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Does the perceived neighborhood environment promote mental health during pregnancy? Confirmation of a pathway through social cohesion in two Spanish samples

Mikel Subiza-Pérez [a,b,c,*], Gonzalo García-Baquero [b,c], Izaro Babarro [a,b], Asier Anabitarte [b,d], Xavier Delclòs-Alió [e], Guillem Vich [f,g,h], Oriol Roig-Costa [h], Carme Miralles-Guasch [h], Nerea Lertxundi [a,b], Jesús Ibarluzea [b,c,i,j]

[a] Department of Clinical and Health Psychology and Research Methods, University of the Basque Country UPV/EHU, Avenida Tolosa 70, 20018, Donostia-San Sebastián, Spain
[b] Biodonostia Health Research Institute, Group of Environmental Epidemiology and Child Development, Paseo Doctor Begiristain S/n, 20014, Donostia-San Sebastián, Spain
[c] Spanish Consortium for Research on Epidemiology and Public Health (CIBERESP), Instituto de Salud Carlos III, C/ Monforte de Lemos 3-5, Madrid, 28029, Spain
[d] Department of Preventive Medicine and Public Health, Faculty of Medicine, University of the Basque Country (UPV/EHU), Barrio Sarriena S/n, Leioa, 48940, Spain
[e] Institute of Urban and Regional Development (IURD), University of California, Berkeley, United States
[f] Geography Department, Universitat Rovira I Virgili, 43480, Vila-seca, Tarragona, Spain
[g] ISGlobal (Barcelona Institute for Global Health), Barcelona, 08036, Spain
[h] Grup D'Estudis en Mobilitat, Transport I Territori (GEMOTT), Departament de Geografia, Universitat Autònoma de Barcelona, Edifici B, Campus de Bellaterra, 08193, Cerdanyola Del Vallès (Barcelona), Spain
[i] Ministry of Health of the Basque Government, SubDirectorate for Public Health and Addictions of Gipuzkoa, 20013, San Sebastian, Spain
[j] Faculty of Psychology, University of the Basque Country UPV/EHU, Avenida Tolosa 70, 20018, Donostia - San Sebastian, Spain

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ABSTRACT

Physical neighborhood attributes such as greenness, walkability and environmental pollution may have an influence on people's behavior and health. It has been claimed that part of such effects may come from the promotion of physical activity and the strengthening of social cohesion. In this study, we recruited samples of pregnant women in two Spanish cities (Donostia-San Sebastián, 440 participants and Barcelona, 360 participants) who filled in a questionnaire and wore an accelerometer for 1 week during the first trimester of pregnancy. The influence of perceived residential greenness, walkability and environmental pollution on mental health (GHQ-12) was tested in two structural equation models that included light physical activity, moderate-to-vigorous physical activity and social cohesion as mediators. Two solutions showing excellent and good fits (Donostia-San Sebastián: $X^2(3) = 2.56$, $p = .465$, $CFI = 1$, $RMSEA < 0.001$; Barcelona: $X^2(6) = 4.86$, $p = .566$, $CFI = 1$, $RMSEA = 0.048$) consistently showed that neighborhood attributes promote mental health through social cohesion in the two cities. Stratified analyses revealed that the social cohesion-mental health effect was only statistically significant for low and medium socioeconomic status groups in the Donostia-San Sebastián sample. Pathways through physical activity were not confirmed.

1. Introduction

Social determinants of health refer to the variety of conditions in which people are born, grow, live, work, and age that might have direct implications for health and well-being (WHO, 2008), among which those occurring at the neighborhood level are of great importance. The neighborhood attributes most commonly studied have been residential greenness, access to green spaces, walkability and environmental noise

* Corresponding author. Department of Clinical and Health Psychology and Research Methods, University of the Basque Country UPV/EHU, Avenida Tolosa 70, 20018, Donostia-San Sebastián. Spain.
E-mail addresses: mikel.subiza@ehu.eus (M. Subiza-Pérez), ggbmoneo@ciberesp.es (G. García-Baquero), izaro.babarro@ehu.eus (I. Babarro), asier.anabitarte@ehu.eus (A. Anabitarte), xavidelclos@berkeley.edu (X. Delclòs-Alió), guillem.vich@isglobal.org (G. Vich), oriol.roig@uab.cat (O. Roig-Costa), Carme.Miralles@uab.cat (C. Miralles-Guasch), nerea.lertxundi@ehu.eus (N. Lertxundi), mambien3-san@euskadi.eus (J. Ibarluzea).

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and pollution, measured via Geographic Information Systems, psychometric questionnaires and other means. Current evidence points to associations between these attributes and physical activity (Bracy et al., 2014; Ding and Gebel, 2012; Foraster et al., 2016; Saelens and Handy, 2008; Sallis et al., 2020), obesity (Ding and Gebel, 2012; Luo et al., 2020; Sallis et al., 2020), social capital (Mazumdar et al., 2018), loneliness (Domènech-Abella et al., 2020), depression (Banay et al., 2019; Berke et al., 2007; Gong et al., 2016; Pun et al., 2018; Song et al., 2019) and indicators of health and well-being (Dzhambov et al., 2017; Han, 2020; Liu et al., 2020; Lu, 2020; Ma et al, 2017, 2018; Parra et al., 2010; Wang et al., 2020). Recently, it has been recommended to shift research towards the mechanisms (or pathways) that might explain these associations (Ding and Gebel, 2012), also referred to as pathways (Dzhambov et al., 2020; Markevych et al., 2017). Candidate mediators are physical activity, social cohesion and psychological stress, under the assumption that positive neighborhood environments — with higher levels of greenness and walkability, and lower exposure to noise and pollution — will improve people's health through increasing the time devoted to physical activity, strengthening social ties and promoting better psychological states.

