HIRIKO GUNE BERDEEK OSASUNEAN DUTEN ERAGINA AZTERTZEN: HIRU IKERKETA EPIDEMIOLOGIKO

ASIER ANABITARTE RIOL

eman ta zabal zazu

Universidad del País Vasco
Euskal Herriko Unibertsitatea

2022

MEDIKUNTZA ETA ERIZAINTZA FAKULTATEA

PREBENTZIO MEDIKUNTZA ETA OSASUN PUBLIKOA SAILA

DOKTOREGO-TESIA

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ZUZENDARIAK:

AITANA LERTXUNDI MANTEROLA

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DONOSTIA – SAN SEBASTIÁN

2022

Universidad del País Vasco Euskal Herriko Unibertsitatea

MEDIKUNTZA ETA ERIZAINTZA FAKULTATEA
FACULTAD DE MEDICINA Y ENFERMERÍA

Universidad del País Vasco Euskal Herriko Unibertsitatea

MDe
Master eta Doktorego Eskola
Escuela de Máster y Doctorado
Master and Doctoral School

Asier Anabitarte Riolek, doktorego-tesi honen egileak, eskerrak eman nahi dizkio Eusko Jaurlaritzako Hezkuntza, Hizkuntza politika eta Kultura sailari, doktore tesia egiteko jasotako diru-laguntzagatik.

Esker onak

Ez nintzateke puntu honetaraino iritsiko askoren laguntzagatik izango ez balitz, izan zuzenean edo izan zeharka. Beraz, garrantzitsua iruditzen zait modu batera edo bestera lagundu didazuenei eskertzea. Eskerrak eman nahi dizkiet ere hitz hauetan agertzen ez diren baina momenturen batean zoriontsu egin nauzuen guztiei. Badakizue ez naizela idatziz asko luzatzekoa, baina benetan oso eskertua nago zuek danoi.

Lehenik eta behin, mila esker Aitana eta mila esker Jesús. Ikerketa taldeko ateak irekitzeagatik, mundu berri bat zabaltzeagatik eta erakutsitako guztiagatik. Eskerrik asko, tesian zehar beti hor egoteagatik, emandako aholku eta zuzenketa guztiengatik, beti adeitsu eta umore onez. Eskerrik asko nigan jarritako konfiantzagatik.

Eskerrik asko Loreto, engranaje bat den ikerketa talde honek funtzionatzeko ezinbesteko pieza. Buru horretan dagoen informazio guztia ez da T/INMAn sartzen! Eskerrik asko, zure prestutasunagatik eta lan guztiagatik.

Eduki ditudan lankide jatorrei ere eskerrik asko. Zuekin batera lan egitea oso erraza eta atsegina da, eskerrik asko denei beti laguntzeko prest egoteagatik. Eskerrik asko tesiko momentu ezberdinetan jasotako laguntzagatik, bai laguntza teknikoa eta bai laguntza animikoagatik, denek dute balio handia.

Moltes gràcies als companys de ISGlobal per acollir-me amb els braços oberts. Gràcies sobretot a la Sala Hipatia i al GIS Team. Antonia, Marta, Montserrat i Albert, em vau obrir un nou món GIS, gràcies per estar sempre disposats a ensenyar-me. Equip "Vamos a comer?" gràcies pels bons moments!

Mila esker, tesi hau posible egin duzuen partaide guztiei, INMAko familiei, UGAREko haurdunei eta Zarautz eta Jakintza eskoletako zuzendari, irakasle eta ikasleei. Ezinbestekoak zarete ikerketak aurrera eraman ahal izateko. Eskerrik asko zuen borondatetasunagatik. Eskerrik asko ere kohorteen sortzaileei, baita jarraipen fase bakoitzean datu bilketan lanean egon zareten guztiei.

Eskerrik asko kuadrillari, erreferente izateagatik eta bizitako momentu on guztiengatik! Mila esker ere, kuadrilaz gain ondoan egon zareten lagunei, Ainhoaren kuadrilari batez ere.

Eskerrik asko Ainhoa, urte hauetan guztietan bidelagun ezin hobea izateagatik eta azken etapa honetan emandako babes guztiagatik.

Familiari, eskerrik asko. Eskerrik asko ama eta aita, denagatik, sostenguagatik, emandako heziketagatik eta maitasunagatik. Eskerrik asko Pili, zaintza guztiengatik, pazientziagatik eta erakutsitako guztiagatik. Lucio, Bernardo, Eugenia eta Xeberiri sortu duzuen familiagatik eta askoz gehiagogatik, eskerrik asko.

Akronimoak

MOE: Munduko Osasun Erakundea

NBE: Nazio Batuen Erakundea

GIS: Geografia Informazio Sistema

NDVI: Normalized Difference Vegetation Index

VCF: Vegetation Continuous Field

NIR: Near Infrared (Infragorri hurbila)

LiDAR: Light Detection and Ranging

GSV: Green Street View

UGARE: Urban Green Activity and Reproductive Effects

ESI: Erakunde Sanitario Integratua

INMA: Infancia y medioambiente

ANT: Attentional Network Test

DAG: Directed Acyclic Graph

QR: Quick Response

Laburpena

Doktorego-tesi honek gune berdeek osasun adierazle ezberdinetan, zehazki ugalketa osasunean eta atentzioan, duten eragina aztertu da. Horretarako, hiru ikerketa epidemiologiko egin dira. Lehenengo lanean, etxebizitza inguruko gune berdeek ugalketa osasunean duten eragina aztertzen da, bitartekari ezberdinak kontuan edukiz eta emakume haurdunak izanik parte hartzaileak. Bigarren lana eskoletako haurrekin egin da, gune berde edo gune girs batera joateak partaideen atentzioan eduki dezakeen eragina aztertuz. Hirugarren lanean, INMA proiektuko partaideak erabili dira, gune berdeek hauen atentzioan epe luzeera izan dezakeen eragina aztertuz. Ondoren, hiru lanetan lortutako emaitzen laburpen bat eta eztabaida nagusi bat egin dira. Gainera, dibulgaziorako bideo eta artikulu bana egin dira informazioa gizarteratze aldera. Azkenik, tesiaren ondorio nagusiak idatzi dira.

Aurkibidea

I.atala: Hasierako atala. Esparru teorikoa, metodologia, emaitzen laburpena eta eztabaida

1. Justifikazioa

Aldaketa klimatikoa eta urbanizazioa, mundu garaikidean ematen diren prozesuak dira, non bien arteko berrelikadura efektuak eragin negatiboak eduki ditzakeen gizakion osasunean (UN-Habitat, 2011). Hori dela eta, urbanizazioa XXI. mendeko osasun publikoaren erronketako bat bilakatu da. Hirietan bizi den biztanleri kopurua etengabean ahazten doa, kasu askotan hirietako oinarrizko baliabideak biztanleriaren behar guztiak ase ezin dituelarik (Vlahov et al., 2006). 2018an dagoeneko, munduko biztanleriaren artean, gehiago ziren hirietan bizi zirenak (%55) herrietan bizi zirenak baino, are gehiago, 2050. urterako munduko biztanleriaren %68a hiri guneetan bizitzea aurreikusten da. Europan, jada, biztanleriaren %75a hiri guneetan bizi da (EEA, 2020c; United Nations, 2018). Hau ikusirik, Nazio Batuen Erakundeak garapen jasangarrirako 11. helburutzat ondorengoa ezarri zuen: hiriak eta giza kokaguneak inklusiboak, seguruak, erresilienteak eta jasangarriak izatea. Ildo beretik, garapen jasangarrirako 3. helburua; guztiontzat eta adin guztietan bizimodu osasungarria bermatzea eta ongizatea sustatzea da (United Nations, 2020). Bi helburu hauek betetze aldera, gune berdeak garrantzitsuak izan daitezke hirien etorkizunean. Historian zehar askotan goraipatu da gune berdeek osasunean duten eragina, nahiz eta, mekanismoak zeintzuk ziren oso ondo ez jakin (Schuyler, 1986). XXI. mendean garatutako teknika berriei esker, ordea, mekanismo hauei buruz zegoen ezagutza zabaldu egin da (WHO Regional Office for Europe, 2016). Hortaz, ebidentzia zientifikoetan oinarrituz, hiri plangintzan eta diseinuan jarduten duten teknikariei erabakiak hartzeko argudioak ematea dagokigu..

Tesia UPV/EHUko EANPsi (Ingurumen epidemiologia eta umeen neuropsikologia) eta Biodonostia Osasun Ikerketako Institutuko Ingurumen Epidemiologia eta Haurren Garapena ikerketa taldean garatu da, bien helburu nagusiak ingurumenak haurren garapen fisiko zein neuropsikologikoan duten eragina aztertzea delarik.

Tesi hau artikuluen bilduma bidez egin da, tesia osatzen duten hiru artikuluak *Journal Citation Reports* datu basean zerrendatutako aldizkari zientifikoetan argitaratuak. Horregatik, tesi honek jarraitzen duen egitura hurrengoa da. Lehenengo atalean sarrera, esparru teorikoa, hipotesiak eta helburuak, emaitzen laburpena eta eztabaida orokorra. Bigarren atala tesiaren ondorio nagusiek eta erreferentziek osatzen dute eta azkenik, hirugarren atalean, eranskin modura, hiru ekarpen zientifikoak. Euskarako C2 titulua eskuratze aldera, tesia, bere osotasunean, euskaraz idatzia dago.

2. Esparru teorikoa

2.1. Sarrera

Landa guneetan eman den eta ematen ari den biztanleri galera ez da gertakari zehatz batzuen harira gertatu, egiturazko sistema batengatik izan da, nahiz eta gertakari zehatz batzuk prozesua azkartu duten. Hala nola, industrializazioak, hazkunde ekonomiko modernoak edota urbanizazioak (Delgado Viñas, 2019). Landa guneen despopulatzea 1950. urtean hasi zen Espainian, hirietan lan aukera eta soldata hobeen eskaintzearen ondorioz, landa guneko biztanleak hirietara joan ziren bizitzera (Camarero et al., 2009; Collantes & Pinilla, 2004, 2011). 1950. urtean munduko biztanleriaren %30a soilik bizi zen hiri guneetan, 2018 aldiz, %55era igo zen eta 2050. urterako munduko biztanleriaren %68a izatea espero da. Europan, berriz, gaur egun, biztanleriaren %75a bizi da hirietan (EEA, 2020c; United Nations, 2018).

Hirietako biztanleria hazi izanak hirietako osasun baldintzak okertzea ekarri zuen (Jori, 2013). Hiri industrialetan eman ziren arazo nagusiak, aire kutsadura, jende pilaketak, hondakinen isurketa kontrolatugabea, hondakinen pilaketak eta edateko uraz hornitzeko berme eza izan ziren. Estolda-sail baten falta izateak askotan hondakin-urak akuiferoetan filtratzea zekarren eta ondorioz, hainbat epidemia eman ziren XIX. mendeko lehen erdian. Hori dela eta, Edwin Chadwick-ek *sanitary movement* mugimendua bultzatu zuen industri hirietan. Johann Peter Frankek Ilustrazio garaian osasun arazoak azaleratu bazituen ere, *sanitary movement* izan zen XIX.mendeko lehen erdiko osasun publiko mugimendu garrantzitsuena. Mugimendu honi esker, 1843. urtean *Health of Towns Commission*-a eratu zen, bi txosten argitaratuz - bertan, *sanitary movement*-aren helburuak nolabait ofizilizatuz- hauetan sareen hobekuntza bultzatzeaz gain, hauek ikuskatzea eta denek ezarpen bera edukitzea gomendatzen zioten gobernu zentralari. Honela, 1848an parlamentuak Osasun Publikoaren legea onartu zuen, zeinetan hirietako administrazioek hirietan osasun hobekuntzak egiteko eskumena zuten, gobernuaren gainbegirada eta laguntzarekin (Ramos Gorostiza, 2014). Leonardo Benevolo-ren arabera, osasun legea onartzearen harira, momentu oso garrantzitsu bat ematen da hiri plangintzan, izan ere, lege honi esker, industri hirietan dauden osasun arazoak konpontzen hasten dira eta hiriak plangintza batean oinarrituta hasten dira hazten (Benevolo, 1994).

Sanitary movement-ak influentzia handia eduki zuen Europa eta Ameriketako Estatu Batuetan. Espainian, esaterako, Mateo Seoane izan zen pertsonaiarik aipagarriena. Seoane Londresen egon zen erbestean eta bertan zegoelarik Jeremy Bentham-en influentzia jaso zuen. Benthamen eskutik ezagutu zuen Seoanek Britainia Handiko osasun publikoaren mugimenduaren hasiera, bertan parte hartzera iritsiz. Espainiara itzuli zenean, Londresen jasotako influentzia horiek guztiak, bere, bi ikasleri helarazi zizkien; hauek Pedro Felipe Monlau eta Francisco Méndez Álvaro izan ziren. Honela hiruko hau izan zen

Espainiako industri hiriak osasun ikuspegi batetik hobetzearen errudun nagusiak (Alcaide González, 1999; Ramos Gorostiza, 2014).

Gaur egungo hiriek ere osasunean eragina dute, hainbat faktore direla medio. Gero eta nabariagoa den faktoretako bat automobil pribatuaren mendekotasuna da (Fariña-Tojo, 2019; WHO, 2008). Europan, Bigarren Mundu Gerra ondoren eman zen aldaketako bat izan zen autoek hirietan hartu zuten nagusitasuna. Autoek, ordura arte hiritarrek betetzen zituzten lekuak konkistatu zituzten eta hiritarrak kale bazterrera bultzatu zituzten. Europan, gaur egun, hiri lurraren %70a ibilgailuentzat bideratzen dira. Hiriak ibilgailuak erdigune zirela eraiki ziren, biztanleri osoak erabili ditzakeen garraio publikoko geltokiak- izan trena, izan autobusa- bigarren maila batean utziz. Hiriko espazio nagusia hartzeaz gain, ibiltarien mugikortasuna ere oztopatzen dute autoek eta hauentzat sortutako azpiegiturek: semaforoen bitartez mugimendu librea oztopatuz, semaforoetako denbora tarteetan autoak lehenetsiz edota zebra-bideen kokapenek bide zuzenena baldintzatuz. Aipatutako guztiaz gain, autoek hirietan ordura arte eman ez zen gertakari bat eragin zuten, izan ere, ibilgailuei esker dentsitate baxuko bizitegi-guneak eraikitzen hasi ziren (Brau, 2018), ordura arteko hiriak guztiz moldatuz eta autoarekiko zegoen dependentzia areagotuz (WHO, 2008).

Gaur egun ezagutzen ditugun hiriak autoari bideratutako hiriak dira eta honek ondorio larriak ditu hiritarren osasunean. Autoekiko dependentzia izateak hiriko bizimodu sedentarioa bultzatzen du, hau da, jarduera fisiko eza. Gainera, isolatze soziala, estresa, aire kutsadura eta kutsadura akustikoa ere bultzatzen ditu (Fariña-Tojo, 2019). Aire kutsadurari dagokionez, NO_2-ak, zein trafikoari oso lotua dagoen kutsatzailea den, Europan 2018. urtean 55000 hildako goiztiar eragin zituela estimatu zen (EEA, 2020a). Zaratak berriz, 12000 hildako goiztiar eragin zituela estimatu zen (EEA, 2020b).

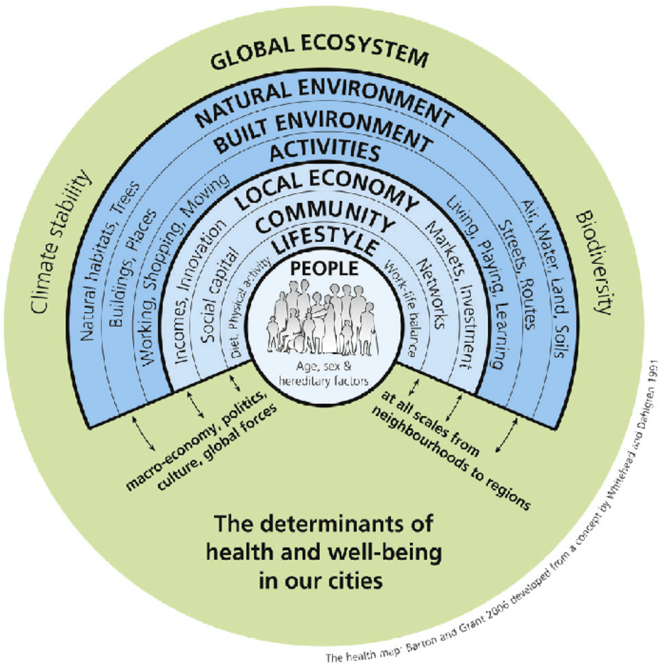
MOEk urbanizazioa izendatu zuen XXI. mendeko osasun publikoaren erronka nagusienetako bat bezala (WHO, 2014), aldi berean, NBEk garapen jasangarri bat lortzeko Agenda 2030-ean ezarritako helburuetako bat hiri eta komunitate jasangarriak garatzea dela aipatu zuen, 11. helburutzat markatutakoa: hiri eta komunitate jasangarriak (United Nations, 2015). Helburu hau hizpide izanik, Espainiako Gobernuak "Agenda Urbana Española" dokumentu estrategikoa sortu zuen, hiri jasangarriak bultzatu nahian, NBE eta Europar Batasunetik ezarritako irizpideei jarraituz (Gobierno de España, n.d.). Esan bezala, bai NBEtik baita Europar Batasunetik bultzatutako helburua hiriak eta komunitateak jasangarriagoak bilakatzea da, hala ere, eta hau alde batera utzi gabe, "Agenda Urbana Española"k bere dokumentuan hiri osasuntsuagoak bultzatzeko apustua egiten du. Horretarako, ibilgailu pribatuan oinarritutako hiri diseinua aldatu beharra azpimarratzen du, bizimodu sedentarioa alde batera uzteko. Bestetik, hirian gune naturalen presentziaren beharra mahai gainean jartzen da, hiriko beste ekipamendu bat bezala hartu ordez natura sare bat bezala ulertuz (Fariña-Tojo, 2019). Izan ere, gune berdeek eragin zuzena eduki dezakete ingurumen jasangarritasunean, osasunean eta osasun ekitatean (Kruize et al., 2019). Osasuna sustatzeaz gain, hainbat gaixotasun saihesteko gai ere badirelako (Gascon et al., 2015). Gainera, hiriko gune berdeak paper garrantzitsu bat joka dezakete aldaketa edo krisi klimatikoaren aurkako borrokan. Aire tenperatura hoztuz eta hiriko bero-irlak gutxituz, isurketa uraren erregulazioaren bitartez uholdeen kalteak gutxituz, karbono-bilketaren bitartez berotegi efektua gutxituz, biodibertsitatea bultzatuz edota uraren kalitatea hobetuz, esaterako (EEA, 2021).

Nahiz eta hirietan osasun zerbitzuak eskuragarriagoak eta aukera ekonomiko oparoagoak izan (Nieuwenhuijsen, 2016), esan bezala, hiriek modu batera edo bestera eragina izan dute bertako biztanleen osasunean, trafikoari lotutako aire kutsadura eta zaratak sortutakoak, esaterako (Vardoulakis et al., 2016). Faktore negatibo hauek osasunean duten eragina aztertzea helburu duen zientzia ingurumen epidemiologia da. Ingurumen epidemiologia, ingurumenean aurkitzen diren faktore fisiko, biologiko eta kimikoek gizakion osasunean duten eragina aztertzen duen zientzia bezala definitua izan zen (National Research Council (US) Committee on Environmental Epidemiology, 1991). MOEk ingurumen osasuna definitzerako garaian, lehenago aipatutako faktoreez gain ingurumeneko faktore sozial eta psikosozialengatik baldintzatua dagoen osasuna, baita bizi-kalitatea, bezala definitu zuen (WHO, 1993).

Antzinako Greziako garaian harremandu zuen Hipokratesek (k.a. 460 – k.a. 377) lehen aldiz ingurumena osasun arazoekin. Zingirak zeuden tokietan Malaria eta sukar horia bezalako gaixotasun gehiago ematen zirela ohartu zen Hipokrates. Bernardino Ramazzinik (1633-1714), laneko medikuntzaren aita kontsideratzen denak, *De morbis artificum diatriba* liburuan azaldu zuen lanpostuetan egoten ziren produktu kimikoak, hautsa, metalak… kaltegarriak izan zitezkeela osasunerako. Ildo berean, Percivall Pottek (1714-1788) tximinietako kedarra kentzen zuten haurrek, eskrotoko minbizia garatzeko arrisku gehiago zutela azaldu zuen (Herr, 2011; Merrill, 2008). 1832. urtean, Edwin Chadwick-ek bultzatuta, *sanitary movement* sortu zen. Lehen aipatu bezala, hiri industriala osasun ikuspegi batetik aldatzeko asmoz, esaterako, hondakin-urak edangarria zen uretik banantzeko asmoz estolderi sistema bat ezarri zen (Ramos Gorostiza, 2014). Urte gutxi batzuk beranduago, 1854. urtean, kolera epidemia bat eman zen Londresen. John Snow, epidemiologia modernoko aitatzat hartzeaz gain, osasun geografiaren aitatzat ere hartzen denak, Soho auzoa mapa batean islatu eta horren gainean kolera kasuak markatzen hasi zen, gehienak Broad Streeteko iturriaren inguruan bizi zirela ikusita, iturria ixteko eskaera egin zuen Kolera Ikertzeko Batzordean. Behin iturria itxita kolera kasuen jaitsiera bat eman zen eta gerora iturriko ura aztertuz, iturria hondakin-urekin kutsatua zegoela konturatu ziren (Cerda L & Valdivia C, 2007; Shiode et al., 2015). John Snow epidemiologia modernoaren aita izateaz gain, epidemiologia espazialaren aitzindarietako bat ere izan zen Koleraren epidemian erabilitako maparengatik, kartografia analitikoa osasunaren arloan lehenengoz erabiliz (Cerda L & Valdivia C, 2007; Olaya, 2012). Snow-ren mapa proto-GIS bat bezala har genezake. Gerora kartografia tradizionala erabili bazen ere antzeko asoziazioak egiteko, modu zehatzago batean analizatzeko beharra ikusi zen eta behar hau GISarekin asetu zen, izan ere, GISak datuak antolatu, biltegiratu, manipulatu, analizatu, modelizatu eta irudikatzeko ahalmena duen erreminta da, horregatik, bilakatu da hain garrantzitsu ingurumen epidemiologian. Esposizioak neurtzeko eta ebaluatzeko duen indarragatik, hain zuzen ere (Nieuwenhuijsen, 2015). Izatez, lehenengo GISa Kanadan sortu zen, Roger Tomlinson-en eskutik CGIS (Canadian Geographic Information System) izenpean. Kanadako lurretako datuen inbentarioa egiteko eta landa lurren kudeaketarako sortu zen eta nahiz eta hasieran batean basoen kudeaketarako lanetan erabili gehienbat, berehala barneratu zen jakintzagai ezberdinetan.

Lehenago aipatu bezala, ingurumen epidemiologia epidemiologiaren arloetako bat da eta hitzak berak dioen bezala ingurumenak osasunean duen eragina aztertzen du. Ingurumenak osasunean duen eragina aztertzeko beharrezkoa da ingurumenean aurkitzen diren eta osasunerako kaltegarriak izan daitezkeen faktoreak ebaluatzea. Ingurumenarekin lotura duten faktore kaltegarri gehienek ezaugarri espaziala dutenez GIS-ak ezinbesteko papera hartzen du diziplina honetan (Nuckols et al., 2004).

Ikusi bezala, hiriek harreman estua izan dute beti osasunarekin, azken urteetan osasun publikoko langile eta hiri planeamenduko profesionalen arteko elkarlana indartu egin da, osasunak garrantzia hartuz hirien plangintzan. Izan ere, Barton eta Grant-en osasun mapan ikus daitekeen bezala (ikus *1 irudia*) bizi garen lekuak gure osasuna baldintzatuko du (Barton & Grant, 2006). Alde horretatik, MOEk osasuna erabateko ongizate fisiko, mental eta soziala izatea bezala definitzen du, eta ez soilik afekzio edo gaixotasun eza bezala (WHO, 1946).



1 irudia. Barton eta Grant-en osasun mapa

Aipatu den bezala, bizi garen inguruak eragin zuzena dauka osasunarekin, honen adibide; maila sozioekonomiko altuko auzoek gune berde gehiago izan ohi dituzte maila sozioekonomiko baxuko auzoekin konparatuz. Gune horiek aldi berean segurtasun handiagoko eta atseginagoak izan ohi dira beste auzoak konparatuz. Horrekin lotua ere, modu kontrajarrian, gune berde gutxiago izanik aire kutsadura eta ingumen zarataren kalteak handiagoak izan ohi dira maila sozioekonomiko baxuetan bizi direnetan (Nieuwenhuijsen & Khreis, 2019). Beraz, auzo batean bizi edo beste batean bizi gure osasunean eragin zuzena izango du (Bolte et al., 2010; Su et al., 2011).

Hortaz, jarri dezagun aztergai hiriko gune berdeek osasunean duten eragina, eta nola gauzatzen duten.

2.2. Hiriko gune berdeen definizioa

Hiriko gune berdeak hiri gunean aurkitzen diren gune naturalak dira. Ez dago definizio bateratu bat eta autore ezberdinen artean ideia nagusi bat badago ere, zehaztasun txikietan dago desadostasuna. Hiriko gune berdeak hirietan aurkitzen diren espazio natural irekiak kontsideratzen dira. Hala ere, definizio ezberdinei erreparatuz badaude gune berdetzat kaleetako zuhaitzak, lorategi pribatuak, haurren jolas parkeak edota irisgaitzak eta erabil ezinak diren landaredi zonaldeak hartzen dituztenak.

Ingurumen epidemiologiako azterketak aurrera eramateko beharrezkoa da gune berdeen neurketak egitea, eta horretarako badaude nahiko onartuak dauden metodologiak. Hurrengo atalean ikusiko ditugu zein aukera ezberdin dauden gune berdeak ezaugarritzeko.

2.3. Gune berdeen esposizioa neurtzeko metodologia

Gune berdeek osasunean duten eragina kuantifikatzeko beharrezkoa da gune berdeei eduki den esposizioa neurtzea. Horretarako bi metodologia nagusi gailentzen dira, objektiboa eta subjektiboa. Bada, aurreko bi hauek bateratzeko gai den beste metodologia bat ere, nahiz eta oso erabilia ez izan: tresna multidimentsionalak deritzona.

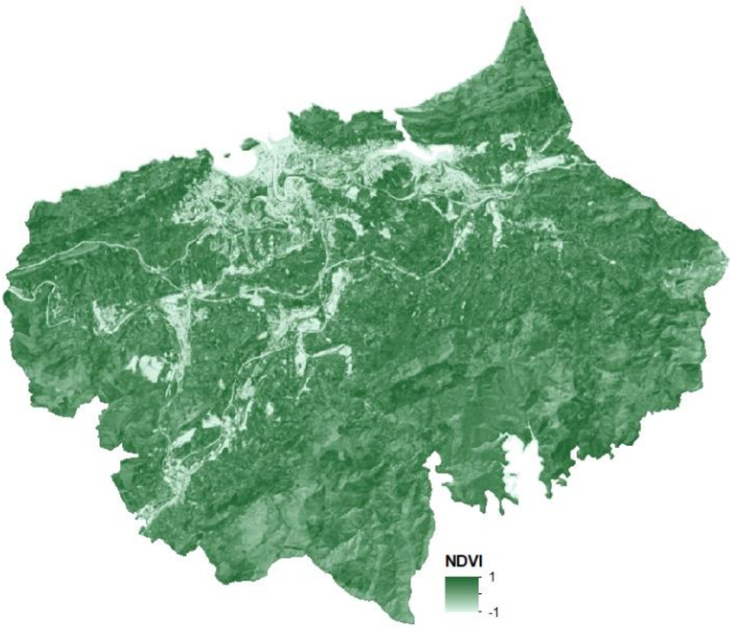
2.3.1. Gune berdeak objektiboki neurtzeko metodologia

Metodologia objektiboan gune berdeen esposizioa GIS erremintaren bitartez neurtzen da, informazio iturri ezberdinak erabiliz. GISa datu espazialen bilketarako, kudeaketarako eta analisirako balio duen *software* informatiko bat da (ESRI, n.d.). Tresna honen bitartez, datu espazialak landu eta pertsonei esposizio ezberdinak, kasu honetan gune berdeei esposizioa, esleitzeko ahalmena ematen digu, besteak beste.

Gune berdeekiko esposizioa kalkulatzeko bi geoinformazio iturri erabiltzen dira, batetik, satelite irudiak eta bestetik, informazio kartografikoa. Satelite irudien banden konbinazioaren bitartez begiekin ikusi ezin daitezken gauza asko ikus daitezke (ESA, n.d.). Banden konbinazioei esker, esan bezala, gizakien begiek ikusi ezin ditzaketen informazio gehigarria lor daiteke, esaterako, landarediaren berdetasuna. Landarediaren berdetasuna NDVI indizearen bitartez kalkulatzen da, indize hau banda gorria (Red) eta banda infragorri hurbila (NIR) konbinatuz lortzen da (Weier & Herring, 2000).

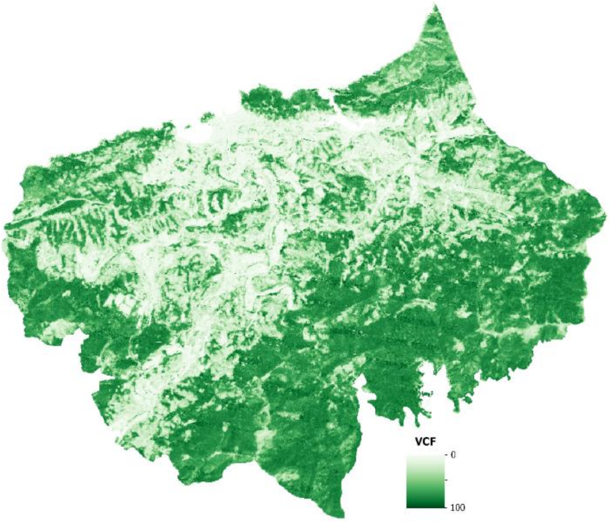
$$NDVI = \frac{NIR - Red}{NIR + Red}$$

NDVI indizeak berdetasun maila altuena 1 balioan du eta baxuena -1 balioan. NDVI indizea biztanleriari esleitu ahal izateko beharrezkoa da biztanleria geolokalizatzea, izan etxebizitzan, lantokian, egindako bide batean etab. Ondoren, honi lekuko balioa esleitu ahal izateko.



2 irudia. Donostialdeako NDVI indizea

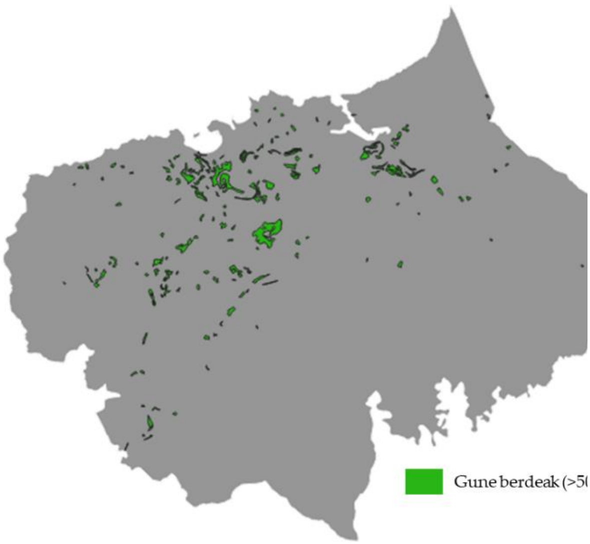
Bestetik, VCF produktua Landsat 5 Thematic MapperTM edota Landsat 7 Enhanced Thematic Mapper Plus (ETM+) sateliteen bidez eskura daiteke, 5 urtetik behin 30x30eko bereizmenarekin. VCF produktuak pixel bakoitzean aurkitzen den 5 metro baino gehiagoko baso zurkare jarraien portzentaiaren informazioa ematen du (Sexton et al., 2013).



3 irudia. Donostialdeako VCF indizea

Informazio kartografikoa berriz, normalean administrazioek sortutako datu espazialak dituen informazioa da. Lur erabilerari buruzko geoinformazioa erabili ohi da, bertatik, gune berde bezala klasifikatuak izan diren lur eremuak lor daitezke. Ondoren, gune hauek zein distantziatara (normalean etxebizitzatik) dauden kalkulatzen da (Nieuwenhuijsen & Khreis, 2019), baita, ea etxebizitzatik, edo interesgarria den puntutik, 300 metrotara 5000m^2 baino handiagoa den gune berde bat dagoen ala ez ere kalkulatzen da. Izan ere, MOEk pertsona bakoitzak 300 metro baino gutxiagora 5000m^2 baino handiagoa den gune berde bat edukitzea gomendatzen du (WHO Regional Office for Europe, 2016). Horretarako, lehenik

5000m²ko gune berdeak kalkulatzen dira, ondoren partaideen lokalizazioek 300 metrotara horrelako gune bat duten kalkulatzeko.



4 irudia. Donostialdeako gune berdeak (>5000m²)

2.3.2. *Gune berdeak subjektiboki neurtzeko metodologia*

Metodologia subjektiboari dagokionez, galdeketa bidez jasotzen da. Ez da oso ohikoa izaten nahiz eta ikerketa batzuetan erabili izan duten (Weimann et al., 2015; M. Yang et al., 2020). Galderak oso ezberdinak izaten dira ikerketa batetik bestera, esan daiteke, ez dagoela galdeketa bateratu bat, nahiz eta bai egon galdetegi balioztatuak. Alde batetik, galdeketa luzeagoak egiten dituzten ikerketak daude (Tan et al., 2019; Wang & Zhao, 2012) eta bestetik, galdera bakarreko eta erantzun errazeko ikerketak daude (Abbasi et al., 2020; M. Yang et al., 2020). Esaterako, galdeketa luzeak erabiltzen dituzten ikerketek hurrengo puntuak eduki ohi dituzte kontuan: kalitatearen eta ezaugarrien ebaluazio subjektiboa, erabilera-patroia, osasun-egoera autoinformatua, soziodemografikoa, irisgarritasuna, jarduera motak gune berdeetan, diseinu eta konfigurazio desberdinetarako lehentasunak eta diseinu eta kalitate estetikoa. Galdera labur eta zuzenak, ordea, etxebizitzaren inguruan gune berderik duzun soilik galdetzen dute, edota nahikoa gune berde dagoen etxebizitza inguruan.

2.3.3. *Gune berdeen kalitatea neurtzeko tresna multidimentsionalak*

Neurketa objektibo eta subjektibo edo pertzepziozkoaz gain, gune berdeak ebaluatzeko tresna multidimentsionalak izan dira gune berde eta osasunaren arteko azterlanetan erabili diren azkenak. 2010ean hasi ziren lehenak, batez ere ariketa fisikoarekin harremandutako ikerlanetan, gerora, beste osasun adierazle batzuekin harremantzeko erremintak garatu dira (Knobel et al., 2019).

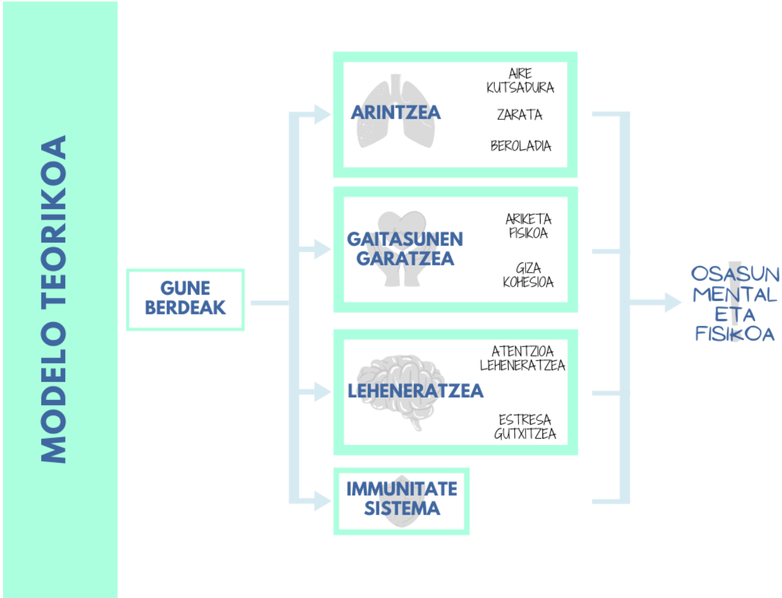
Hainbat dira literaturan aurki daitezkeen tresna multidimentsionalak, denak gune berdeak beste aldagai zehatz batzuekin alderatzeko helburuarekin. Hurrengo dimentsio edo ezaugarriak dira gune berdeak ebaluatzeko erabili ohi direnak: ingurua, irisgarritasuna, erosotasuna, estetika, gizalege eza, segurtasuna, erabilerak, estalkiak, animali biodibertsitatea edota landaredi biodibertsitatea. Adituak izan ohi dira tresna hauek erabilita gune berdeak ebaluatzen dituztenak, nahiz eta ikerketa batzuk erabiltzaileen artean ere pasa izan duten tresna multidimentsionala (Knobel et al., 2019).

2.4. Gune berdeek osasunean duten eragina

1800. urte inguruan Londresen egoitza zuten hainbat erakunde hasi ziren gune berdeak osasunerako onuragarriak zirelaren ideia onartzen. Hauek, hirietako birikak zirela eta eraikin dentsitate handiko guneetan egotea beharrezkoa zirela adierazi zuten (Hickman, 2013). Ebidentzia zientifikoaren arabera gune hauek onuragarriak izan daitezke, ez soilik karbono dioxidoaren xurgatzaileak direlako, baizik eta, jarduera fisikoa egiteko, obesitate arazoak murrizteko, osasun mentala hobetzeko, jaiotza emaitzak hobetzeko, osasun kardiobaskularra hobetzeko edota hilkortasun tasa jaisteko ere balio dutelako. Gune berdeen eragina osasunean hainbat bideren bitartez eman daiteke.

2.4.1. Modelo teorikoa

Esan bezala, gune berdeek bide ezberdinak erabiliz eragina dute osasunean. Jarraian azalduko den modelo teorikoa (*5 irudia*) Hartig, Mitchell, de Vries, & Frumkin (2014), Kihal-Talantikite et al. (2013) eta Markevych et al. (2017) autoreen modeloetan oinarrituta dago. Bertan, gune berdeek osasunean eragiteko dituen bideak azaltzen dira.



5 irudia. Gune berde eta osasunaren arteko erlazioaren modelo teorikoa

Gune berdeek eragina dute osasunean zenbait bitartekarien bitartez (5 *irudia*) eta hauek aldi berean, ondorioak dituzte osasun fisiko zein mentalean. Gune berdeek hiriko ingurumen esposizio negatiboak gutxitzeko ahalmena dute, hala nola, aire kutsadura, zarata eta tenperatura. Bestetik, ariketa fisikoa egitera bultzatzea, atentzioa berrezartzea eta estres mailak gutxitzea eragiten dute. Era berean, giza kohesioa bultzatzen du eta immunitate sisteman ere eragin positiboa izan dezake (Terry Hartig et al., 2014; Kihal-Talantikite et al., 2013; Markevych et al., 2017). Aipatutako bitartekariek eragina dute osasun arazo ezberdinetan, hala nola, haurren jaiotza emaitzetan (Agay-Shay et al., 2014; Banay et al., 2017; Dzhambov et al., 2014, 2019; Hystad et al., 2014), atentzioan (Asta et al., 2021; Dadvand et al., 2015, 2017; Schutte et al., 2017; Wells, 2000), obesitatean (Cummins & Fagg, 2012; Lachowycz & Jones, 2011), osasun mentalean (Annerstedt et al., 2012; Gascon et al., 2015; Triguero-Mas et al., 2015; Twohig-Bennett & Jones, 2018), gaixotasun kardiobaskularrean (Maas et al., 2009; Markevych et al., 2014; Tamosiunas et al., 2014; Twohig-Bennett & Jones, 2018), asma eta alergian (Eldeirawi et al., 2019; Fuertes et al., 2016) eta hilkortasun tasan (James et al., 2016; Ji et al., 2019; Mitchell & Popham, 2008; Villeneuve et al., 2012; Wilker et al., 2014). Ebidentzia guzti hau aintzat harturik MOEk 300 metro baino gutxiagoan 5000m^2 baino gehiagoko gune berdeak edukitzea gomendatzen du (WHO Regional Office for Europe, 2016).

Gune berdeek osasunean izan dezaketen eragina ikusirik, azterlan baten arabera, hiru modu ezberdinen bitartez konekta dezakegu gune berdeekin. Batetik, natura begiratuz, paisaia erreal bat begiratuz ala birtualki ikusi daitekeen zerbait, hala nola, margolanak edo telebistan ager daitezkeen natura irudiak. Bigarren konexio mota, gertuko naturaren presentzia litzake, hau da, beste edozer zeregin egiten den bitartean ohartu gabe gertuko gune berdetik jaso daitekeen esposizioa, eta azkenik, naturarekiko kontaktu zuzena, gune berdera joateko erabakian parte-hartze aktiboak izanik. Edonola dela ere, hiru lotura moduren bitartez dute eragin positiboa gune berdeek osasunean (Pretty, 2004).

2.4.2. *Gune berde eta bitartekarien arteko harremana*

Gune berde eta osasunaren artean dauden bitartekariak hiru talde nagusietan klasifikatu zituzten Hartig (2016) eta Markevych et al.ek (2017). Arintze (*mitigation)*, leheneratze *(restoration)* eta gaitasunen garatzea (*instoration)* dira talde nagusi horiek. Lehen taldeak aire kutsadura, zarata eta muturreko beroaldiak biltzen ditu, gune berdeak hauen mailak arintzeko ahalmena duelarik. