (0.345, 0.376)*	0.366 (0.350, 0.381)*	ref.	-0.004 (-0.020, 0.012)
	T3	ref.	0.069 (0.054, 0.084)*	0.074 (0.059, 0.090)*	ref.	-0.004 (-0.020, 0.013)
Ln(LF)	T1	ref.	0.001 (-0.100, 0.102)	0.009 (-0.093, 0.111)	ref.	-0.017 (-0.126, 0.092)
	T2	ref.	-1.373 (-1.475, 1.272)*	-1.191 (-1.293, -1.089)*	ref.	-0.191 (-0.301, -0.082)*
	T3	ref.	-0.304 (-0.406, -0.203)*	-0.337 (-0.439, -0.235)*	ref.	0.024 (-0.086, 0.133)
Ln(HF)	T1	ref.	-0.038 (-0.166, 0.089)	-0.046 (-0.174, 0.083)	ref.	-0.004 (-0.142, 0.134)
	T2	ref.	-2.257 (-2.385, -2.130)*	-2.023 (-2.150, -1.893)*	ref.	-0.247 (-0.385, -0.109)*
	T3	ref.	-0.411 (-0.539, -0.284)*	-0.416 (-0.545, -0.287)*	ref.	-0.007 (-0.145, 0.131)
Ln(LF/HF)	T1	ref.	0.047 (-0.039, 0.133)	0.062 (-0.025, 0.149)	ref.	-0.013 (-0.105, 0.078)
	T2	ref.	0.976 (0.890, 1.062)*	0.886 (0.799, 0.973)*	ref.	0.092 (0.000, 0.184)*
	T3	ref.	0.113 (0.027, 0.199)*	0.084 (-0.003, 0.171)*	ref.	0.031 (-0.061, 0.122)
Ln(SDNN)	T1	ref.	-0.045 (-0.006, 0.097)	0.066 (0.014, 0.119)*	ref.	-0.026 (-0.082, 0.031)
	T2	ref.	-0.534 (-0.585, -0.482)*	-0.469 (-0.522, -0.417)*	ref.	-0.069 (-0.125, -0.013)*
	T3	ref.	0.001 (-0.050, 0.053)	0.003 (-0.049, 0.055)		-0.006 (-0.062, 0.051)
Ln(RMSSD)	T1	ref.	-0.021 (-0.091, 0.049)	-0.032 (-0.102, 0.039)	ref.	0.003 (-0.074, 0.080)
	T2	ref.	-0.920 (-0.990, -0.850)*	-0.819 (-0.890, -0.748)*	ref.	-0.108 (-0.185, -0.031)*

T3	ref.	-0.255 (-0.325, -0.185)*	-0.227 (-0.297, -0.156)*	ref.	-0.036 (-0.113, 0.041)

[a]Time period refers to the moment when the HRV parameters were measured. Time=1 (T1): pre-exposure; Time=2 (T2): during exposure; Time=3 (T3): post-exposure (see Figure 1)

*Statistically significant (p-value≤0.05)

Table S13. Association between exposure environments (i.e. control, blue, urban), and logarithmic HRV variables. HRV variables included (i) frequency domain measurements: heart rate (HR), low frequency power (LF), high frequency power (HF), and the ratio of LF to HF (LF/HF); and (ii) time domain measurements: standard deviation of NN interval (SDNN), and the root mean square of successive NN interval differences (RMSSD). **Models adjusted by physical activity** [(A) Mean VM[b] recorded at T2, i.e. during the exposure; and (B) Weekly mean VM[b]].

		Analysis scenario 1			Analysis scenario 2	
		Control	**Blue**	**Urban**	**Urban**	**Blue**
	Time period[a]		Coef. (95% CI)	Coef. (95% CI)		Coef. (95% CI)
A) Adjusted by VM at T2						
Ln(HR)	T1	ref.	0.021 (0.005, 0.036)*	0.026 (0.010, 0.041)*	ref.	-0.005 (-0.021, 0.012)
	T2	ref.	0.306 (0.270, 0.342)*	0.308 (0.271, 0.344)*	ref.	-0.003 (-0.020, 0.015)
	T3	ref.	0.072 (0.056, 0.087)*	0.077 (0.062, 0.093)*	ref.	-0.005 (-0.022, 0.011)
Ln(LF)	T1	ref.	-0.004 (-0.102, 0.095)	-0.006 (-0.105, 0.093)	ref.	-0.001 (-0.107, 0.104)
	T2	ref.	-0.905 (-1.132, -0.679)*	-0.731 (-0.961, -0.501)*	ref.	-0.177 (-0.288, -0.067)*
	T3	ref.	-0.290 (-0.388, 0.191)*	-0.339 (-0.438, -0.240)*	ref.	0.045 (-0.059, 0.150)
Ln(HF)	T1	ref.	-0.038 (-0.162, 0.087)	-0.054 (-0.179, 0.071)	ref.	0.012 (-0.120, 0.144)
	T2	ref.	-1.494 (-1.780, -1.207)*	-1.271 (-1.561, -0.980)*	ref.	-0.224 (-0.364, -0.085)*
	T3	ref.	-0.406 (-0.531, -0.282)*	-0.422 (-0.547, -0.297)*	ref.	0.011 (-0.121, 0.143)
Ln(LF/HF)	T1	ref.	0.042 (-0.045, 0.128)	0.056 (-0.0.31, 0.142)	ref.	-0.015 (-0.106, 0.077)
	T2	ref.	0.644 (0.446, 0.842)*	0.550 (0.348, 0.751)*	ref.	0.092 (-0.005, 0.188)
	T3	ref.	0.122 (0.0.036, 0.208)*	0.088 (0.001, 0.174)	ref.	0.034 (-0.058, 0.125)
Ln(SDNN)	T1	ref.	0.045 (-0.006, 0.096)	0.065 (0.014, 0.117)*	ref.	-0.023 (-0.078, 0.032)
	T2	ref.	-0.325 (-0.441, -0.207)*	-0.244 (-0.363, -0.125)*	ref.	-0.078 (-0.136, -0.020)*
	T3	ref.	-0.004 (-0.047, 0.055)	0.002 (-0.049, 0.0537)		-0.000 (-0.055, 0.054)
Ln(RMSSD)	T1	ref.	-0.024 (-0.092, 0.044)	-0.037 (-0.105, 0.032)	ref.	0.009 (-0.064, 0.082)
	T2	ref.	-0.532 (-0.689, -0.376)*	-0.443 (-0.601, -0.284)*	ref.	-0.088 (-1.165, -0.011)*

	T3	ref.	-0.255 (-0.322, -0.187)*	-0.230 (-0.299, -0.162)*	ref.	-0.028 (-0.101, 0.045)
B) Adjusted by weekly VM						
Ln(HR)	T1	ref.	0.017 (0.001, 0.033)*	0.017 (0.001, 0.034)*	ref.	-0.001 (-0.019, 0.016)
	T2	ref.	0.367 (0.351, 0.383)*	0.369 (0.353, 0.386)*	ref.	-0.004 (-0.021, 0.013)
	T3	ref.	0.073 (0.057, 0.089)*	0.073 (0.057, 0.090)*	ref.	-0.001 (-0.019, 0.016)
Ln(LF)	T1	ref.	0.002 (-0.102, 0.107)	0.014 (-0.093, 0.122)	ref.	-0.013 (-0.127, 0.100)
	T2	ref.	-1.396 (-1.501, -1.291)*	-1.193 (-1.301, -1.086)*	ref.	-0.203 (-0.317, -0.090)*
	T3	ref.	-0.303 (-0.408, -0.198)*	-0.340 (-0.448, -0.232)*	ref.	0.036 (-0.078, 0.150)
Ln(HF)	T1	ref.	-0.030 (-0.161, 0.102)	-0.028 (-0.163, 0.107)	ref.	-0.002 (-0.143, 0.139)
	T2	ref.	-2.29 (-2.425, -2.161)*	-2.047 (-2.182, -1.912)*	ref.	-0.247 (-0.388, -0.105)*
	T3	ref.	-0.417 (-0.549, -0.285)*	-0.405 (-0.540, -0.270)*	ref.	-0.012 (-0.154, 0.129)
Ln(LF/HF)	T1	ref.	0.040 (-0.050, 0.130)	0.049 (-0.043, 0.141)	ref.	-0.010 (-0.105, 0.086)
	T2	ref.	0.995 (0.905, 1.084)*	0.907 (0.815, 0.999)*	ref.	0.087 (-0.008, 0.183)
	T3	ref.	0.118 (0.028, 0.208)*	0.071 (-0.022, 0.163)	ref.	0.047 (-0.049, 0.142)
Ln(SDNN)	T1	ref.	0.044 (-0.010, 0.097)	0.073 (0.018, 0.127)*	ref.	-0.025 (-0.083, 0.033)
	T2	ref.	-0.543 (-0.597, -0.490)*	-0.461 (-0.516, -0.407)*	ref.	-0.078 (-0.136, -0.020)*
	T3	ref.	-0.012 (-0.065, 0.041)	0.012 (-0.042, 0.067)		-0.021 (-0.079, 0.038)
Ln(RMSSD)	T1	ref.	-0.020 (-0.092, 0.051)	-0.020 (-0.094, 0.054)	ref.	0.002 (-0.077, 0.080)
	T2	ref.	-0.937 (-1.001, -0.865)*	-0.829 (-0.903, -0.756)*	ref.	-0.106 (-1.185, -0.027)*
	T3	ref.	-0.267 (-0.339, -0.195)*	-0.226 (-0.300, -0.152)*	ref.	-0.039 (-0.117, 0.040)

[a]Time period refers to the moment when the HRV parameters were measured. Time=1 (T1): pre-exposure; Time=2 (T2): during exposure; Time=3 (T3): post-exposure (see Figure 1)

[b]VM: vector magnitude

Models adjusted by: age, gender, body mass index (BMI), days of the week (see Table S2 – Supplementary Material), and physical activity levels.

*Statistically significant (p-value≤0.05)

1. DISCUSSION

This thesis contributes to the limited evidence on the association between the exposure to blue spaces and health. It provides insights on the use of blue spaces and related infrastructure in urban areas and estimates the impact on health of the use of such infrastructures. According to the thesis' objectives, three studies, with different methodologies each, were conducted. The main results of these studies have been already described and discussed in the results section. In this section, an overall description of the results will be provided, as well as a comprehension discussion of its methodological issues, inputs for future research, and potential implications for public health and policy.

1.1 Main findings and contribution to current knowledge

1.1.1 Impact of blue infrastructures

Blue infrastructure in urban areas (e.g., ornamental fountains, rain gardens, riverside parks, canals, urban wetlands, ponds, etc.) might benefit physical and mental health because of, for example, the ecosystem services, environmental protection, equity, and social inclusion (Andreucci and Russo 2019). However, the evidence is still scarce and not consistent and the effectiveness of these infrastructures in terms of health and health-related economic benefits is not usually assessed.

This thesis presents, for the first time, a comprehension assessment of the health and health-related economic benefits of an urban riverside regeneration project, which in this case was conducted in the Besòs Riverside Park. The analyses conducted in *Paper I* and *Paper II* of this thesis include a combination of a HIA, quantitative systematic observations of the users, and qualitative interviews. This resulted in the following outcomes: the quantification of users in the riverside area, the identification of sociodemographic characteristics, levels of physical activity and the neighbourhood residents' perception of the area. Also, the estimates on health and well-being indirectly related to the exposure to a blue space and the use its related infrastructure. The results emphasize the importance of enabling the access of quality blue spaces in urban areas to promote the health and well-being of the population. Using different methodologies for the same purpose allowed to have holistic view of the study area, the relationship between the area and the population, and its effects on their health and well-being. Findings of this assessment are detailed in the next sub-sections of this thesis.

Recently, the health impacts of an urbanistic redesign of the Llobregat fluvial area, also in the Barcelona Metropolitan Area, were reported (Casajuana Kögel et al. 2020). In particular, this study identified several health impacts, mainly related to environmental, public safety, lifestyle, socioeconomic, and political contexts. In contrast to the HIA conducted in the present thesis (*Paper II*), the study conducted by Casajuana et al. was a prospective non-quantitative HIA and included the involvement of politicians, professionals, and citizens for identifying the health impacts

(Casajuana Kögel et al. 2020). This does not apply in this thesis given that the HIA conducted in *Paper II* was retrospective and it was done once the intervention was already completed. In this case, the assessment of the health impacts of an urban regeneration project provides quantitative health benefit estimates based on the actual use of the area evaluated. Moreover, *Paper II* goes one step further by including an assessment of the health-related economic impacts of an urban riverside regeneration project.

Other studies have evaluated social use and public perceptions about the regeneration of rivers in urban areas, but not the impacts on health (Åberg and Tapsell 2013; Özgüner et al. 2012; Vall-Casas et al. 2019). These studies found that, in general, people consider the rivers as places for leisure and meeting after the intervention, whereas before the intervention those rivers were perceived as polluted and dangerous environments (Åberg and Tapsell 2013; Özgüner et al. 2012; Vall-Casas et al. 2019).

Also, other similar studies have evaluated health impacts of other types of urban regeneration projects different than a riverside park (e.g., vacant lot greening program, regeneration of deprived neighbourhoods, regeneration of a port area, etc.). These studies showed discordance on the results, given that some studies found benefits for health (Branas et al. 2011; Droomers et al. 2016), whereas others found little or no benefits (Mohan et al. 2017; Ruijsbroek et al. 2017), and others reported inconsistent findings (Egan et al. 2015; Serrano et al. 2016; Venegas-Sánchez et al. 2013).

- *The use of blue infrastructures*

Findings of the present thesis suggest that interventions developed to facilitate the access to blue spaces in socioeconomically deprived urban areas promote the use of these natural settings, particularly to users that are usually underrepresented in such environments (e.g., women, children or migrants). This might have a positive impact on the health and well-being of the population and in the reduction of health inequalities.

Accessible blue spaces and related infrastructure in urban areas might promote physical activity and social interactions, which are factors known to promote health and well-being. In *Paper I* of thesis, I found that more than 90% of the users of the Besòs Riverside Park were engaged in moderate or vigorous levels of physical activity. In the post-intervention evaluation, it was observed an increase of the users engaged in sedentary and moderate levels of physical activity, as already reported by other similar studies (Kramer et al. 2017; Schultz et al. 2017). This type of activities seemed to mostly facilitate relaxation and interactions among neighbours, as previously suggested by other studies (Kaźmierczak 2013), enhancing mental health and well-being. Residential proximity and access to parks may facilitate physical activity among residents of the area, even if it is only by providing destinations to which people can walk or cycle. However, park-based physical activity may account only for a small proportion of the total physical activity people conduct (Cohen et al. 2007; Stewart et al. 2018).

- ❖ *Adding qualitative research to quantitative research: self-perception of the blue infrastructure*

In *Paper I* of this thesis, a qualitative approach was included to have a more holistic view of the impacts of an intervention in a blue space in an urban area. The insights provided by the qualitative assessment (e.g., neighbourhood residents' willingness of preserving the fauna and flora of the area), were discussed once the intervention was finished and they might be useful to be considered in future interventions or to modify what is already done, if possible. However, a qualitative assessment like the one conducted in *Paper I* of the present thesis might be especially useful if it is conducted before the design and the implementation of the intervention. Thus, the design of the intervention would consider thoughts, recommendations, and requests of the population, the future users of the renovated area, to make it more effective and successful.

- ❖ *Impact on health and well-being*

Health and well-being impacts related to the blue infrastructure have been quantitatively and qualitatively assessed in the present thesis. Regardless of the methodology and the study design, findings of *Paper I* and *Paper II* of this thesis concluded that the regeneration of blue infrastructures in urban areas might contribute on the promotion of health and well-being of the population.

On the one hand, individual face-to-face interviews conducted in *Paper I* of this thesis revealed that the neighbourhood residents of the

Besòs Riverside Park acknowledged the health and well-being benefits of having the river close to their homes. They highlighted its potential role in restoration, calmness, and enjoyment. On the other hand, in *Paper II* it was estimated an annual reduction of 5-7 deaths, 4-6 cases of diseases (including ischemic heart disease; ischemic stroke; type 2 diabetes; cancers of the colon and breast; and dementia), and 7-11 DALYs among the users of the Besòs Riverside Park associated with the physical activity conducted in the area thanks to its renovation. The range on the estimated morbidity and mortality corresponds to the two different scenarios considered in *Paper II* (i.e., Scenario 1: assumed that 100% of the physical activity in the park was new. Scenario 2: assumed that 50% of the physical activity in the park was new). As already reported on other studies using a HIA approach, health benefits (and health-related economic benefits – described in the next section of this thesis) estimated in *Paper II* were mainly driven by mortality rather than morbidity (Rojas-Rueda et al. 2013; Woodcock et al. 2013).

❖ *Economic impact of blue spaces exposure*

Not only health impacts were considered in this thesis, but also health-related economic impacts, as rarely done before by other similar studies – for exceptions see Taddei et al. 2015. In *Paper II*, the total health-related economic benefits due to the urban riverside regeneration project in the Besòs River were of 15-23 million euros.

Improved health reduces health-care economic costs, for example, because of reductions of absenteeism at work or visits to mental health practitioners (Buckley et al. 2019). Therefore, the conservation and the access provision to quality natural settings in urban areas might reduce costs for the health-care system, as reported in *Paper II*.

6.1.2 Blue spaces and health

Besides the health and well-being impacts related to urban regeneration projects in blue spaces and related infrastructure detailed in the previous section, the present thesis also includes an experimental randomized crossover study (N=59) to evaluate psychological and physiological short-term health effects caused by the direct exposure to blue spaces (*Paper III*). Findings of this study suggest that repeated short walks (20 minutes/day during 4 consecutive days) along blue spaces are significantly associated with improved well-being and mood. However, results do not show significant effects for any of the cardiovascular outcomes assessed in the study (i.e., blood pressure, pulse rate, and HRV parameters). In addition, results of *Paper III* are consistent with other similarly-designed studies, reporting better well-being and mental health outcomes after walking in natural environments (Bielinis et al. 2018; Bratman et al. 2015; Brown et al. 2014; Gidlow et al. 2016; Koselka et al. 2019; Song et al. 2019; Triguero-Mas et al. 2017a). However, the present thesis fills in an important gap by evaluating mental health responses to blue spaces' exposure, as rarely done before (Gidlow et al. 2016; Triguero-Mas et al. 2017b). Findings for the three main health outcomes described in the *Introduction* of this thesis are detailed below.

- *General health*

In this thesis, I did not observe a statistically significant positive association between acute repeated exposure to blue spaces and general health. This health parameter was self-reported by study participants (*Paper III*) every day before and after the exposure (20 minutes' walk) using a single question (*"How is your health in general?"*) from the SF-12 Physical and Mental Health Summary Scales (Ware et al. 1995). In the particular case of *Paper III* of the present thesis, this question might not capture short-term effects of the exposure to blue spaces, but it has a holistic view of the health state of the participants which might not be influenced by the repeated acute exposure to a blue space for 4 consecutive days. In fact, all the studies that have found a statistically significant positive association between exposure to blue spaces (mostly assessed using residential coastal proximity) and self-reported general health, had a cross-sectional (Garrett et al. 2019a, 2019b; Pasanen et al. 2019; Wheeler et al. 2012) or an ecological design (Wheeler et al. 2015), implying a continuous and long-lasting exposure to blue spaces. Hence, this thesis provides evidence on the short-term general health effects of acute repeated exposure to blue spaces for the first time.

❖ *Physical health*

Among all the physical health outcomes that have been suggested to be associated with exposure to blue spaces (see *Introduction*), in this thesis the causal relationship between blue spaces and physical health has been assessed in terms of cardiovascular outcomes. CVDs are a leading cause of mortality worldwide, its association with blue spaces exposure has been scarcely researched and findings are still inconsistent (Brown et al. 2014; Gidlow et al. 2016; Triguero-Mas et al. 2017b).

In the present thesis I did not find a statistically significant association between acute exposure to blue spaces and cardiovascular health. In *Paper III* of this thesis, cardiovascular health was assessed by measuring (i) participants' BP and pulse rate every day before and after the exposure, and (ii) participants' HRV parameters every day before, during, and after the exposure, which resulted in a 1 hour per day of HRV records. As expected, I observed an activation of the sympathetic nervous system (SNS) activity, and deactivation of the parasympathetic nervous system (PNS) activity during the time participants were exposed to the blue and the urban environments, because of the physical activity conducted by the participants (Goldberger and Stein 2019). The activation of the SNS and the deactivation of the PNS is characterized by an increased HR and LF/HF, and a decreased HF and LF (highly correlated with RMSSD and SDNN, respectively) (Castaldo et al. 2015; García Martínez et al. 2017; Shaffer and Ginsberg 2017). However, after the exposure, I expected to observe a reactivation of the PNS activity – responsible for recovering the normal cardiovascular situation (García Martínez et al. 2017; Massaro and Pecchia 2019) –, being higher when participants were exposed to the blue space than when they were exposed to the urban space. Under my hypothesis, participants would be more relaxed after walking in the blue space than in the urban space, as already observed in other similar design studies (e.g., Lee et al., 2011; Song et al., 2019; Triguero-Mas et al., 2017b). However, the hypothesis could not be confirmed in *Paper III* and these unexpected findings were not explained by the physical activity levels, which were the same in both exposure environments. Possible explanations could be the study sample (e.g., highly exposed to blue spaces regularly) or the study design (e.g. short time period between the exposure and the post-exposure assessment, or short time of exposure). Besides that, HRV parameters assessed in *Paper III* of the present thesis were related to repeated acute exposures and corresponded to short-term effects of the exposure to blue spaces, whereas cardiovascular health might positively improve because of continuous and long-lasting exposure to blue spaces, which might result into long-term effects.

The present thesis has contributed to the evaluation of short-term cardiovascular responses to acute exposure to blue spaces. Since *Paper III* of the present thesis is the first study in doing so, further studies are required to establish consistency among the results. A similar study which evaluated the impact on HRV and HR of repeated short walks on a nature route did not find significant results either (Brown et al. 2014).

❖ *Mental health*

Paper I of the present thesis already suggested that residential proximity to blue spaces and the use of blue spaces and related infrastructure might enhance well-being. Also, in *Paper II* I estimated a reduction of up to 3.5 cases/year of dementia associated with increased levels of physical activity thanks to the regeneration of the Besòs Riverside Park. In line with these findings, in *Paper III* of this thesis, it was shown that well-being and mood of the participants were better when these were exposed to the blue space environment, compared with the urban space or the control site environments. The association between blue spaces and mental health was assessed using a set of questionnaires to evaluate well-being and mood responses before and after the exposure to the different exposure environments. These questionnaires were validated and previously used in other studies with a similar purpose and allowed us to identify a wide range of changes on well-being and mood, not only focusing on a specific outcome.

Thus, considering the results of the three papers included in this thesis, the overall findings are in line with the existing evidence already suggesting mental health benefits associated with the exposure to blue spaces (Britton et al. 2018; Gascon et al. 2017; Völker and Kistemann 2011). Mental health and well-being benefits as a consequence of being in contact with nature have been broadly described (Bratman et al. 2019; Frumkin et al. 2017) and different theories might explain this association. One is the biophilia hypothesis (Wilson 1984), that suggests that human have an inherent affinity to nature, and their well-being is improved when they are in contact with it (Nieuwenhuijsen et al. 2017a; Yeager et al. 2019). Also, as detailed in the *Introduction* of the present thesis, positive effects on well-being related to the exposure to blue spaces might be explained by the ART or the SRT. These are two theories that acknowledge the role of blue spaces on facilitating stress reduction, restoration, and relaxation, which might lead to better well-being. The pathways underlying the association between blue spaces and mental health and well-being were not explicitly assessed in *Paper III*. However, among study participants, self-perception of the blue space was rated better than the urban space; participants rated positively the quality, the safety, and the lack of garbage and vandalism in the blue space. Also, they reported feeling more satisfied when walking along the blue space, as compared with the urban space. Air pollution and noise were negative aspects of the urban route. These better perceptions of the blue space environment might explain the improved well-being and mood scores, as compared with the other exposure environments.

- *Long-term vs. short-term health effects*

The evidence shows that psychological outcomes are more consistently associated with exposure to blue spaces than physiological outcomes. Findings of this thesis are consistent in showing direct or indirect long-term (i.e., caused by a long-lasting exposure and maintained over time, as observed in *Paper I* and *Paper II*) and short-term (i.e., immediate and caused by an acute exposure, as observed in *Paper III*) mental health and well-being benefits of blue spaces. Nevertheless, the evidence is not that consistent with the physiological outcomes. *Paper I* of this thesis suggested indirect long-term physical health benefits of physical activity in a blue space after a big-size intervention in such space, whereas *Paper III* did not find an association between exposure to blue spaces and physical short-term health effects. This might suggest that psychological outcomes are more sensitive to the exposure to blue spaces, while physiological outcomes are only evident after long-term and sustained exposure to blue spaces. Nevertheless, the existing evidence is still insufficient for determining this, and further research, including different study designs, is needed.

6.2 Methodological considerations

This thesis employed different study designs and methodologies to assess the impact of blue spaces and related infrastructure on health and well-being and contributed to the current evidence, which is threatened by the heterogeneity on the assessment of the exposure to blue spaces and related health outcomes. On *Paper I* I conducted a mixed methods pre-post intervention evaluation. *Paper II* used a HIA approach to quantitatively assess health and health-related economic benefits of an urban riverside regeneration project. Ultimately, for *Paper III*, a randomized crossover study was conducted. Each of these methodologies has its strengths and limitations, which are described in detail below. The methodological considerations on the assessment of blue spaces are also discussed below.

6.2.1 Strengths and limitations

❖ *Mixed method pre-post intervention evaluation*

The use of a mixed methods approach is cutting edge and innovative and leads to a better understanding. One methodology complements the other (and vice versa), enhancing the benefits and minimizing the weaknesses or limitations of each other. Mixed methods research enables greater understanding of the findings, and provides opportunities to corroborate results with two different methodologies, which strengthen their credibility (Almalki 2016; Gaber and Overacker 2012; Shenton 2004).

The quantitative research of *Paper I* was conducted using the SOPARC, an easy-to-use, non-expensive tool, with no participant burden. SOPARC has been mainly used in the USA, thus, *Paper I* of this thesis was one of the first studies in Europe that used SOPARC to assess an intervention in an urban setting [for exceptions, (Pawlowski et al. 2017; Van Dyck et al. 2013; Van Hecke et al. 2017)], and also the first to use it in the assessment of a blue space intervention. Besides the limitations of the SOPARC tool already described in *Paper I (Results* section of this thesis), a weakness of that tool is that observations are conducted at a specific moment in time. At that moment, the physical activity levels of the individuals present in the study area are recorded. However, some individuals might be doing a type of activity at this moment, which does not correspond to the type of activity mainly conducted during the rest of his/her stay in the study area. A sufficient number of systematic observations need to be conducted to overcome this limitation (Evenson et al. 2017), as I did in *Paper I* (13 one-hour sessions for each period of evaluation). Additionally, observations should be conducted from the least visible location by park users. This is to avoid changes in users' behaviour due to their perception of being observed (Parra et al. 2010). Finally, using SOPARC does not allow researchers to distinguish whether users are newcomers or former users, neighbourhood residents or not (Veitch et al. 2012), which complicates their characterization. In *Paper I* of this thesis, this limitation was overwhelmed combining the use of the SOPARC with qualitative methods. Besides, other methodologies could also be employed, as the administration of questionnaires to the neighbourhood residents and the users of the riverside park. This would provide a representative and sufficiently big study sample, that would report their use of the area and provide information on their sociodemographic characteristics. This type of questionnaires requires a positive response rate by the neighbourhood residents and the users of the study area, which was not achieved in *Paper I* of the present thesis, although I tried. This might be explained by the lack of interest by the potential respondents, language difficulties, or other unidentified reasons.

When qualitative methods are chosen for a study, sometimes it is complex to decide which method is the most appropriate to address the objective of this study. In the present thesis, semi-structured face-to-face interviews were employed. A weakness of this technique is that the study sample might not be representative of the study population, and the sample size is usually small because this kind of interview has to be done individually, which takes time and resources. However, semi-structured face-to-face interviews allow the possibility of changing or adding more questions while the interview is being conducted. Also, face-to-face interviews allow the interviewer to capture emotions, behaviours, and body language, which might also provide information of interest for the study. And it allows an in-depth understanding of the beliefs and motive of the interviewees. This is the most used type of interview in qualitative health research (Berenguera et al. 2014).

The study design of *Paper I* allowed a comparison between the time before and after the intervention, and between the renovated and the non-renovated areas. This is a strength given that the non-renovated area can be used as a control, and because it allows the assessment of changes along time associated with the intervention.

- *Health Impact Assessment*

HIA is rather a new tool, although it is the most commonly used tool to evaluate health impacts of urban policies or other interventions and has shown to be effective for this purpose. However, the feasibility of implementing a HIA always depends on the availability of supportive evidence, and assumptions are required to estimate health impacts (Thomson et al. 2008). Assumptions are based on the existing evidence and the in-deep knowledge and familiarity with the policy or intervention that is assessed (Briggs 2008). Assumptions might also lead to the incorporation of different scenarios in the same analysis, as in *Paper II* of this thesis (further details in the *Results* section). Generally, one scenario is more optimistic than the other, in terms of the health impacts' estimates.

The HIA conducted in *Paper II* of the present thesis was retrospective and did not include the stakeholder's involvement. However, results and recommendations from *Paper II* were shared in social media and by email to specific stakeholders, and thus these were available for the community and the local administration. I acknowledge the importance of including stakeholders in the development of a HIA that evaluates an urban regeneration project because they can provide unique insights relevant for the assessment, and because it is important to consider the issues that concern the affected community (Joffe and Mindell 2005). In this sense, the qualitative assessment conducted in *Paper I* complements *Paper II* by providing the perspectives of the local community affected. Even though this information was not considered in the development of the urban regeneration project, it could be taken into account for future similar projects.

❖ *The "Blue Active Tool"*

For the present thesis, I developed a bespoke tool – the "*Blue Active Tool*" – used in the analysis of *Paper II* to model the relationship between physical activity and the health outcomes with a non-linear function. This tool was created ad-hoc for *Paper II* of the present thesis to estimate health (including morbidity and mortality) and health-related economic benefits of physical activity conducted in the Besòs Riverside Park, and it is available from authors upon request.

The *“Blue Active Tool”* might be used not only by researchers but also by urban planners or policymakers to estimate the health-related impacts of an urban regeneration project. This is a chance to integrate health into urban planning, to make cities healthier, thus enhancing public health.

The *“Blue Active Tool”* can be adapted for each study that desired to use it, although its usability depends on the data availability. In *Paper II* of this thesis, the health benefits could be underestimated because of the unavailability of data related to both the characterization of the study population and some dose-response functions (e.g., between physical activity and depression, anxiety, or obesity). Moreover, only the health impacts related to physical activity were estimated, not considering other health determinants such as social interaction, or the reduction of noise or air pollution.

- *Randomized cross-over study*

In a randomized cross-over study (as in *Paper III* of this thesis) participants are randomly distributed to different exposures, being allocated to all the possible exposures by the end of the study. Hence, by conducting a study with a cross-over design, participants serve as their own control. This allows the comparability of different exposure environments and its related outcomes within each study participant, increasing the precision of estimation. Also, the influence potentially produced by confounders is reduced. Another strength of randomized cross-over studies is that this type of studies requires a smaller sample size (Busti 2015). However, as it happens with all study designs, randomized cross-over studies also have some limitations. One of the main concerns of using this study design is that it might lead to the risk of a carryover effect. This means that the effects observed in one exposure environment might be transferred to the other exposure environment. This could be arranged by having a time period in between one exposure environment and the other (Sczesny-Kaiser et al. 2019; Sibbald and Roberts 1998). In *Paper III* there was a time period of at least 3 days between one exposure and the other, and participants were blinded to the exposure until the first day of each study week. Moreover, in the analysis of *Paper III* it was tested whether it was necessary or not to adjust the models by the order in which participants were exposed to each exposure environments. It is always suggested to test the data for evidence of carryover effect in studies with a randomized crossover design; in the case, the carryover effect happened in a study, the outcomes for a given exposure would vary in accordance to its position in the sequence of exposures (Sibbald and Roberts 1998). Another limitation of this type of studies is that it might take a long time to be conducted because all the participants need to be exposed to each of the exposures (Busti 2015).

6.2.2 The assessment of blue spaces

The definition of blue spaces by the BlueHealth consortium (Grellier et al. 2017) – detailed in the *Introduction* of this thesis – is broad and includes different types of blue spaces that might have different characteristics. Oceans and seas are considered blue spaces, as well as canals and rivers, fountains, and also outdoor swimming pools, among others. The population might interact differently with each type of blue space, and consequently, the impact on their health and well-being might also be different. Water visibility, accessibility, and quality, as well as the degree of urbanity and the sociodemographic characteristics of the nearby area, might also have a significant role on the provision of health and well-being.

- ❖ *Types of blue spaces*

The blue spaces assessed by the studies from the present thesis include an urban riverside park (*Paper I* and *Paper II*) and an urban beach (*Paper III*). Hence, this thesis provides insights into the health and well-being impacts of inland and coastal blue spaces. This fills in an important gap (detailed in the next section, *"6.3. Future research"*) in the evidence regarding the association between blue spaces and health, as most of the research so far has focused on coastal blue spaces.

In the present thesis, it has been shown that inland blue spaces are attractive in terms of promoting health when proper interventions are conducted there. Nevertheless, it is unknown whether the use and the impacts on health of an urban regeneration project in a coastal blue space (e.g., promenade), in a lake, or a canal – for example – would have had been the same as the use and the health impacts observed in the present thesis for an urban regeneration project in a riverside area. Likewise, there is uncertainty on determining whether positive well-being and mood effects observed on participants of *Paper III* when they were exposed to the blue space would have been magnified, reduced, or even omitted if this exposure had been another type of blue space instead of an urban beach. The wildness and other characteristics (such as type, quality or context) of the selected site could influence the magnitude of the observed health effects (Cheesbrough et al. 2019; Wheeler et al. 2015). Besides that, socio-geographical and climate conditions of the area, as well as seasonality, might influence the type of activity conducted in or next to the blue space. Potential changes on the riverbed (e.g., because of the dry and wet seasons) or the coastline (e.g., changes on the influx of people depending on the time of the year) can modify its characteristics, accessibility, or the type of activities that can be done in these areas, which may affect the impact on public health.

Also, it is still unknown whether blue spaces should be assessed on their own or combined with green spaces. In fact, blue and green spaces are both part of the natural environment and can be highly correlated. The evidence is still inconsistent on reporting whether health effects of green spaces might be magnified or reduced if these are together with blue spaces and vice versa. Some studies have already included green spaces in the analysis of association between blue spaces' exposure and health (Amoly et al. 2014; Elliott et al. 2015; Triguero-Mas et al. 2015; White et al. 2013b, 2014; Wood et al. 2016). However, it is still not clear whether this is the best approach to assess the health impacts of blue spaces, and more research should be conducted to clarify this point. In the assessment of the urban riverside park of this thesis, I did not distinguish between the blue space (i.e., the river) and green spaces (i.e., riverbank, and the green area in the Besòs Riverside Park). Thus, it is unknown whether the health and well-being benefits estimated in *Paper I* and *Paper II* were related to the blue space, to the green space, or both. Further qualitative interviews might help to clarify this point.

- *Study design*

Most of the existing quantitative research on the evaluation of health and well-being impacts of exposure to blue spaces are composed of cross-sectional studies (Gascon et al. 2017). These are observational studies whose main characteristics is that data on the exposure and the outcome is collected at the same time. Cross-sectional studies are useful to evaluate large study samples and are usually used to evaluate the prevalence of a specific outcome or to estimate the association between a given exposure and an outcome. However, the main limitation of cross-sectional studies is that it is not possible to determine whether the outcome was caused by the exposure because there is no temporal relationship between both. Also, cross-sectional studies do not usually account for other exposures that could explain the findings for the outcomes (Carlson and Morrison 2009; Kesmodel 2018). In this sense, the present thesis contributes to the evidence of the causal relationship between the exposure to blue spaces and health and well-being because it includes an experimental study (*Paper III*). Also, *Paper III* accounted for the potential influence of physical activity, air pollution, noise and other factors that might influence the association between blue spaces and health and well-being.

❖ *Methods and tools to assess exposure to blue spaces*

There exists heterogeneity on the methodology used to assess the exposure to blue spaces. Many studies use information based on geographical data to determine, for example, residential proximity to blue spaces, blue spaces coverage, or blue spaces availability (e.g., Dzhambov 2018; Gascon et al. 2018; Hooyberg et al. 2020). Nevertheless, most of these studies do not consider the residential history (i.e., whether these people had been living in this residence for at least 12 months), which threaten the conclusion of long-term effects of blue spaces (Gascon et al. 2017). Geographic Information Science (GIS) is a method widely used to evaluate green and, most recently, blue spaces too. It is an effective method because it allows the analysis of the relationship between geographical and spatial variables. Residential proximity to blue spaces might be assessed based on the blue spaces' presence in different buffers (e.g. 100, 300, and 500 m) around the residence. However, there are some concerns regarding the definition of the buffer zone distances, because this might influence the results (Labib et al. 2020). In fact, there is still not a consensus on the distances that should be used to evaluate the exposure to blue spaces, although Elliott et al. recently developed distance categories for different types of blue spaces (Elliott et al. 2020). However, blue spaces might not be identified in some occasions when land-cover maps with a coarse spatial resolution are used, because of the narrow shape of some of these spaces (e.g., rivers) (Elliott et al. 2020). Similar to GIS data, street view using Google Maps or equivalent (Helbich et al. 2019) is another method employed to assess the exposure to blue spaces, although it is scarcely used for the moment, and it has some limitations (e.g., data protection issues, inability to capture season changes and inaccessible locations like private gardens, etc.). Due to the study designs of the present thesis, GIS has not been used to assess the exposure to blue spaces. Nevertheless, I acknowledge that GIS data could have been useful in *Paper III* to provide an accurate measure for the assessment of the residential exposure to blue spaces of the participants of the study. In *Paper III* residential exposure to blue spaces was assessed using a questionnaire.

Besides this, a more extensively used method to assess exposure to blue spaces is the use of surveys or questionnaires (e.g., White et al. 2013a). It allows the assessment of blue spaces' exposure in terms of its use, and it is also possible to assess the type of activity that is being conducted in the blue space. In *Paper II* of this thesis, survey data was used to provide input data for the *"Blue Active Tool"*. The survey itself was not designed for the research purpose of *Paper II*, thus it did not include all the questions that would have been desired to completely achieve the aims of *Paper II* (e.g., data on the user physical activity behaviour before the intervention). Most of the studies conducted in England – where there is the largest number of studies on blue spaces and health – face the same limitation given that most of these studies employed the Monitor for Engagement with the Natural Environment (MENE) survey. This survey is undertaken yearly around the whole country since 2009, involves face-to-face interviews, and it is used to collect data on recent visits to the natural environment, activities performed there, motivations, and attitudes towards these environments. Despite all the advantages of using the

MENE survey (e.g., sample size, representativeness, longitudinal data, etc.), the studies that employ this survey are constrained by its questions (de Bell et al. 2017; White et al. 2013c).

Although not used in the present thesis, within the BlueHealth project, it has been recently developed a tool – the BlueHealth Environmental Assessment Tool (BEAT) – which is used for the assessment of environmental aspects and attributes that influence access to, use of and health-promoting activities in blue spaces (Mishra et al. 2020). The BEAT allows the comparison between blue spaces and it might be used to improve the design and development of blue infrastructure in urban areas. A standardised tool to evaluate the exposure to blue spaces might facilitate the comparison of the results between studies. Moreover, the assessment of blue spaces might improve the comprehension of its effects on the population's health and well-being, considering the environmental aspects and attributes of these spaces.

6.3 Future research

Research on the effects of the exposure to blue spaces on health and well-being has recently gained interest. This is shown not only by the BlueHealth project but also by the rise of, for example, "Seas, Oceans & Public Health in Europe" – the SOPHIE project – (https://sophie2020.eu/), and the Oceans and Human Health Chair (http://www.oceanshealth.udg.edu/). Consequently, new scientific studies are contributing to the evidence on the benefits of blue spaces for human health (mainly mental health and well-being), and the promotion of physical activity and social interactions. Also, recent evidence has shed light into potential risks of blue spaces (Borja et al. 2020). Nevertheless, some knowledge gaps are still evident.

6.3.1 Assessment of all types of blue spaces

As previously discussed, there is a lack of evidence concerning potential health impacts of inland blue spaces. This might be justified because of the vast area covered by the oceans (about 70% of the Earth surface) and the amount of people living by the coast (10% of the world population) or within 100 km to it (40% of the world population) (United Nations 2017). However, all types of blue spaces, including small blue spaces, should be evaluated in future studies (e.g., ponds, lakes, rivers, canals, etc.) and not only the oceans and seas. It is important to examine the health impacts of inland blue spaces, as these are also part of our environment, sometimes closer to the residence of part of the population than coastal blue spaces. Furthermore, within the inland and the coastal blue spaces, health and well-being outcomes might be differently affected by the type of blue space (e.g., sea, canal, fountain, river, etc.) and not many studies have evaluated this yet. Thus, future research should address this point by evaluating different types of blue spaces and their potential differences in the impact on humans' health and well-being.

Apart from that, the existing evidence on blue spaces and health is not distributed homogeneously across the globe. Most of the studies have been conducted in high-income countries (Gascon et al. 2017), being England the country with the highest representation. Further research should be conducted in different countries or geographical areas, because the meaning of blue spaces, the impact, and the relationship between blue spaces and the population may vary across countries and cultures. Also, different climates might impact differently the use of blue spaces, and their effects on people's health and well-being (Gascon et al. 2017).

6.3.2 *Common approach to the assessment of blue spaces*

An interdisciplinary approach is needed to improve the evidence of an association and causal relationship between exposure to blue spaces and health, considering medical and public health fields, economic, ecologic, marine, social, and behavioural science, together with stakeholder communities (Borja et al. 2020). Future research should include studies with a longitudinal cohort design to evaluate the causality between exposure to blue spaces and health outcomes. Nevertheless, other study designs should also be employed simultaneously to account for the strengths and limitations inherent with each in isolation (Borja et al. 2020). Longitudinal studies require a long time to be conducted, whereas experimental studies – such as the one conducted in *Paper III* of this thesis – may not. Thus, this thesis provides evidence on the beneficial effects of blue spaces although these findings should be replicated using both, experimental and longitudinal studies. A common approach for the assessment of blue spaces' exposure would facilitate the comparison of findings between studies (Gascon et al. 2017).

6.3.3 Health outcomes and pathways

The present thesis includes the assessment of different health outcomes, considering both, physical and mental health outcomes. Findings of this thesis suggest a positive effect of blue spaces on mental health, while the evidence is not that consistent for physical health – particularly for cardiovascular outcomes – as already suggested by the existing scientific evidence (Britton et al. 2018; Gascon et al. 2017). Thus, it is necessary to identify physical health outcomes that should be assessed in future studies because of its potential association with blue spaces, or because of the lack of existing evidence for the specific outcome (e.g. mortality). In addition, although the evidence so far supports the hypothesis that exposure to blue spaces promotes mental health, this outcome should continue to be included in further analysis to confirm previous results, including those of the present thesis. Also because mental health problems are highly prevalent across the population, representing 3% of the GDP and 30-40% of chronic sick leave in Western countries (World Health Organization 2020c).

In addition, there is a need for the identification of a common approach for the assessment of both, physical and mental health outcomes. For example, future studies using questionnaires to assess health outcomes should use existing, standardized, and validated questionnaires to enhance the validity of the results (Gascon et al. 2017). In this thesis, all the mental health outcomes that have been evaluated (except for dementia, assessed in *Paper II*) have been self-reported and mostly related to momentary mood and perceived well-being. It would be interesting to conduct further studies that evaluate the effects of exposure to blue spaces on mental health measured objectively (e.g., by using a medical diagnosis of a mental illness such as depression or anxiety). Some studies have already addressed this point, although most of them had a cross-sectional design (de Vries et al. 2016; Dempsey et al. 2018; Gascon et al. 2018; Triguero-Mas et al. 2015), whose limitations have already been described above. Regarding the findings on dementia found in *Paper II* of this thesis, it cannot be concluded that exposure to blue spaces has a direct effect on dementia, but rather an indirect effect. The exitance of an urban riverside park promotes the physical activity levels of the population living nearby, and consequently this could have a positive impact on health outcomes, including dementia. However, as already detailed in the *Introduction* of this thesis, other pathways (e.g., social interaction, lower air pollution and noise, etc.) could explain the association between blue spaces and health, although these pathways could not be included in the analysis of *Paper II*. In this sense, more research is needed on the assessment of the pathways that might explain the association between blue spaces' exposure and health.

6.3.4 Improved blue infrastructures, better health

Degraded or damaged blue spaces and related infrastructure (like the Besòs River in the 1960s) have a negative impact on socio-cultural values and well-being, and the community might feel less connected with the area (Garcia et al. 2019). The regeneration of these blue spaces is an opportunity to ameliorate its quality and consequently having a positive impact on the population, who could benefit from its ecosystem services. However, the evaluation of health (and, if possible, health-related economic) impacts of existing blue infrastructure, and particularly of urban regeneration projects involving blue infrastructure, is still scarce.

Moreover, urban regeneration projects in blue spaces usually involve the quality preservation of these spaces (Hunter et al. 2012; Mcdougall et al. 2020; Šebo et al. 2019), which might be controversial because of the lack of acceptance by the population or the public authorities (due to the cost, for example). Thus, there is a need for studies that evaluate the health impacts of blue infrastructures and it is important to consider all the stakeholders involved or affected by the project (e.g. neighbourhood residents, engineers, local authorities, etc.) to avoid conflicts and ensure the sustainability and success of the projects (Garcia et al. 2019). Likewise, future studies should include all the population groups to identify the impacts on health among those more underrepresented in the area and those more socioeconomically deprived. This might promote the reduction on inequalities and facilitate the equal use of the area among all the population groups.

The evaluation of urban and peri-urban regeneration projects in terms of health might help policymakers and stakeholders to improve urban planning, creating healthy urban environments and promoting health in all policies' approach, as shown in *Paper I* and *Paper II* of the present thesis.

6.3.5 Risks of blue spaces

The present thesis has been framed within the assessment of positive impacts on health and well-being driven by the exposure to blue spaces. Nevertheless, the hazards and risks associated with these environments are also evident and should not be ignored. Even though risks of blue spaces have not been assessed in this thesis, the need to incorporate a risk assessment in future studies becomes evident.

❖ *Risks of water*

The water itself might be hazardous on some occasions due to its own physical, biological and chemical characteristics. Some infectious diseases like dengue, yellow fever or malaria can be transmitted through vectors supported by water (e.g. aquatic snails) (World Health Organization 2017a). Besides, water itself might be the transmitting habitat of some diseases like diarrhoea, causing 2 million deaths each year worldwide (World Health Organization 2020a). Low- and middle-income countries are the most affected by these water hazards, although some waterborne diseases (e.g. Legionella) are frequent in high-income countries as well (World Health Organization 2007). One of the most likely sources of infection of Legionella in high-income countries, as an example, are decorative fountains, which can be found in many cities and towns (U.S. Department of Health and Human Services. CDC 2016). Thus, solely the presence of water in urban settings might be a risk for the population if its good quality and adequate management have not been guaranteed. An appropriate and regular quality assessment of blue spaces should be conducted to ensure the reduction and, if possible, the mitigation of the risk associated with poor-quality blue spaces. Part of the strategies to ensure the quality of blue spaces include the detection, prevention, and remediation of water pollution [e.g. microbial, bacterial, (micro-) plastics, etc.]. Appropriate awareness of which are the threats and which are its sources is fundamental to find an effective solution to this problem (Borja et al. 2020).

- *Climate change*

The abovementioned risks might increase during events of adverse climate conditions, which, from now on, are expected to be more frequent and virulent due to climate change (IPCC 2014). Water and its related infrastructure have an undesired starring role in the climate change context. It is well known that climate change will have an important impact on drought, but also flooding. Besides its potential impact on household water and sanitation infrastructure and its related health effects, drought and flooding have also an impact on the environmental ecosystem which will also affect human's health. Not to mention the impact on agriculture, and consequently food shortage which, in turn, may affect people's health and well-being (Costello et al. 2009). Also related to climate change, coastal areas – where more than half of the world population live (Depledge et al. 2019) – are vulnerable settings due to the expected sea-level rise, and the increase on the incidence of extreme weather events and natural disasters like earthquakes or tsunamis. Despite its impact on mortality and morbidity, this also has an effect on mental health (Depledge et al. 2017; Gruebner et al. 2017; Matthies-Wiesler and Fleming 2019). Also, although blue spaces might be considered opportunities for mitigating extreme temperatures in urban areas, an adequate design of these blue spaces is essential to guarantee its cooling effect (Gunawardena et al. 2017). Other consequences of climate change include the spread of toxic algal bloom, which is harmful to humans' health and ecosystem services (Borja et al. 2020; Depledge et al. 2019).

The Besòs Riverside Park, a blue space evaluated in this thesis (more details in the *Methods* section), is expected to have similar characteristics than those in the south of Spain or the north of Africa by the end of this century, in terms of temperature and climate conditions (Climate-KIC 2019). Besides that, increased floods and lower availability of resources are expected to be part of the future scenario in the area (Climate-KIC 2019). Thus, this should be considered in further studies evaluating the health effects of this urban riverside park and should also be considered in potential new interventions in this or similar areas. On the same line, it may happen that the estimated human health and well-being benefits of living near the coast, already reported in previous sections of this thesis, might be counteracted by climate change effects. Hence, from now on, the management of blue spaces and its infrastructures should be conducted considering climate change scenarios that might occur in the near future and alter characteristics of blue spaces and consequently its impacts on humans' health and well-being.

- *Risks of the use of blue spaces*

In a context more related with the direct interaction between blue spaces and humans, there are also some associated direct and indirect risks that can be detrimental to human's health and well-being. The main risk directly related to blue spaces is drowning, a leading cause of death worldwide. Despite it is considered a global public health threat, drowning rates are three times higher in low- and middle-income countries than in high-income countries (Grellier et al. 2017; World Health Organization 2014a). Apart from drowning, blue infrastructures are potential spaces likely to have slippery surfaces that may cause accidents. Also, water sports (e.g. swimming, surfing, sailing, canoeing, etc.), like almost all other types of sports, are subject to accidents. Moreover, people usually using coastal environments for water sports or recreation might be more exposed to antibiotic-resistant bacteria, present in coastal waters, like *Escherichia Coli* (Borja et al. 2020). Finally, the use of blue spaces for conducting activities near these spaces or even into the water might be associated with impacts on health unrelated to water itself. For example, spending time in blue spaces is likely related with being exposed to the sun. Thus, increasing the risk of dehydration, sunburn and skin cancer (Grellier et al. 2017). All these impacts should be considered as well when conducting research on the health impacts of blue spaces.

- *Risk of gentrification*

The present thesis has reported on the public health benefits of urban regeneration projects in urban areas to facilitate access to blue spaces. Nevertheless, population necessities and requests need to be understood and considered on the design and development of new blue infrastructures or the regeneration of existing ones. This type of projects should take into account the risk of gentrification, defined as the displacement of people from one neighbourhood to another as a result of increased costs in the restored area (e.g., higher rents) (Formoso et al. 2010; McCartney et al. 2017). Gentrification might cause health inequalities due to the displacement of the poorer residents (Cole et al. 2017), and estimated health and well-being benefits of – for example – blue spaces, might not have an impact on those residents forced to move out due to economic reasons. Further research on the health impacts of blue infrastructure should focus on the assessment of health inequalities in the most socio-economically deprived groups. The design and development of these urban interventions must guarantee equal use and enjoyment among all the population considering different age groups, gender, ethnicity, or socioeconomic status.

The Besòs Riverside Park renovations evaluated in this thesis could have had an impact on the local property values and increase the affluence of nearby neighbourhoods. This might drive changes in the amenities and services available in the neighbourhood, increasing the cost of living in the area, and facilitating the real state of speculation. In any case, the available data on average rental price along the years in the municipalities nearby the Besòs Riverside Park does not suggest gentrification in this area (Àrea Metropolitana de Barcelona 2018).

- *Against the risks*

Risk prevention, mitigation, and reduction can be undertaken differently. First, there is a need for the implementation of policies and practices to ensure the quality and adequate maintenance of blue spaces. Second, there should be regulations for adequate use of blue spaces and related infrastructure. Third, it is necessary to empower the population and provide them with the required resources to avoid risks related to the use of blue spaces and blue infrastructures (to avoid drowning, for example). Fourth, future scenarios related to climate change should be considered as well as the strategies to minimize its detrimental effects. Fifth, urban regeneration projects should be conducted together with policies and regulations to minimize or impede the effects of gentrification (e.g., safeguard affordable housing, protect senior homeowners, land use regulation, etc.).

6.4 Implications for public health

Nowadays, the population worldwide is facing an urbanization process that is expected to increase in the coming years. In 2018, 74% of the population in Europe was living in urban areas. This fact shows the progressive disconnection of humans from nature, and the challenge of the impact of urban exposome on public health, which increases the burden of non-communicable diseases and mental illnesses. Non-communicable diseases – considering CVD, cancer, respiratory diseases and diabetes (the four major non-communicable diseases) – are the leading cause of mortality worldwide, whereas mental health accounts for 14% of the global burden of diseases. Environmental factors in cities represent an important determinant of the health and well-being of the population. However, environmental factors are modifiable and changes in the design and planning of our cities might lead to changes in our health and well-being. Thus, policies for sustainable development are required to successfully overcome the process of rapid urbanization and its consequences for health (United Nations 2018; World Health Organization 2014b).

Contact with nature has been shown to positively affect the population's health and well-being. The presence of nature in urban areas improves its environmental condition because of air pollution and noise reductions. Also, the availability of nature in urban areas encourage people to be physically active, to socialize with other people, and enhances restoration and stress reduction. This, in consequence, have a positive effect on the physical and mental health of the population (Nieuwenhuijsen et al. 2017a). Whereas most of this evidence has been described for green spaces, the present thesis has contributed to filling in an important gap on the evidence of the health impacts associated with exposure to blue spaces.

❖ *Blue infrastructure and health*

The restoration of blue spaces in urban or peri-urban areas have been shown to be effective in terms of facilitating the access, use and exposure to blue spaces, reducing social inequalities, promoting physical activity and social interactions, and improving the health and well-being of the population (*Paper I* and *Paper II*).

The urban riverside regeneration project assessed in the present thesis should be considered as a successful intervention in terms of its impact on public health. Similar interventions could be replicated in other urban areas, as it has already happened, for example, with two other rivers (Ripoll and Caldes Rivers) also in the Barcelona Metropolitan Area (Ajuntament de Sabadell 2014; Vall-Casas et al. 2019), although in this case the impacts on health and well-being have not been assessed.

❖ *Blue spaces and health*

The present thesis showed that even short walks along blue spaces might benefit the well-being of the population (*Paper III*). Thus, individual-level interventions similar to the one assessed in the present thesis could be promoted among the population, and especially among those suffering from mental health disorders as a strategy to ameliorate their mental health and well-being.

7. CONCLUSIONS

The present thesis assesses the health effects of exposure to blue spaces and related infrastructure and contributes to the limited evidence we have so far on this relationship. Taking into consideration that this is a relatively new research topic, the concept "blue space" has been discussed in detail in this thesis, and the methods employed to evaluate the exposure to blue spaces and their potential impact on health have been thoroughly explained.

In line with the objectives of this thesis, findings from *Paper I* and *Paper II* were consistent in showing the effectiveness of the regeneration of a blue space in urban and peri-urban areas. Results showed an increase not only of the number of people using the infrastructure after the intervention, but also an increase of individuals from underrepresented population groups. Furthermore, improved access to blue spaces suggested to facilitate physical activity and social interactions, both of which translated into health and well-being and, indirectly, into health-related economic benefits. Findings from *Paper III* evaluated the role of repeated acute exposure to blue spaces on physical and mental health. In particular, benefits for both well-being and mood were clear, although no effects were observed for cardiovascular health.

Even though research on the effects of the exposure to blue spaces on health and well-being is gaining attention, it still remains in its infancy and there are still some issues that need to be addressed. First, future research should include the assessment of all different types of blue spaces and consider blue spaces from different parts of the world. Second, there is a need for longitudinal studies that allow an evaluation of the causal relationship between the exposure to blue spaces and the health of the population. Moreover, these studies should also assess the pathways underlying this association. Third, methods that are used to evaluate the exposure to blue spaces and their potential effects on health and well-being should be homogeneous among studies, in order to facilitate the comparison between findings. Forth, population groups with distinct sociodemographic characteristics should all be represented in the analyses. Fifth, and finally, future studies should also consider including an assessment of the risks, and not only the benefits, related to the exposure to blue spaces.

The positive effects of blue spaces and related infrastructure on health and well-being are becoming more and more evident and it is thus necessary to maximise their presence in cities. Science communication and close interaction not only with policymakers but also with the general population is key to promoting a healthy design of urban areas and facilitating healthy lifestyles among citizens. Investing in proper blue spaces and other natural settings in urban areas could translate into benefits for public health.

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APPENDICES

This section includes the description of other activities conducted by the PhD candidate during her PhD.

A. Other (co-)authored papers

- Natalie Mueller, Carolyn Daher, David Rojas-Rueda, Laura Delgado, Horacio Vicioso, Mireia Gascon, Oriol Marquet, Cristina Vert, Irene Martin, Mark Nieuwenhuijsen. **Integrating health indicators into urban and transport planning: a narrative literature review and participatory process.** [Submitted to Cities, in March 2020]

- Members of the International Consortium on Teaching Epidemiology*. **A structured, international effort to define core competencies for academic epidemiologists to tackle tomorrow's health research challenges.** [Under review at the American Journal of Epidemiology, since December 2019]

  **The PhD candidate attended the 1st International Meeting on Teaching Epidemiology, in June 2018 in Zurich (Switzerland). The attendees of this meeting discussed about the competencies that epidemiologist should have, and it resulted in a paper, recently submitted to the American Journal of Epidemiology.*

- Mireia Gascon, Gonzalo Sánchez-Benavides, Payam Dadvand, David Martínez, Nina Gramunt, Xavier Gotsens, Marta Cirach, Cristina Vert, José Luis Molinuevo, Marta Crous-Bou, Mark Nieuwenhuijsen. **Long-term exposure to residential green and blue spaces and anxiety and depression in adults: A cross-sectional study.** Environmental Research. 2018; 162:231–239. DOI: 10.1016/j.envres.2018.01.012

- L. McCay, A. Abassi, G. Abu-Lebdeh, Z. Adam, S. Audrey, A. Barnett, G. Carrasco-Turigas, E. Cerin, W. Elias, G. Hand, C. Kelly, N. Loder, M. Lüke, KE. MacLeod, C. Moutou, A. Puig-Ribera, E. Rykala, S. Schwartz, IN. Sener, C. Shaw, C. Vert, K. Witten, A. Woodcock, B Zapata-Diomedi, M. Żołnierczuk. **Scoping assessment of transport design targets to improve public mental health.** Journal of Urban Design and Mental Health. 2017;3:8.

- Mireia Gascon, Wilma Zijlema**,** Cristina Vert, Mathew P. White, Mark J. Nieuwenhuijsen. **Outdoor blue spaces, human health and well-being: A systematic review of quantitative studies.** International Journal of Hygiene and Environmental Health. 2017; 220(8) 1207-1221. DOI: 10.1016/j.ijheh.2017.08.004

B. Grants and awards

Throughout the PhD, the work conducted by the PhD candidate has been recognised as follows:

- 1st call for Research Proposals of the **Planetary Wellbeing Initiative**. *University Pompeu Fabra (2019)*

- Award for the **best chalk talk presentation**. *ISGlobal PhD Symposium (2019)*

- **Mobility grant for teaching staff, researchers, and PhD students working at the university or research centres**. *Societat Econòmica Barcelonesa d'Amics del País* (2018)

- **SEE grant for attending the School of Public Health of Menorca.** *Sociedad Española de Epidemiología (SEE) (2017)*

C. Presentations at scientific conferences

The PhD candidate has participated in different national and international scientific conferences and meetings, presenting the work conducted during her PhD.

- **International Conference on Transport and Health (ICTH).** 26-29 June 2017, Barcelona (Spain)
  Poster presentation: *"Health impact assessment of riverside regeneration in active travel"*

- ***Reunión Anual Sociedad Española de Epidemiología (SEE).*** 6-8 September 2017, Barcelona (Spain)
  Oral presentation: *"Health Impact Assessment of riverside regeneration in Barcelona"*

- **International Conference on Urban Health (ICUH).** 26-29 September 2017, Coimbra (Portugal)
  Oral presentation: *"Health Impact Assessment of riverside regeneration in Barcelona"*

- **3rd Early Career Researchers Conference on Environmental Epidemiology (ISEE young).** 19-20 March 2018, Freising (Germany)
  Oral presentation: *"Health Impact Assessment of riverside regeneration in Barcelona"*

- **Conference of the International Association People-Environment Studies (IAPS).** 8-13 July 2018, Rome (Italy)
  Oral presentation: *"Urban riverside regeneration: a pre/post evaluation of park-use and wellbeing of the local population"*

- **ISEE Joint Annual Meeting.** 26-30 August 2018, Ottawa (Canada)
  Oral presentation: *"Health Risk Assessment of Community Riverside Regeneration in Barcelona"* (Presented by Dr. David Rojas-Rueda)

- **Oceans and Human Health Chair**. 28 September 2018, Roses (Spain).
  Oral presentation: *"Blue spaces and health: insights of the BlueHealth project"* (co-presented with Dr Wilma Zijlema)
  And organization and development of a workshop about the Health effects of blue spaces. For more details, follow this link.

- **Urban Transitions 2018.** 25-27 November 2018, Sitges (Spain)
  Oral presentations: *"Urban riverside regeneration: a pre/post evaluation of park-use and wellbeing of the local population"* and *"Health benefits of physical activity related to an urban riverside regeneration project"*

- **ISEE Joint Annual Meeting.** 25-28 August 2019, Utrecht (The Netherlands)
  Oral presentation: *"Individual-level intervention assessing short-term effects of blue spaces: The Walking Office Workers (WOW) study"*
  Poster presentation: *"Impact of a riverside accessibility intervention on use, physical activity, and wellbeing: A mixed methods pre/post-evaluation"*

- **International Conference on Environmental Psychology (ICEP).** 4-6 September 2019, Plymouth (United Kingdom)
  Oral presentation: *"Individual-level intervention assessing short-term effects of blue spaces: The Walking Office Workers (WOW) study"*

- **International Conference on Urban Health (ICUH).** 4-8 November 2019, Xiamen (China)
  Poster presentations: *"Impact of a riverside accessibility intervention on use, physical activity, and wellbeing: A mixed methods pre/post-evaluation"* and *"Individual-level intervention assessing short-term effects of blue spaces: The Walking Office Workers (WOW) study"*

D. Invited speaker

The PhD candidate has collaborated with the **Urban Planning, Environment and Health Initiative (UPEHI)** from ISGlobal. The Initiative is led by Prof Dr Mark Nieuwenhuijsen and coordinated by Dr Carolyn Daher. The PhD candidate has been invited to participate in different scientific sessions and outreach activities, to either talk about the work conducted in the UPEHI, and to talk about the BlueHealth project, and the studies that the PhD student has conducted for the doctoral thesis.

- **Open Day PRBB.** 7 October 2017, Barcelona (Spain)
  Oral presentation: *"Espais blaus: més enllà del popular sol i platja""*

- ***Cicle de debats: Salut i Natura.*** 8 and 15 October 2018, Palau Macaya Barcelona (Spain).
  Presentation of the BlueHealth project and the case-studies conducted in Barcelona and surroundings.
  For more details, follow this link.

- ***XVI Jornada Prevenció de Riscos Laborals i RSC per a la Comunitat Portuària.*** 8 November 2018, Barcelona harbour (Spain)
  Oral presentation: *"BlueHealth: Els espais blaus com a font de salut"*

- ***VIII Congrés de la Societat Catalana de la Medicina de l'Esport.*** *16 November 2018, Hospital de Terrassa (Spain)*
  Oral presentation: *"Com contribuir a tenir ciutats més saludables i actives?"*

- **Science Week.** 2017 and 2018, Castellar del Vallès and Barcelona (Spain).
  Oral presentation: *"Espais blaus: més enllà del popular "sol i platja""*
  For more details, follow this link.

- **Smart citiy. Regreso a la escala humana.** 21 February 2019, Barcelona Roca Gallery, Barcelona (Spain). For more details, follow this link.

- ***Jornada de Promoció de l'Activitat Física per a la Salut.*** *11 May 2019, INEFC Barcelona (Spain)*
  This was a training activity within the Official Master on Physical Activity and Health.
  Oral presentation: *"Com contribuir a tenir ciutats més saludables i actives?"*

- ***Cicle debats Associació Cultural Casa Orlandai.*** *5 June 2019, Casa Orlandai Sarrià, Barcelona (Spain)*
  Oral presentation and discussion: *"Natura de proximitat a la ciutat"*

- ***2030 Maritime Strategy of Catalonia.*** *20 June 2019, Maritime Museum of Barcelona (Spain)*
  Oral presentation: *"The ocean - a key ally for a healthy society"*

- ***SOM Besòs Santa Coloma de Gramenet.*** *30 June 2019, Santa Coloma de Gramenet (Spain)*
  Participation in an event organized by the neighbourhood organization of *Santa Coloma de Gramenet*. The PhD candidate talked about the health evaluation projects conducted in the Besòs river and discussed with the neighbours.

- **Session on healthy work environment.** *25 September 2019, Generalitat de Catalunya, Girona (Spain)*
  Oral presentation: *"Entorns urbans afavoridors de la salut"*

- Talk to **university students** of the degree on **Environmental Science**. March 2018 and 2020, Barcelona (Spain)
  Oral presentation: *"Espais verds i blaus i salut"*

E. Workshops and training activities

Within the **UPEHI**, the PhD candidate has participated in different outreach activities, which are detailed below:

- The PhD candidate took part of a meeting with the municipality of *Barberà del Vallès* (Barcelona Metropolitan Area) about the new Local Health Plan. The PhD candidate did a presentation about the health determinants and the urban exposome and collaborated in the development process of the Local Health Plan.
  Oral presentation: *"Ciutats i salut. Com crear ciutats més saludables?"*
  Barberà del Vallès, 16 October 2018

- The PhD candidate participated in a training activity in the *Generalitat de Catalunya* in Girona, to talk about the determinants of health in an urban context.
  Oral presentation: *"Com crear ciutats més saludables?"*
  Girona, 22 November 2018

Besides the activities conducted within the UPEHI, the PhD candidate has also participated in other outreach activities:

- The PhD candidate has attended and actively participated in the BlueHealth Annual Meetings. These were held in Barcelona in 2017, Estonia in 2018, The Netherlands in 2019, and again in Barcelona in 2020.

- The PhD candidate participated in the multi-country stakeholder consultation workshop of the European EnTIRE project (http://entireconsortium.eu/). In this two-day workshop in Barcelona and Amsterdam (February 2017), the PhD candidate was part of a focus group on research ethics and integrity. The discussion resulted in a set of recommendations for stakeholders, which are summarized in the website.

- The PhD candidate collaborated in the European AELCLIC project, led by the University of Valencia. The PhD candidate attended a workshop in Barcelona (September 2019) to discuss the strategies to mitigate the effects of climate change in the Besòs Riverside Park. The output of the workshop can be found in the website.

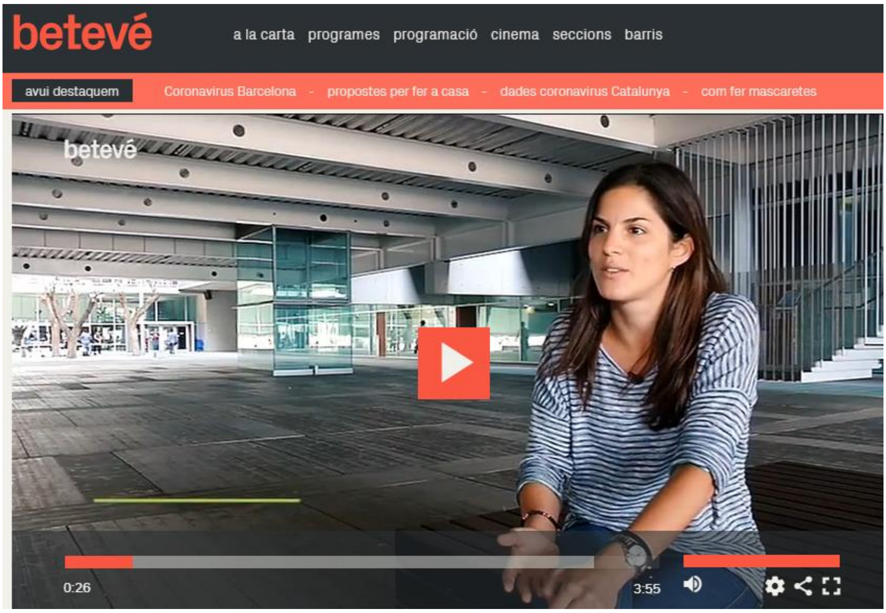
F. BlueHealth book

The PhD candidate is a co-author of the Chapter 6 and the Chapter 8 of the BlueHealth book, which compiles all the work that has been done within the BlueHealth project, as well as all the evidence that has been created. The book is under preparation and it is expected to be submitted by July 2020.

Chapter 6, entitled “Observing behavior for site planning and design”, introduces and describes methods and tools used to capture and map user’s behaviour in a specific site. Chapter 8, entitled “Assessing city-wide and local health and wellbeing benefits” discusses the use of different surveying tools in the BlueHealth project to investigate the impact of the exposure to blue spaces on the populations’ health and well-being.

G. Media attention

- Radio: CADENA SER *"A vivir que son dos días"*. March 2019.
- Newspaper and TV (selected).



The full video can be found at this link.

elPeriódico

23 Febrero, 2019

FERRAN NADEU

►► El parque fluvial del Besòs, desde uno de los accesos situado en el lado de Santa Coloma de Gramenet.

URBANISMO Y BIENESTAR

El parque fluvial del Besòs fomenta hábitos saludables

Un estudio relaciona la transformación del río y el incremento de la actividad física

El ahorro en gasto sanitario podría ascender a 23 millones de euros

LUIS BENAVIDES
BARCELONA

Hacer deporte o simplemente pasear por el parque fluvial del Besòs podría estar evitando hasta siete muertes al año. Esta es una de las conclusiones del último estudio realizado por el Institut de Salut Global de Barcelona (ISGlobal), que ha analizado el impacto en la salud de la población de la transformación de los últimos nueve kilómetros del cauce del río, conocido en un pasado no tan lejano por una degradación que se remontaba a la década de los 60. El mismo informe estima que el ahorro en gasto sanitario, por los beneficios de esta zona verde, asciende a 23 millones de euros.

La transformación del río en un enorme parque con áreas para caminar e ir en bicicleta en ambos márgenes fomenta que la gente haga deporte o, cuando menos, tenga una vida menos sedentaria. Partiendo de esta idea, los resultados del informe presentado por el centro de investigación impulsado por La Caixa relacionan el diseño urbano y el bienestar de la ciudadanía. Es decir, cómo el urbanismo influye en el comportamiento y el modo de vida. «Aunque los impactos en la salud de los espacios verdes se han estudiado más que los relacionados con los espacios azules –fuentes, lagos, ríos o mares accesibles para la ciudadanía–, recientemente una revisión de literatura científica ha asociado estos espacios con una mejor salud mental y bienestar, con la promoción de la actividad física», explican los autores del estudio.

La medición de los impactos en la salud y el bienestar de este proyecto de regeneración del río se fundamenta principalmente en una encuesta realizada por el Consorci del Besòs a unas 1.000 personas adultas para conocer qué actividades realizaban en el parque y el conteo de usuarios del parque en un año.

UNOS 6.000 USUARIOS AL DÍA // El parque, abierto al público todos los días del año, atrae a unas 6.000 personas adultas al día y las actividades principales son ir en bicicleta (casi el 50% de las personas usuarias), caminar (38%) y correr (12%). Esta actividad física, según el estudio de ISGlobal, «puede contribuir a evitar hasta siete muertes y seis casos de enfermedad por año» (embolias, diabetes, cáncer de colon, cáncer de pecho y demencia).

La mejora del cauce del río Besòs comienza en 1995, cuando los ayuntamientos de Barcelona, Montcada i Reixac, Sant Adrià de Besòs y Santa Coloma de Gramenet firmaron un convenio de colaboración para recuperar mediambientalmente el espacio. El estudio de ISGlobal podría demostrar ahora que «esta intervención también proporciona beneficios para la salud a la población que utiliza esta infraestructura». ≡

EL PUNT AVUI+

23 Febrero, 2019

La regeneració del Besòs evita set morts l'any, segons ISGlobal

X.A.
BARCELONA

Un estudi de l'Institut de Salut Global de Barcelona (ISGlobal) estima que l'activitat física que es realitza al parc fluvial del Besòs té uns efectes beneficiosos per als seus usuaris que eviten cada any fins a set morts i diversos casos de malalties greus com la demència. Per aquest motiu, la recerca calcula que les 22 hectàrees d'ús públic als últims nou quilòmetres de llera del Besòs a Barcelona, Santa Coloma de Gramenet i Sant Adrià de Besòs han servit per estalviar 23,4 milions d'euros anuals al sistema de sanitat públic. "El desenvolupament del parc fluvial del Besòs es va realitzar principalment per millorar l'ecologia de l'àrea, però la nostra avaluació demostra que aquesta intervenció també proporciona beneficis de salut a la població", explica Cristina Vert, investigadora del centre impulsat per La Caixa. L'estudi estima que el parc del Besòs atreu prop de 6.000 persones adultes al dia i que el ciclisme és l'activitat més practicada, seguida de caminar per plaer i córrer. ■

20 minutos

25 Febrero, 2019

El Parc Fluvial del riu Besòs evita set morts per any

Un estudi assenyala que l'activitat física que s'hi realitza estalvia 23 milions d'euros anuals a la salut pública

R.B.
zona20barcelona@20minutos.es / @20mBarcelona

L'activitat física que es realitza al Parc Fluvial del Besòs des que es va remodelar el 2004 per recuperar la llera del riu i fomentar-ne l'ús públic pot contribuir a evitar fins a set morts i sis casos de malaltia per any, sobretot de demència. Així ho estima un estudi que ha presentat l'Institut de Salut Global de Barcelona (ISGlobal) sobre els impactes en la salut d'aquest espai verd, i també assenyala que contribueix a estalviar 23,4 milions d'euros anuals a la salut pública.

D'altra banda, l'informe, que forma part del projecte europeu BluHealth i s'ha fet a partir d'una enquesta del Consorci del Besòs a 1.000 persones adultes, assenyala que el parc atreu prop de 6.000 adults al dia i que la meitat d'ells van en bicicleta. El 38% caminen per plaer, el 12% corren i l'1% camina per anar a algun lloc, per exemple, el seu lloc de treball o un espai d'oci.

«El desenvolupament del Parc Fluvial del Besòs es va realitzar principalment per millorar l'ecologia de l'àrea, però la nostra avaluació demostra que aquesta intervenció també proporciona beneficis de salut a la població que utilitza aquesta infraestructura, al fomentar que es realitzi activitat física», assenyala Cristina Vert, principal autora de la publicació presentada.

Per la seva banda, Mark Nieuwenhuijsen, director de la Iniciativa de Planificació Urbana, Medi Ambient i Salut d'ISGlobal, destaca «l'impacte de la planificació urbana a la salut pública d'una ciutat» i afirma que «una mesura a prioritzar és la regeneració d'ambients naturals en entorns urbans».

El Parc Fluvial del Besòs és un espai ubicat en els últims nou quilòmetres de llera del riu Besòs i colinda amb les ciutats de Barcelona, Santa Coloma de Gramenet, Sant Adrià de Besòs i Montcada i Reixach. Té una superfície de 22 hectàrees d'ús públic i una vegetació formada sobretot per gespa. Disposa d'àrees per caminar, fer esport i anar amb bicicleta. ●

L'APUNT

60 parcel·les de zones humides

El Parc Fluvial del Besòs es troba envoltat de zones de prat fluvial, platges, illes, meandres i un total de 60 parcel·les de zones humides. La desembocadura del riu, restringida a l'ús públic, és un espai estratègic pel seu interès ecològic i paisatgístic.

H. Blogs

The PhD candidate has (co-)authored different blog articles:

- *"Els espais blaus i la salut".* **Diputació de Barcelona.** More details can be found at this link.

Diputació Barcelona

espaiS@lut

Juny 2019 - #86

Inicio

El Servei de Salut Pública informa

Els espais blaus i la salut

© fezbot / Unsplash

És molt freqüent la visió de la platja com un espai d'oci, propici per a la desconnexió i per a eliminar l'estrès. Una cosa semblant passa amb la vora dels rius. I, per algun motiu, molts parcs urbans incorporen fonts i altres espais aquàtics. De fet, tradicionalment **la medicina ha vinculat els espais naturals amb aigua amb la salut**. Era freqüent recomanar a determinat tipus de pacients passar una temporada a la costa i aquest és l'origen també dels balnearis. Però quin és el vincle real entre aquests espais naturals amb la salut? Què se'n sap realment?

El món científic actual ha encunyat una terminologia genèrica per referir-se als espais a l'aire lliure que compten amb aigua de manera prominent i que són accessibles a les persones. Si els espais amb vegetació són coneguts com a espais verds, **als espais amb aigua els coneixem com espais blaus**. Dintre d'aquesta categoria es contemplen **els espais naturals, com els oceans o els rius, i també els artificials, com els estanys o fins i tot les fonts ornamentals** que trobem als parcs.

Evidència científica escassa

Tot i la concepció tradicional dels espais blaus com a llocs favorables per a la salut i, per estrany que pugui semblar, **l'evidència científica sobre aquesta qüestió és en realitat molt escassa**. Només de manera molt recent s'ha generat interès acadèmic per tractar d'esbrinar si realment existeix una relació entre espais blaus, benestar i salut i quins serien els beneficis que aquests reportarien.

Un estudi publicat fa dos anys per l'Institut de Salut Global de Barcelona (ISGlobal) va fer una recerca de les diverses publicacions científiques sobre la relació entre espais blaus i salut existents en la literatura científica. L'equip signant va ressaltar la dificultat d'arribar a conclusions, donada l'escassetat de referències i les diferències metodològiques que hi havia entre les existents. Tot i això, sí que van trobar estudis que coincidien en destacar que **viure a prop d'espais blaus i/o fer ús dels mateixos s'associa amb un nivell més elevat d'activitat física i un millor estat de salut mental.**

Espais blaus i activitat física

El fet de tenir un espai blau a prop augmenta les probabilitats de realitzar activitat física i, per tant, **afavoreix la lluita contra el sedentarisme**, que és un factor de risc important. De fet, es creu que bona part dels beneficis dels espais blaus per a la salut poden venir donats per la seva associació amb un estil de vida més actiu. Hi ha alguns estudis que ofereixen proves d'aquesta associació. Una recerca ealitzata a Austràlia amb més de 10.000 adults majors de 40 anys, va trobar que **la probabilitat de caminar més de 300 minuts a la setmana era major entre aquells qui vivien més a prop de la costa o d'un riu**. Un any després, el 2012, es va donar a conèixer un altre estudi fet a França amb més de 7.000 adults majors de 30 anys i que va trobar que hi havia més persones que havien sortit a córrer la setmana anterior a la participació en la investigació entre aquelles que vivien e menys d'un quilòmetre d'un llac. Per últim, un treball publicat l'any 2015 i on van participar més de 70.000 persones d'Anglaterra, va arribar a la conclusió que les persones que havien visitat zones de costa recentment mostraven **més nivells d'activitat física que aquelles que havien estat en contacte amb espais verds rurals o amb àrees urbanes**.

Espais blaus i salut mental

Pel que fa a la salut mental, hi ha estudis que mostren un efecte beneficiós del contacte amb espais blaus. Un d'ells es va fer a la ciutat de Barcelona, amb la participació de més de 2.000 nens i nenes d'entre 7 i 10 anys. Els resultats, publicats l'any 2014, mostraven que en aquells casos on s'havia declarat passar més temps a la platja al llarg de l'any s'observaven **menors problemes emocionals i millor comportament prosocial**. L'altre estudi, publicat només un any abans i realitzat al Regne Unit amb població adulta, va concloure que **les persones que vivien més a prop de la costa mostraven una millor salut mental**.

Tot i això, també és cert que hi ha estudis que no van aconseguir detectar efectes positius de l'exposició a espais blaus en relació tant amb l'activitat física com amb la salut mental. Aquesta aparent disparitat, unida a l'escassa recerca existent, fa palès que **encara és molt més allò que es desconeix que allò que podem donar per establert** i que el món científic té molts deures pendents pel que fa als espais blaus. El projecte Blue Health, finançat per la Unió Europea a través del programa Horizon 2020 i amb una pota a Catalunya de la mà d'ISGlobal, és una iniciativa que pretén contribuir a pal·liar aquest dèficit de coneixement.

Mentrestant, cal tenir present que vivim a un territori privilegiat per la seva abundància d'espais blaus. Aprofitar-los al màxim depèn també de l'existència d'infraestructures adequades que puguin fer aquests indrets accessibles per a la població, sempre i quan els projectes s'abordin des de la sostenibilitat i el respecte per la natura. Un exemple d'actuació recent és la **recuperació del Parc Fluvial del Besòs**, que segons una anàlisi realitzada en el marc del projecte Blue Health permetrà evitar fins a set morts i estalviar 23 milions d'euros **en despesa pública cada any**. Esperem que en un futur a mig termini puguem comptar amb evidències molt més sòlides sobre els beneficis dels espais blaus per a la salut i també amb més i millors infraestructures per gaudir-los al màxim.

Cristina Vert
Investigadora doctoral
Institut de Salut Global de Barcelona (ISGlobal)

Boletín: EspaiS@lut
Número de boletín: #86 - Juny 2019

Servei de Salut Pública
Àrea de Cohesió Social, Ciutadania i Benestar
Passeig de la Vall d'Hebron, 171
Recinte Mundet
Edifici Serradell Trabal, Planta 2
08035 Barcelona
Tel. 934 022 468
https://www.diba.cat/web/salutpublica/default
ssp.espaisalut@diba.cat

- *"Espacios azules: beneficios para la salud mental".* **DKV.** More details can be found at this link.

DKV Salud y bienestar

Contacto Conócenos

Negocio Responsable Sociedad Medioambiente Entrevistas

Inicio

Espacios azules: beneficios para la salud mental

27 JUN 2018

Las zonas costeras y otros espacios relacionados con el agua son considerados por la sociedad lugares propicios para la salud. En cambio, la evidencia científica es escasa y solo recientemente han aparecido estudios que respaldan sus efectos positivos sobre la salud y el bienestar.

¿Sabías que estar en contacto con los espacios azules, como los ríos o los océanos, aporta beneficios a tu salud?

Popularmente, se da por sentado que las zonas costeras y otros espacios acuáticos, como los ríos o los lagos tienen un efecto relajante e incluso terapéutico. Las propiedades terapéuticas del agua han sido aprovechadas tradicionalmente desde el sector de la salud a través de balnearios, sanatorios u otros tipos de centros (Foley and Kistemann 2015). Pero, ¿qué se sabe realmente acerca la relación entre espacios acuáticos y salud? ¿Qué evidencias científicas existen al respecto?

Hoy en día, a estos espacios acuáticos se les denomina espacios azules. Entendemos por espacios azules aquellos **espacios al aire libre** —ya sean naturales o artificiales— **que cuentan con agua de manera prominente y son accesibles para los humanos de manera próxima (estando en, dentro o cerca del agua)** o virtual (pudiendo ver, escuchar o sentir de otra manera el agua) (Grellier et al. 2017). Esto incluye desde los océanos, hasta las fuentes ornamentales que se suelen encontrar en las áreas urbanas, pasando por los ríos y lagos, entre otros.

Espacios azules y sus beneficios

Hasta la fecha, la mayoría de los estudios científicos que han evaluado los efectos de los espacios naturales en la salud y el bienestar de la población han centrado la atención en los espacios verdes: parques urbanos, jardines, calles arboladas o bosques, entre otros. La exposición a estos espacios se ha asociado a una reducción de la mortalidad y a una mejor salud general y mental, entre otros (Nieuwenhuijsen et al. 2017). **Aun así, en los últimos años se ha detectado un creciente interés en evaluar también los efectos de los espacios azules en la salud**, hasta ahora bastante desconocidos e inexplorados. Sorprendentemente, la literatura científica al respecto es todavía muy escasa y destaca por la notable **heterogeneidad en la metodología utilizada.**

Una revisión sistemática realizada recientemente (Gascon et al. 2017) recogió las evidencias disponibles sobre los beneficios de los espacios azules para la salud y el bienestar de las personas. En concreto, concluía que podría haber una asociación entre vivir cerca de, y/o utilizar los espacios azules, con un mejor estado de salud mental y un incremento de la práctica de la actividad física (Gascon et al. 2017).

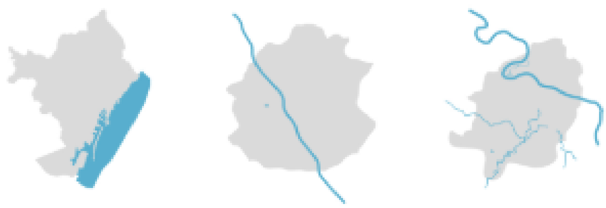
Espacios azules y salud mental

Por ejemplo, un estudio longitudinal realizado en el Reino Unido reveló un mejor estado de salud mental entre los individuos que vivían cerca de la costa (a menos de 5 km) comparado con aquellos que vivían más lejos (White et al. 2013). En otro estudio, con una muestra de 2.111 niños y niñas de entre 7 y 10 años y residentes en la ciudad de Barcelona, se observó que aquellos cuyos progenitores dijeron pasar más tiempo en la playa a lo largo del año, tenían menos problemas emocionales y mejor comportamiento prosocial (Amoly et al. 2014).

Estos resultados van en la misma dirección que los de otro estudio transversal desarrollado con 1.041 residentes de zonas urbanas con espacios azules en Alemania, que reportó una asociación entre la frecuencia de uso de espacios azules y un mejor estado de salud mental (Völker et al. 2018). En esta misma línea, una investigación realizada en Hong Kong con una muestra de 1.000 personas mayores apuntó mejores resultados de bienestar y menor riesgo de depresión entre aquellas que visitaban espacios azules intencionadamente con más frecuencia (Garrett et al. 2019).

Por último, en otro estudio realizado con adultos mayores en Irlanda se observaron menos síntomas de depresión entre los individuos que gozaban de más vistas al mar (Dempsey et al. 2018).

ESPACIOS AZULES DE VARIAS CIUDADES DEL PAÍS



Espacios azules y actividad física

Parte de los beneficios en salud que se atribuyen a los espacios azules son debidos a la actividad física realizada en ellos. Y es que varios estudios sugieren que vivir cerca de espacios azules, así como usar estos lugares, aumenta la probabilidad de realizar actividad física y de tener un estilo de vida menos sedentario (Gascon et al. 2017).

Un estudio transversal realizado en Francia con una muestra de 7.290 participantes adultos (de entre 30 y 79 años) sugirió que la presencia de un lago a 1 km de casa estaba asociado con reportar haber salido a correr durante la semana anterior (Karusisi et al. 2012). En esta misma línea, una investigación realizada en Australia con 10.286 adultos de entre 40 y 65 años encontró que vivir cerca de un río o de la costa, estaba asociado a una mayor probabilidad de caminar más de 300 minutos a la semana (Wilson et al. 2011). Finalmente, en el año 2015 Elliot et al. publicaron un estudio en el que se sugería un aumento de los niveles de actividad física entre aquellas personas que habían visitado zonas costeras, en comparación con aquellas que habían visitado espacios verdes rurales o áreas urbanas (Elliott et al. 2015).

Aun así, es conveniente precisar que, tanto para la salud mental como en lo referente a actividad física, los resultados no son del todo concluyentes y existen algunos estudios que no sugieren tales beneficios (Humpel et al. 2004; Witten et al. 2008). Por otra parte, en la revisión sistemática publicada en 2017 por Gascon et al., se especifica que los resultados de los estudios que evaluaron la relación entre los espacios azules y la salud general, la obesidad, y la salud cardiovascular, fueron menos congruentes y por lo tanto no se pudo afirmar que existiera una asociación (Gascon et al. 2017). La principal limitación detectada fue la escasez de estudios disponibles, lo cual pone de manifiesto que, efectivamente, se trata de un campo de estudio poco explorado y que hay una necesidad evidente de más investigación.

La infraestructura azul

En Europa, la mayoría de la población vive cerca de espacios azules (costeros o no). Sin embargo, no siempre se obtiene el máximo beneficio potencial de estos espacios, ya sea porque no están accesibles, no están en buenas condiciones o simplemente porque no son lo suficientemente conocidos. Por esta razón son importantes las infraestructuras alrededor de los espacios azules, para promocionar su uso y así maximizar los beneficios en salud para la población. Rehabilitar espacios ya existentes o construir otros nuevos cuando sea posible son medidas que facilitan que toda la ciudadanía tenga acceso a ellos, que sean de calidad, que ofrezcan distintos usos y que sean aptos para distintos grupos de población.

Teniendo en cuenta que cada vez es mayor el interés en conocer los efectos de los espacios azules en la salud y el bienestar, es de esperar que en los próximos años la evidencia científica sea mayor y cada vez más consistente y nos permita entender el impacto que estos espacios tienen en nuestra salud y bienestar. Entre las cuestiones a explorar por parte de la comunidad científica figuran interrogantes como si todos los tipos de espacios azules tienen los mismos efectos, qué tipo de exposición ofrece mayores beneficios, cuáles son las infraestructuras azules más adecuadas para promocionar la salud y el bienestar o los posibles riesgos derivados de la exposición a estos espacios. Todo ello, además, debe abordarse desde el respeto y la coherencia para evitar la degradación o la sobreexplotación de los espacios azules.

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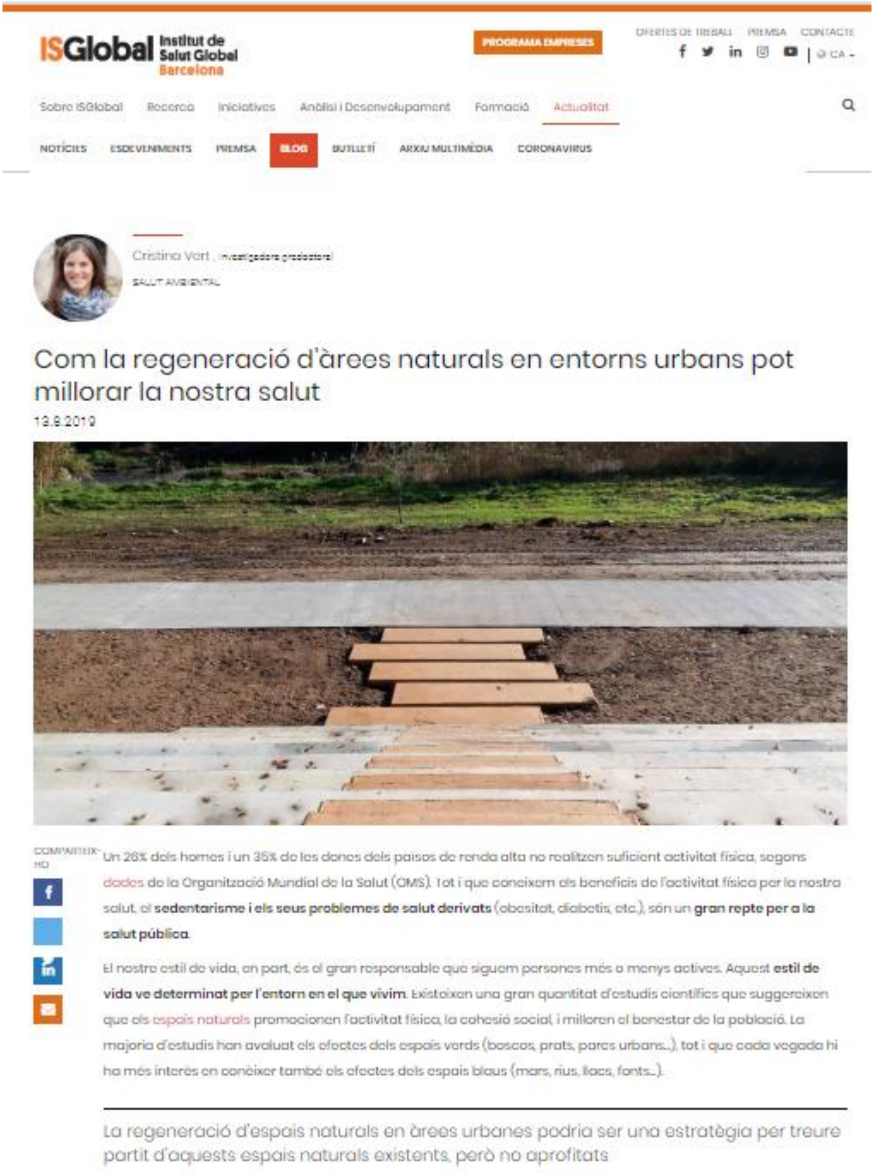
Etiquetas: Naturaleza saludable

Comentarios

Para realizar comentarios debe iniciar sesion con una Red Social:

- *"Com la regeneració d'àrees naturals en entorns urbans pot millorar la nostra salut".* **ISGlobal blog.** More details can be found at this link.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Cristina Vert , investigadora predoctoral

SALUT AMBIENTAL

Com la regeneració d'àrees naturals en entorns urbans pot millorar la nostra salut

13.8.2019

COMPARTEIX-HO

Un 26% dels homes i un 35% de les dones dels països de renda alta no realitzen suficient activitat física, segons dades de la Organització Mundial de la Salut (OMS). Tot i que coneixem els beneficis de l'activitat física per la nostra salut, el **sedentarisme i els seus problemes de salut derivats** (obesitat, diabetis, etc.), són un **gran repte per a la salut pública**.

El nostre estil de vida, en part, és el gran responsable que siguem persones més o menys actives. Aquest **estil de vida ve determinat per l'entorn en el que vivim**. Existeixen una gran quantitat d'estudis científics que suggereixen que els espais naturals promocionen l'activitat física, la cohesió social, i milloren el benestar de la població. La majoria d'estudis han avaluat els efectes dels espais verds (boscos, prats, parcs urbans...), tot i que cada vegada hi ha més interès en conèixer també els efectes dels espais blaus (mars, rius, llacs, fonts...).

La regeneració d'espais naturals en àrees urbanes podria ser una estratègia per treure partit d'aquests espais naturals existents, però no aprofitats

Per tant, i tenint en compte que la majoria de la població vivim en àrees urbanes, un dels objectius a marcar-nos és **apropar la natura a la ciutadania**. Això no sempre és fàcil. Tot i que és possible que hi hagi entorns naturals més a prop del que ens pensem, sovint aquests no es troben en bon estat, no són accessibles, o simplement ens són desconeguts. La regeneració d'espais naturals en àrees urbanes podria ser una estratègia per treure partit aquests espais naturals existents, però no aprofitats.

Un exemple és el **projecte de regeneració del Parc Fluvial del Besòs**, a la província de Barcelona. Es tracta d'un espai públic ubicat al llarg dels darrers nou quilòmetres de la llera del riu Besòs, amb àrees per caminar i anar amb bicicleta. Un estudi d'ISGlobal que vam publicar a principis d'any va concloure que la regeneració d'aquest espai reportava beneficis per a la salut gràcies a la promoció de l'activitat física i estalvi per al sistema sanitari, en concret, **evitava fins a set morts a l'any i 23 milions d'euros en despeses de salut pública**.

L'estiu del 2016 es va iniciar la regeneració de la zona de la llera dreta del riu que queda just davant del barri La Ribera del municipi de Montcada i Reixac. L'objectiu d'aquesta intervenció era facilitar l'accés a la llera del riu perquè **la població en pogués fer ús** i s'aprofités el potencial d'aquest espai natural tan proper a casa seva.

Parc Fluvial del Besòs, a la província de Barcelona

Des d'ISGlobal vam voler **avaluar l'impacte d'aquesta intervenció en un barri socioeconòmicament deprimit com és el barri de La Ribera**. Vam analitzar els canvis en l'ús de l'àrea, en els nivells d'activitat física dels seus usuaris, i la percepció d'aquest espai per part de la població del barri.

L'objectiu de l'estudi d'ISGlobal va ser avaluar l'impacte de la regeneració del Parc Fluvial del Besòs al barri de la Ribera, una àrea socioeconòmicament deprimida

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Per una banda, vam aplicar el mètode SOPARC, que es basa en **observacions sistemàtiques a l'àrea d'estudi** amb l'objectiu de quantificar el número d'usuaris i les seves característiques (edat, sexe, ètnia), així com els nivells d'activitat física d'aquests (sedentària, moderada, o vigorosa). Les observacions les vam dur a terme durant 13 sessions d'una hora cadascuna, tan abans com després de la intervenció.

A més, vam realitzar **entrevistes individuals** a una mostra de la població de La Ribera: vam preguntar sobre la seva percepció dels espais naturals i del barri, el seu estat de salut i benestar, d'activitat física i les relacions socials.

Vam observar un **augment significatiu del número total d'usuaris** –del 30% abans de la intervenció al 38% després de la intervenció– a l'àrea renovada (llera dreta del riu), i un descens significatiu a l'àrea no renovada –del 70% al 64%–. Així mateix, després de la intervenció també vam observar alguns canvis en les característiques sociodemogràfiques dels usuaris. Per començar, tot i que en el conjunt del Parc vam identificar més homes que dones, després de la intervenció vam observar un **increment del 43% de dones a l'àrea renovada**. En segon lloc, vam observar un **lleuger increment del grup d'infants**, tot i que els grups d'edat més representatius van ser les persones adultes i la gent gran. Per últim, més del 90% dels usuaris del Parc van ser identificats com a caucàsics, encara que vam observar un increment significatiu de població no caucàsica a l'àrea renovada després de la intervenció (del 3% al 8%).

Vam observar un augment significatiu del número total d'usuaris –del 30% abans al 36% després de la intervenció

Pel que fa als nivells d'activitat física, a l'àrea renovada hi vam observar un **augment de persones usuàries realitzant activitat física moderada o sedentària**, mentre que a l'àrea no renovada hi vam observar un augment d'activitat física vigorosa. Aquests resultats suggereixen que l'àrea renovada podria estar sent utilitzada pels veïns i veïnes del barri, per passejar, relaxar-se, i passar una estona en companyia, i no tant per realitzar-hi activitat física vigorosa, tot i que sí moderada (el sol fet de caminar fins al riu ja implica realitzar una activitat física, que potser no feien abans). Aquest tipus d'activitats podrien tenir un impacte positiu per a la salut mental i el benestar dels veïns i veïnes de La Ribera.

Les **persones del barri, en general, van comentar estar satisfetes amb la intervenció.** Moltes d'elles van declarar ser usuàries del Parc i van destacar que els hi agradava viure a prop del riu i anar-hi sovint ja que els hi donava sensació de calma i gaudi. Les entrevistes també van ser adients per identificar les principals crítiques dels veïns i veïnes respecte la intervenció (sensació d'inacabada, problemes amb gossos, civisme, etc.).

Aquest estudi reforça l'evidència que la regeneració d'espais naturals en àrees urbanes és útil per crear oportunitats d'interacció social, espais per relaxar-se i divertir-se, i promocionar l'activitat física, millorant així la salut i el benestar de la població que utilitza aquests espais

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- "Citizen science in Geneva". **BlueHealth blog.** More details can be found at this link.

Citizen science in Geneva

POSTED ON: 25 JULY 2018 | BY: CRISTINA VERT

What can we learn from BlueHealth research in different countries? Cristina Vert shares her thoughts from a recent study placement in Geneva.

For the last two years, my work on BlueHealth has focused on our Besòs River project, where our team at ISGlobal has been evaluating the health and wellbeing impacts of changes to an urban river.

Yet in March, I was fortunate enough to spend 4 months at the Institute of Global Health in Geneva, Switzerland, where I learned about another initiative to improve a city waterway.

During my stay, I met with Sandrine Motamed, Senior Lecturer at the Institute of Global Health, and Director of the Geneva Association for Community Development – a non-profit organisation aiming to promote quality of life, wellbeing and health through community participation.

Sandrine took me to a site she has been studying in Versoix, an area of Geneva where a river flows right through the local neighbourhood.

Sandrine standing at the study site in Versoix

In 2015, an intervention was conducted on this river to improve its environmental quality, to help prevent flooding, and to create a pedestrian promenade along it. Since Versoix is divided by roads and a railway, a key objective of this work was also to use the river to connect different parts of the area.

Fairly straightforward so far, but what I found really exciting about Sandrine's work was the way she and her team listened to the needs of the local community and shaped their intervention accordingly.

Citizen science played a key role in the study design, with the local community helping to assess the area and choose appropriate plans for development. In one example, volunteers surveyed the needs of people with reduced mobility to ensure wheelchair accessible areas were made available and any obstacles removed.

A fountain at the site in Versoix

Members of the community team now make regular visits to the area to identify sections of river that need to be maintained, and also to respond to the way people are using the regenerated spaces. Through this kind of approach they've been able to spot possible design flaws, such as the need for benches to be made higher to help older people sit down and stand up.

This process has also led to some wonderfully simple yet effective plans: free bags are provided for picking up dog poo; drinking fountains can be found at regular intervals; and – my favorite – shrubs have been planted with edible fruit so people can enjoy a healthy snack while they sit next to the river.

Although Sandrine and her team are still analysing the data, this kind of community-led approach has clear benefits not only in ensuring that local people believe in an intervention, but that it is tailored to fit their needs.

Whilst we must acknowledge socioeconomic and cultural differences between countries, I would love to see this kind of approach adopted here in Barcelona to help boost the benefits of our own blue spaces.

I am very grateful to Sandrine, her team and the Institute of Global Health for making my stay in Geneva productive and enjoyable. I hope to continue our interdisciplinary relationship when I'm back at ISGlobal.

I. Other activities

Within the PhD programme, the PhD candidate has been in charge of the organization of: (i) the internal weekly ISGlobal seminars, from September 2017 until March 2018; and (ii) the 4th PhD Symposium (November 2017).

J. Research stay

The PhD candidate conducted a research stay (from April to July 2018) at the *Institut de Santé Globale*, Faculty of Medicine at the University of Geneva (Switzerland), under the supervision of Prof Dr Emiliano Albanese. During the stay, the PhD candidate learned about the evaluation of mental health in a natural disaster context, using social media data. Also, the PhD candidate designed a manual for using the Research Electronic Data Capture (REDCap) Software. This is a tool to be used for collecting health data.