Here we focus on neighborhood physical attributes in which mental health is the outcome of interest. Evidence is not always consistent across all exposure and mediator variables[1] used, but overall it shows that the conceptual relationships between them and with mental health are well grounded. In an early paper, Sugiyama et al. (2008) found that perceived residential greenness exerted a direct positive impact on mental health and that this was mediated by walking for leisure and social cohesion. Liu et al. (2019b) replicated these results but failed to confirm psychological stress as mediator. Liu et al. (2019a) used c.20, 000 participants in China to show that residential greenness affected depression scores through all of physical activity, social cohesion and stress. Two Bulgarian studies associated environmental pollution annoyance with mental health, partially mediated by social cohesion and physical activity (Dzhambov et al., 2017; Dzhambov et al., 2018a, 2018b).

To our knowledge, no studies have used this type of mediation approaches in the walkability literature. Nonetheless, we consider it highly plausible to expect an analogous pattern of interactions given the existing evidence of links between walkability, physical activity and social cohesion (Mazumdar et al., 2018; Saelens and Handy, 2008; Sallis et al., 2020).

1.1. A brief note on environmental health inequalities

Awareness has been raised of the double burden (or double jeopardy) that low socioeconomic status populations might be carrying (Bolte et al., 2011; Geer, 2014). These would emerge from the joint action of limited individual resources (education, income, and prospects) and unequal distribution of environmental exposures (Gerrish and Watkins, 2018; Gray et al., 2013; Ma et al., 2017; Nikšič, 2017; Watkins and Gerrish, 2018; WHO, 2012). Such deficits likely interact and deepen the health gaps between disadvantaged and more affluent population groups (Morello-Frosch and Shenassa, 2006). Besides, a growing body of literature suggests that improvements in the physical environment help to reduce social inequalities in health (Astell-Burt et al., 2014; Mitchell et al., 2015; Mitchell and Popham, 2008; Sugiyama et al., 2016; Ward Thompson et al., 2016).

1.2. Environmental determinants of mental health during pregnancy

Mental health during pregnancy is important not only because of the general health of mothers, but also because it might cause subsequent health consequences. Firstly, poor maternal mental health might be related to pregnancy outcomes, such as preterm birth or low birthweight, although results are inconsistent (Accortt et al., 2015; Lima et al., 2018). Further, maternal psychological health during pregnancy is associated with children's sleep quality and physical health conditions such as wheezing, respiratory tract infections and diarrhea, asthma, dermatitis and allergic rhinitis, years after delivery (Baird et al., 2009; Flanigan et al., 2018; Rusconi et al., 2019).

Studies investigating the links between physical neighborhood attributes and pregnancy-related health outcomes have mostly assessed pregnancy outcomes (Anabitarte et al., 2020; Dadvand et al., 2012, 2014; Gray et al., 2014; Nieuwenhuijsen et al., 2013, 2019; Ristovska et al., 2014), while less attention has been paid to mental health or candidate mediators. De Avila-Quintana et al. (2018) found relationships between walkability components and physical activity. However, Nichani et al. (2017) failed to find association between residential greenness and prenatal depression in Australian pregnant women. Similarly, Krzepota et al. (2018) found little support for the notion that physical activity promotes psychological quality of life. By contrast, McEachan et al. (2016) indicated that residential greenness was directly associated with lower odds of experiencing depressive symptoms during pregnancy and also indirectly associated through physical activity. Albeit we did not expect a radically divergent framework of relationships among variables from that observed in former studies with other populations, we could not discard either that the importance of direct and indirect effects differ in pregnant women, given the bio-psychological changes that occur during pregnancy.

Research has also revealed that, generally, pregnant women with low socioeconomic status are exposed to more environmental pollution (Llop et al., 2011; Woodruff et al., 2003) and live in less green residential areas (Dadvand et al., 2014), but the literature is not consistent (Dadvand et al., 2012; Nichani et al., 2017). McEachan et al. (2016)'s study found that access to green spaces in the home vicinity was associated with lower odds of depression symptoms during pregnancy but only for women with a low level of education, providing more evidence for the claim that the effects of environmental determinants of health vary across social groups.

1.3. Study aim and meta-model

In accordance with the evidence reviewed above, the objective of this study was to test the substantive model shown in Fig. 1. In this study, we focused on perceived environmental variables because they might account better for the individual's cognitive representation of their environment (Dzhambov et al., 2018) and therefore be more determinant of subsequent health-related behaviors and experiences (Choi et al., 2015).

Given the objective of the study, we selected structural equation modelling as the appropriate analysis technique, since it combines graphical methods with systems of linear regression-based equations (Duncan, 1975; Heise, 1975). This allows the analysis of complex networks and is therefore suitable for testing a meta-model such as that presented in Fig. 1. Path coefficients of the final structural equation models were then re-estimated for different income groups to explore whether any effects detected vary by sociodemographic status.

2. Methods

2.1. Sample and recruitment procedure

Participants were recruited when attending the ultrasound scan that is routinely conducted at week 12 of pregnancy in the gynecology services of the public health systems in the Basque Country and Catalonia (through the Donostialdea Integrated Healthcare Organization and Hospital del Mar in the case of the San Sebastian and Barcelona samples,

[1] Other studies have considered perceived restorativeness (Dzhambov et al., 2018) or perceived safety (Bracy et al., 2014; Weimann et al., 2017) as mediators, but they are not reviewed here.

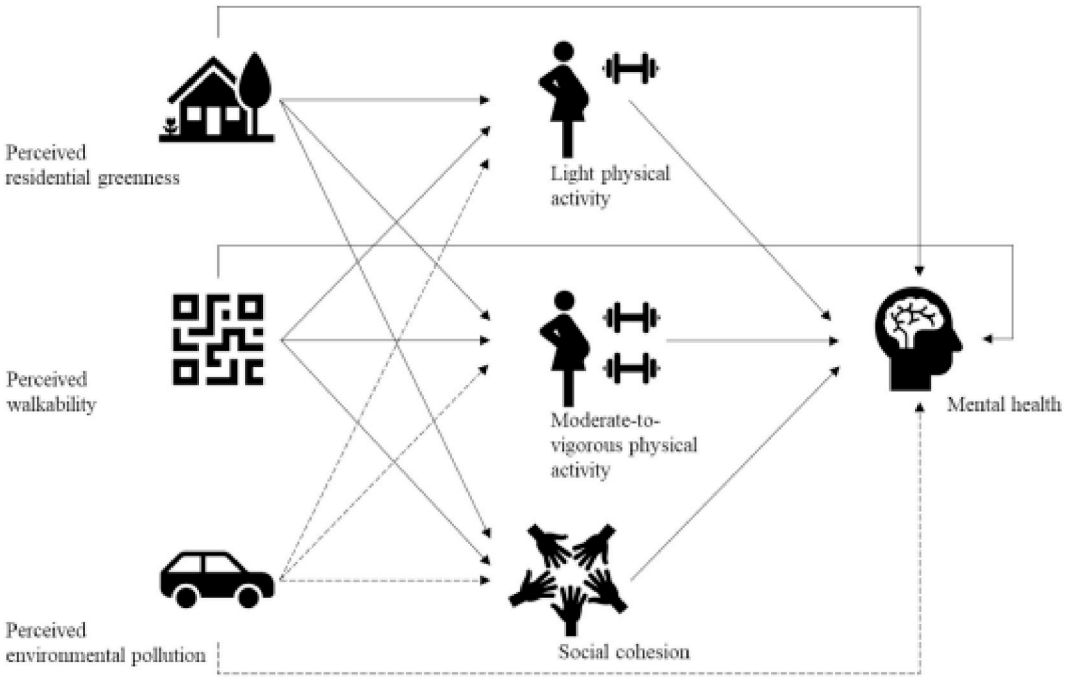

Fig. 1. Substantive model to be tested in the study. Dashed arrows indicate expected negative relationships.

respectively). Women were invited to participate in the study provided that they resided in the study area[2] and were able to communicate in Spanish, Basque or Catalan, and their pregnancy was not classified as high risk. All eligible women were provided with detailed information about the study after the ultrasound scan and asked to sign an informed consent form if showed interest in taking part in the study. Those who gave written informed consent then received the study questionnaire and an accelerometer (ActiGraph GT3X-BT; ActiGraph LLC, Pensacola, FL, USA) which they were instructed to wear for 1 week from the day of recruitment. The study protocol, part of the Urban Green Activity Reproductive Effect (UGARE) research project, was approved by the Research Ethics Committee of the Health Department of the Basque Government (reference number: PI2018108) and the Ethics Committee of the Hospital del Mar (reference number: 2018/8373/I). More information on the general characteristics of the study is available elsewhere (Anabitarte et al., 2020; Mendinueta et al., 2020). The spatial distribution of participants in each study location is showed in Fig. 2.

Supplementary Table 1 lists the descriptive data for both samples. In general, most participants had normal weight, were married, had a university education and were working at the time of data collection. Some between-sample differences were observed, namely, that the level of education and percentage of women working were both higher in the Donostia sample than the Barcelona sample.

2.2. Study variables

2.2.1. Predictors

Perceived environmental variables were measured with three different instruments included in the paper-and-pencil questionnaire. Perceived greenness (Cronbach's $\alpha = 0.72$) was assessed using three items: neighborhood greenness, green views from home windows and walking distance (in minutes) from home to the nearest park or green

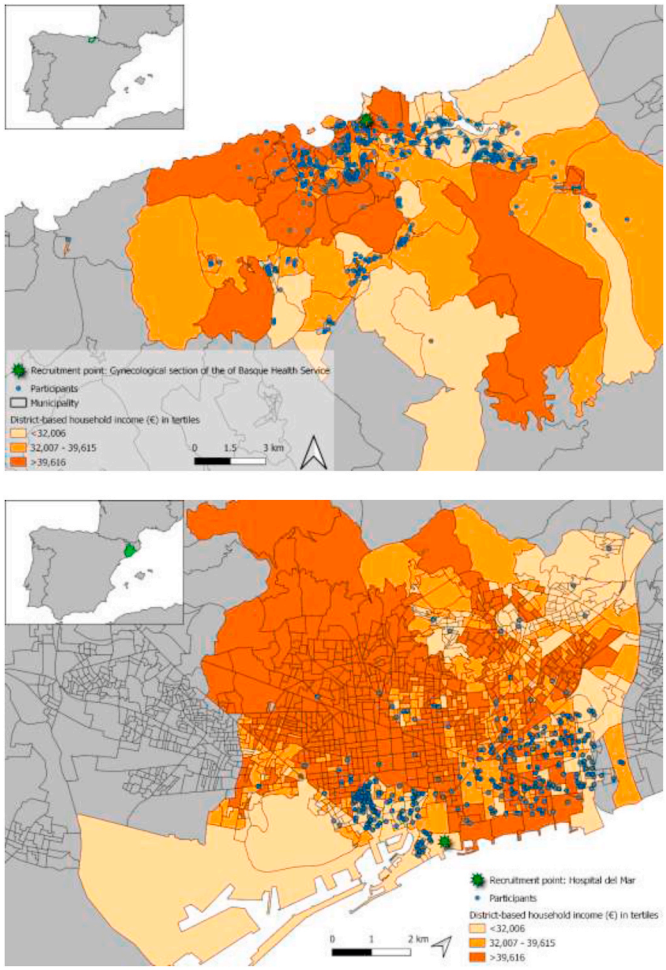

Fig. 2. Spatial distribution of participants and income district-based household income in Donostialdea (top) and Barcelona (bottom).

[2] All participants in Barcelona resided in the city. Participants attending the gynecology services of the Basque public health system resided in several municipalities included in the functional area of Donostia-San Sebastián: Astigarraga, Errenteria, Hernani, Lasarte-Oria, Lezo, Oiartzun, and Pasaia and Usurbil.

space. Items were rated on a 5-point Likert scale (1 = not at all green, 5 = extremely green) and walking distance data were converted to quartiles. Perceived walkability was measured with the Neighborhood Environment Walkability Scale – Abbreviated version (NEWS-A, Cerin et al., 2009), which is composed of 53 items covering domains such as density, land use, neighborhood esthetics and pedestrian safety. This scale showed good internal consistency (Cronbach's α = 0.89) and the raw scores were converted to z-scores, following previous recommendations (Nichani et al., 2019). Exposure to environmental pollution was operationalized with two different 0-to-10 opinion scales measuring neighborhood air pollution and environmental noise annoyance designed *ad hoc,* which also showed good internal consistency (Cronbach's α = 0.82).

2.2.2. Mediators

Physical activity was objectively assessed by the accelerometer worn by the study participants for a week. This measurement was considered representative of participant's daily activity if they wore it at least 10 h a day for at least 3 days. These thresholds were determined following previous research (Delclòs-Alió et al., 2020; Marquet et al., 2020b) Sleeping hours (23:00–06:00) were not considered, and Freedson's 1987 thresholds were used to calculate the minutes of LPA and MVPA. Even though MVPA is the type of physical activity most widely used by researchers in this field, a recent study also considered LPA (Kim et al., 2020). We understand that, as these intensities of physical activity tend to correspond to different modalities, they might not be equally determined by environmental factors or related to health outcomes (see also Pasanen et al., 2019).

To measure social cohesion, we used four items of the scale of Sampson et al. (1997) (e.g., *people in this neighborhood can be trusted)* rated on a 0 to 4 Likert scale and calculated mean scores. A higher score on these items indicates higher perceived social cohesion and trust in the neighborhood. Cronbach's alpha for this scale was 0.79. Although the scale has been extensively used in environmental epidemiology and related sciences as an overall indicator of social cohesion, it clearly reflects notions of both classical definitions of social cohesion (e.g., trust and attachment to the community) and sociological-network approaches focused on the availability of resources within communities and generally gathered under the term of social capital (Carpiano, 2006; Ehsan et al., 2019; Yip et al., 2016).

2.2.3. Outcome

Participants' psychological health status during the first trimester was measured with the Spanish version of the 12-item General Health Questionnaire (Rocha et al., 2011). The items are related to various psychological symptoms (e.g., *have you felt sad or depressed)* and aspects of daily functioning and rated on a 4-point Likert scale (0–3), respondents being asked to report whether they have experienced such problems and to what extent. The scores are summed to a total score, ranging from 0 to 36, and higher scores indicate a worse psychological state and/or a greater experience of stress. The internal consistency of the scale for this study was good (α = 0.77).

2.2.4. District-based socio-economic status

Participants' socio-economic status was determined via data available in the Spanish National Statistics Institute (INE[3]), of which we selected the average household income per census district in 2017.

2.3. Data analyses

We used R software v. 4.0.3 (R Core Team, 2020) to conduct all statistical analyses. As initial descriptive analyses, we performed correlations and *t*-tests to assess the relationships between study variables and the possible between-city differences in them. We then used structural equation modelling (SEM) to model the relationships between the perceived environmental variables (residential greenness, walkability and pollution), the set of mediators selected (LPA, MVPA and social cohesion) and mental health hypothesized in our theoretical framework (see Fig. 1). For this, we followed the guidelines of Grace et al. (2012). We decided to fit separate models for the two cities, using the meta-model presented in Fig. 1 and employing data from only complete cases[4] (see Fig. 3). The assumptions of linearity in the relationships between continuous variables and Gaussian error terms is necessary for structural equation modelling and, following Tukey's (1977) suggestions summarized in Supplementary Figures 1 and 2, we square-root transformed MVPA, squared social cohesion and fourth-root transformed income variables. This was sufficient to ensure the linearity of relationships, and hence, the suitability of the global estimation method. We then constructed a meta-model based on previous theoretical knowledge and empirical results (Fig. 1) and applied global estimation with the maximum likelihood method (Grace et al., 2012). The meta-model was thus tested using the sem() function of the R package lavaan (Rosseeel, 2012) and discrepancies between the data and the fitted models were assessed with the function modindices() from the same package. Then we conducted an iterative process that assessed data-to-model consistency using chi-square tests, which ended when the null hypothesis of model consistency could not be rejected (chi-square p-value $> .05$) and the output of the modindices() function suggested no additional modifications. Additionally, two other goodness-of-fit measures were used: the comparative fit index (CFI) and the root mean square error of approximation (RMSEA) (Chen et al., 2008; Kenny and McCoach, 2003; Kenny et al., 2015). A model was considered definitive when the chi-square p-value was greater than 0.05, CFI greater than 0.95 and RMSEA less than 0.05. Due to the limited sample sizes, especially in the case of Barcelona, we contemplated all the relationships with p-values $< .10$, albeit, finally, only one relationship with $0.10 < p$-value $< .05$ was included in a fitted model (all other included relationships had p-values $\leq .05$).

3. Results

Supplementary Tables 2 and 3 show the distribution of the study variables in the two samples. In the exploratory analyses (Supplementary Figures 1 and 2), several statistically significant correlations were detected. In Donostia (Supplementary Figure 1), perceived residential greenness was positively associated with perceived walkability ($r = 0.17$, $p = .005$), LPA ($r = 0.14$, $p = .015$) and social cohesion ($r = 0.30$, $p < .001$), while perceived environmental pollution was negatively associated with social cohesion ($r = 0.15$, $p = .011$), and social cohesion was negatively associated with mental health ($r = -0.22$, $p < .001$). No other relationships were observed between predictors, mediators and the outcome of interest, namely, mental health. In Barcelona (Supplementary Figure 2), associations were found between perceived greenness and perceived walkability ($r = 0.38$, $p < .001$) and between perceived walkability and perceived environmental pollution ($r = -0.16$, $p = .045$). Perceived greenness was also linked to MVPA ($r = -0.17$, $p = .039$), while LPA and MVPA were negatively correlated ($r = -0.17$, $p = .032$). Social cohesion was associated with perceived greenness ($r = -0.22$, $p = .006$), perceived walkability ($r = 0.39$, $p < .001$), perceived environmental pollution ($r = -0.26$, $p = .001$) and mental health ($r = -0.23$, $p = .004$).

[3] Information available in https://www.ine.es/jaxiT3/Tabla.htm?t=31007&L=0. Accessed on 15/01/2020.

[4] A series of *t*-tests was conducted to determine whether complete cases differed from the entire sample. There were no significant differences in Donostia's sample, but complete cases in Barcelona seemed to differ in walkability [$t = -2.57$, $p = .010$, $d = 0.12$] and income [$t = -1.85$, $p = .066$, $d = 0.17$], with complete cases having higher walkability and income scores.

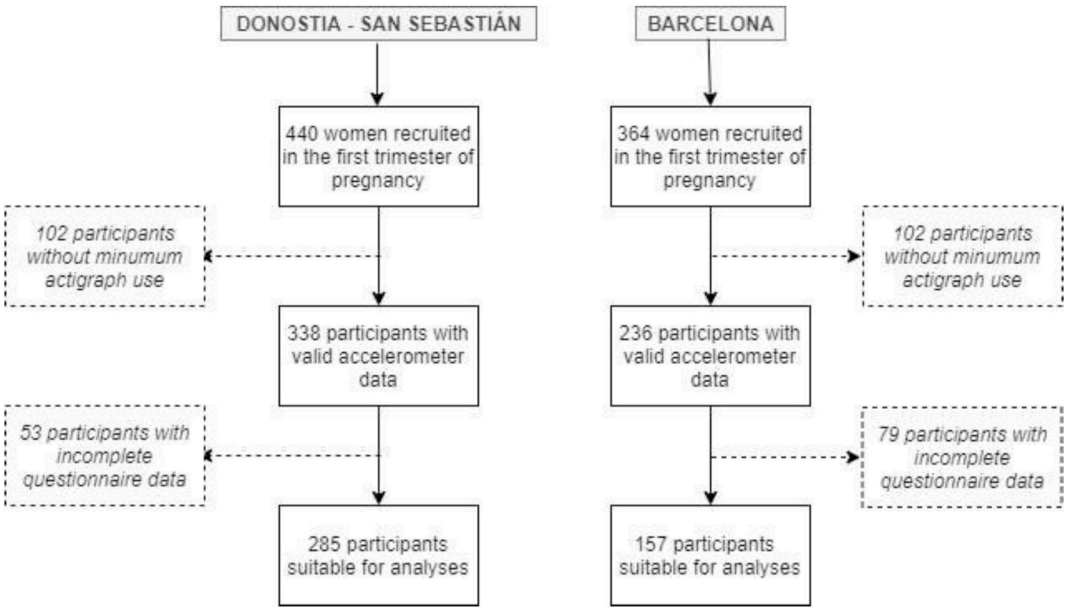

Fig. 3. Flow of participants though the study to inclusion in the structural equation modelling analyses reported in this manuscript.

Independent-samples *t*-tests were conducted and revealed that participants in the Donostia sample perceived their residential environment to be more green [$t(645) = 9.32$, $p < .001$, $d = 0.76$] and less affected by environmental pollution [$t(651) = -9.52$, $p < .001$, $d = 0.75$] than their counterparts in Barcelona. Further, in the Donostia sample, women did more light PA [$t(576) = 2.18$, $p = .029$, $d = 0.18$], reported higher social cohesion [$t(613) = 6.37$, $p < .001$, $d = 0.52$] and lived in households with a higher income [t(799) = 9.37, $p < .001$, $d = 0.67$]. No differences were detected for walkability, MVPA or GHQ score.

3.1. Structural equation models

The model fitted to the Donostia sample achieved a very satisfactory goodness of fit [X2(3) = 2.56, p = .465, CFI = 1, RMSEA < 0.001] and explained a small percentage of variance in mental health (4.7%). Only 4 of the 15 proposed paths were confirmed and none of the predictors were directly associated with the outcome of interest (see Fig. 4). Results show that perceived greenness increased light PA (0.12), but this effect was not then connected with mental health. MVPA was not associated with any other variable included in the model. Perceived greenness (0.31) and walkability (0.10) increased social cohesion, which in turn exerted a positive influence on mental health (−0.22; lower GHQ scores being indicative of better mental health). This is the only full mediation path that was confirmed. Full model results are presented in Table 1.

The model fitted with data from the Barcelona sample (Table 2) yielded a fair goodness of fit [$X^2(6) = 4.83$, $p = .566$, $CFI = 1$, $RMSEA = < 0.001$] and explained a slightly higher percentage of variance in mental health (5%). In this case, significant results supported 5 of the 15 paths but we were not able to confirm any direct associations between the predictors and the outcome (see Fig. 5). None of the variables included in the model was significantly associated with LPA, but perceived greenness and walkability were linked to MVPA (−0.25 and 0.21 respectively), although this intensity of physical activity was not in turn associated with mental health. The only path that was fully

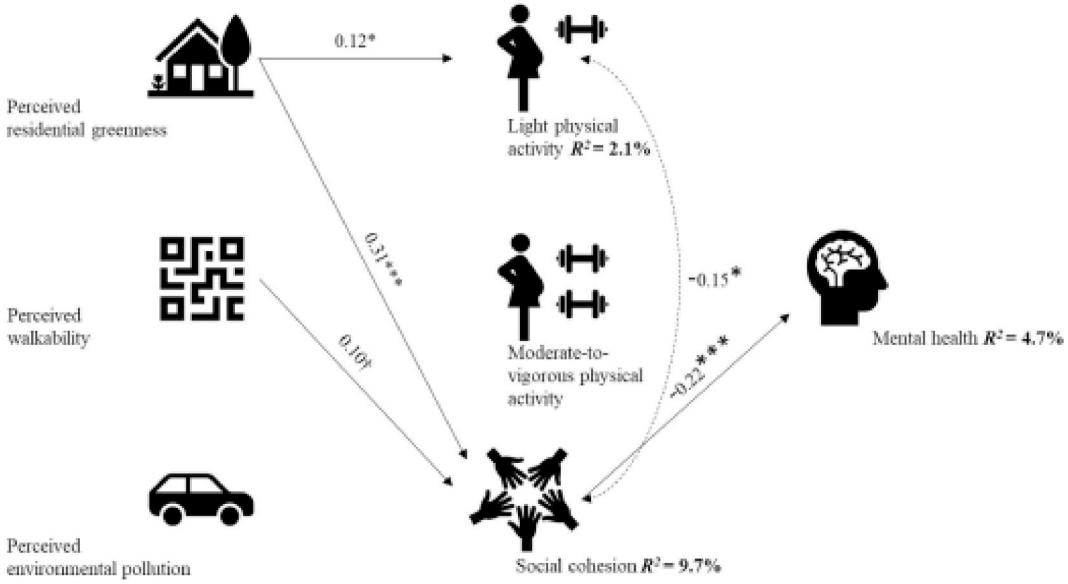

Fig. 4. Final structural equation model fitted with data from the Donostia sample. † = $p < .10$, * = $p < .05$, *** = $p < .001$. R^2 = explained variance.

Table 1
Non-Standardized effect sizes, together with standard errors, z-values and p-values for the structural equation model depicted in Fig. 3 (where standardized coefficients are provided). These results correspond to Donostia sample.

From	To	Estimate	Std. Error	95% CI	*z*-value	*p*-value
Perceived greenness	LPA	13.10	5.34	2.63–23.56	2.45	.014
	Social cohesion	1.40	0.26	0.90–1.90	5.49	<.001
Perceived walkability	Social cohesion	0.10	0.06	−0.01–0.21	1.75	.081
Social cohesion	Mental health	−0.21	0.06	−0.32 – (−0.10)	−3.73	<.001

Note: LPA: light physical activity; MVPA: moderate-to-vigorous physical activity; Std.: standard.

Table 2
Non-standardized effect sizes, together with standard errors, z-values and p-values for the structural equation model depicted in Fig. 4 (where standardized coefficients are provided). These results correspond to Barcelona sample.

From	To	Estimate	Std. Error	95% CI	*z*-value	*p*-value
Perceived greenness	MVPA	−0.57	0.19	−0.95– (−0.19)	−2.94	.003
Perceived walkability	MVPA	0.10	0.04	0.02–0.19	2.47	.013
	Social cohesion	0.39	0.08	0.24–0.54	4.55	<.001
Perceived environmental pollution	Social cohesion	−0.27	0.10	−0.47 – (−0.08)	−2.72	.007
Social cohesion	Mental health	−0.24	0.08	−0.41 – (−0.08)	−2.89	.004

Note: LPA: light physical activity; MVPA: moderate-to-vigorous physical activity; Std.: standard.

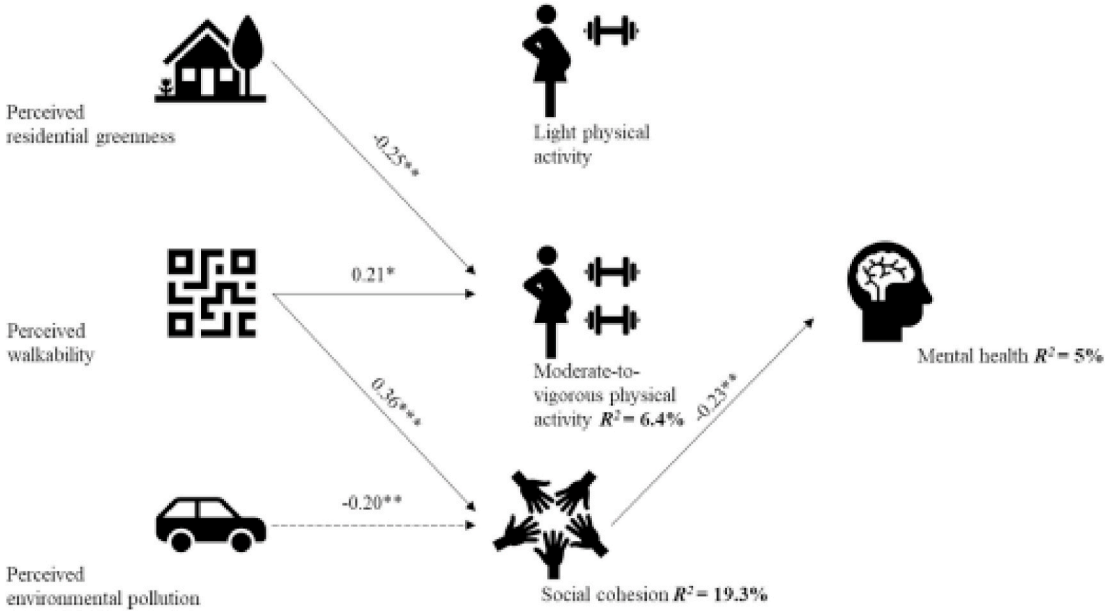

Fig. 5. Final structural equation model fitted with data from the Barcelona sample. * = $p < .05$, ** = $p < .01$, *** = $p < .001$. R^2 = explained variance.

confirmed was through social cohesion, which was determined by perceived walkability (0.36) and environmental pollution (−0.20), and was again negatively related to mental health (−0.23).

3.2. Effect modification by income

District-based household income was positively related to walkability ($r = 0.13$, $p = .029$) and social cohesion ($r = 0.18$, $p = .002$) in the Donostia sample. In the Barcelona sample, income was positively associated with perceived greenness ($r = 0.29$, $p = < 0.001$), perceived walkability ($r = 0.19$, $p = .015$) and social cohesion ($r = 0.25$, $p = .002$).

In order to ascertain whether income moderated the relationships between model variables in the Donostia sample, we re-estimated path coefficients separately for participants with low (n = 98), medium (n = 95) and high (n = 92) incomes without otherwise altering the model structure (Fig. 1). This analysis showed that the link between perceived greenness and social cohesion was consistent across the three income groups (0.29–0.37) but that the link between perceived walkability and social cohesion was only statistically significant in the high-income group (0.21). Further, and more interestingly, we detected that social cohesion only exerted a positive influence on mental health in the low (−0.20) and medium (−0.28) income groups. The effect was in the same direction for high-income participants but did not reach statistical significance. No other differences were detected in comparison to the full sample solution (Fig. 3, Table 1). Full model results are provided in Supplementary Table 4. This analysis was not repeated with the Barcelona sample due to its small sample size.

4. Discussion

Most studies in environmental epidemiology focusing on pregnant women have explored the association of neighborhood physical attributes with outcomes such as preterm birth or birth weight (Anabitarte et al., 2020; Dadvand et al., 2012, 2014; Gray et al., 2014; Nieuwenhuijsen et al., 2013, 2019; Ristovska et al., 2014). Our interest in this study was to analyze their influence on maternal mental mental health

during pregnancy, which is also an important health outcome (Accortt et al., 2015; Baird et al., 2009; Flanigan et al., 2018; Lima et al., 2018; Rusconi et al., 2019). Building on previous research in other populations (Dzhambov et al., 2017; Dzhambov et al., 2018a, b; Ye Liu, Wang, Grekousis, et al., 2019; Sugiyama et al., 2008), we proposed a meta-model specifying a total of 15 paths between 3 environmental predictors (perceived greenness, perceived walkability and perceived environmental pollution), 3 candidate mediators (LPA, MVPA and social cohesion) and mental health, the outcome of interest.

Initial analyses showed small-to-moderate correlations between predictors and some of the candidate mediators, of which only social cohesion was significantly related to mental health. Further, we detected that the women in the Barcelona sample lived in less green and more polluted residential environments, did less LPA per day, reported lower social cohesion and resided in lower income households than their counterparts in the Donostia sample. The differences were large in the case of neighborhood attributes, moderate in social cohesion and small in LPA.

More relevant to our study objective, we were able to obtain two models showing good to excellent fit indices which revealed a consistent effect of neighborhood variables on mental health through the strengthening of social cohesion. In Donostia, social cohesion was predicted by perceived greenness and walkability, whereas in Barcelona, perceived walkability and environmental pollution were the relevant correlates. Although results are inconclusive (Botterman et al., 2012; Hooghe and Botterman, 2012; Martin et al., 2017), it has been posited that social cohesion may differ quantitatively and qualitatively between towns and cities of different sizes – as is the case of Donostia and Barcelona. In our study, we detected moderate size between-city differences in social cohesion and observed that this variable was not determined by the same set of neighborhood attributes in the two samples (the only overlap being in perceived walkability). Nonetheless, a similar link was found between social cohesion and maternal mental health during pregnancy in both cases. We also found that physical activity levels were weakly influenced by neighborhood attributes and that they were not associated with mental health in either city. Here, we also saw that perceived greenness was negatively associated to MVPA in Barcelona. Other authors have explained this counterintuitive result arguing that greener environments might show lower levels of urbanization and therefore less human-made features supporting walking or exercising (e.g. walkability; see Gascon et al., 2019; Marquet et al., 2020a). This does not directly mean that urban greenness is a negative factor given that it improves human health through various pathways besides the promotion of physical activity (Dzhambov et al., 2020; Markevych et al., 2017).

These results are compatible with findings of other studies testing greenness and environmental pollution pathways to human health (Dzhambov et al., 2017; Dzhambov et al., 2018a, b; McEachan et al., 2016; Sugiyama et al., 2008) but did not succeed in confirming all the pathways proposed as has been done in research elsewhere (Liu et al., 2019a). Our failure to obtain positive results regarding physical activity might be related to our choice of measures. The studies cited above relied on self-report data, using validated questionnaires in only half of cases. To our knowledge, our study is the first using accelerometer data with pregnant women and a multiple pathways approach. We encourage further research seeking to replicate our findings using objective physical activity data to ascertain whether the lack of effect observed here is generalizable or an exception.

Our data also allowed us to study effect modification by socioeconomic status in the Donostia sample. In line with previous literature (Dadvand et al., 2014; McEachan et al., 2016; Mitchell et al., 2015; Mitchell and Popham, 2008), we found that social cohesion only predicted mental health in the low- and medium-income groups. This meets the results of a recent study showing that social cohesion protected against feelings of loneliness in a sample of elder adults but only for those reporting low and medium subjective social status (Yu et al., 2021). Authors of that study reasoned that socioeconomically challenged people have less individual resources to meet every day needs and subsequently the presence or absence of social support would make a difference for mental health (see also Veenstra et al., 2005). Another possibility is that high-SES populations have access to resources (e.g. better working conditions, high quality health services and housing, increased leisure and tourism participation) with greater implications for mental health which turn the impact of social cohesion negligible. Unfortunately, data gathered in this study does not allow to test any of these speculations. The observed negative association between perceived walkability and LPA in the low-income group might be explained by unmeasured social and environmental factors that could hinder physical activity in relatively walkable environments. Previous studies have evidenced that low-income neighborhoods tend to have lower levels of maintenance and a higher sense of insecurity (Franzini et al, 2008, 2010). Nonetheless, we are not able to assess whether this was the case for the low-income participants in the Donostia sample with the data collected for this study. Despite our inability to disentangle the mechanisms behind these patterns in our results, they clearly indicate that improvements in the quality of neighborhood environments can help to reduce health inequalities during pregnancy.

4.1. Strengths and limitations

In view of the current state of the art regarding environmental correlates of mental health, this study is of interest due to the use of three different neighborhood attributes, which allowed us to analyze the effects of each one after controlling for the others, which is not possible in studies considering only one predictor (Dzhambov et al., 2017; Liu et al., 2020; Sugiyama et al., 2008). Additionally, the use of two variables to describe objective physical activity (light and moderate-to-vigorous) is a strength of the study. Finally, this research is also relevant because we studied a specific population, namely, pregnant women, that is potentially very important from a public health perspective. Studies on greenspace pathways, or indeed on other environmental factors and using a pathway approach, have rarely studied a period as distinctive as pregnancy (Dzhambov et al., 2020), although some researchers have focused on breast cancer patients (O'Callaghan-Gordo et al., 2018) and depressive symptoms in older women (Banay et al., 2019). Our study is, after that of McEachan et al. (2016), the second on spatial determinants of mental health during pregnancy which has used pathway analysis.

On the other hand, this study also has several limitations which need to be taken into account when interpreting its results and drawing conclusions. The samples were relatively small due to large amounts of missing data, and this may have undermined our ability to find significant effects due to low statistical power, even though the complete cases were closely comparable to the missing ones. Self-selection and single source biases should be considered as participants were voluntary and most of the study variables — with the exception of physical activity and district-based household income — were obtained through self-report questionnaires, that is, from the same source. Finally, it may be that our participants spent relevant amounts of time in places other than their immediate residential environment (Kwan, 2009, 2012). If so, environmental attributes of those settings would have been more closely linked to some of the candidate mediators (e.g. LPA and MVPA) and mental health, the outcome of interest. Despite the fact that this bias has been correctly detected in the literature, most studies in the area suffer from the same limitation (McEachan et al., 2016; Sugiyama et al., 2008; Liu et al. 2019a, 2019b) and more solid approaches are needed in future studies. Perceptions of the urban environment are thought to be good indicators of individuals' cognitive representation of their residential neighborhood and are therefore recommended to study its effects on health (Choi et al., 2015; Dzhambov et al., 2018). Despite this, the question of whether objective or subjective measures should be used is still open (Lin and Moudon, 2010; Shatu et al., 2019; Tilt et al., 2007; Zhang et al., 2019) and it is currently recommended to use both (Bailey

et al., 2014; Nyunt et al., 2015; Orstad et al., 2017; Sallis et al., 2020). In future research, it would be of great interest to build models with both objective and perceived environmental variables to assess the importance of each kind of measure in the presence of the other.

5. Conclusion

In the pursuit of healthier and more sustainable cities, we must improve our understanding of which neighborhood attributes promote healthier lifestyles and reduce dependency on fossil fuels (Forum, 2016; United Nations, 2015, 2018). Indeed, the United Nations' Sustainable Development Target 11.2 (United Nations, 2015) calls for special attention to be given the needs of those in vulnerable situations, women, children, persons with disabilities, older persons and low-income populations. Only if we implement urban policies thinking of these groups will we be able to achieve healthy, sustainable and inclusive environments to improve people's health and well-being. This study contributes to that endeavor by showing that, in a sector of the population with special needs due to the vulnerability associated with pregnancy, residential greenness, walkability and environmental pollution do influence social cohesion which in turn is linked to better psychological health and might serve to inspire urban policies and initiatives promoting these goals.

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Declaration of competing interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

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Appendix A. Supplementary data

Supplementary data to this article can be found online at https://doi.org/10.1016/j.envres.2021.111192.

Credit author statement

Mikel Subiza-Pérez: Conceptualization, Methodology, Formal analyses, Writing- original draft. Gonzalo García-Baquero: Conceptualization, Methodology, Formal analyses, Writing- Review & Editing. Izaro Babarro: Investigation, Writing- Review & Editing. Asier Anabitarte: Investigation, Writing- Review & Editing. Xavier Delclòs-Alió; : Investigation, Writing- Review & Editing. Guillem-Vich: Investigation, Writing- Review & Editing. Oriol Roig-Costa: Investigation, Writing-Review & Editing. Carme Miralles-Guasch: Conceptualization, Writing-Review & Editing. Nerea Lertxundi: Conceptualization, Writing- Review & Editing. Jesús Ibarluzea: Conceptualization, Writing- Review & Editing, Supervision.

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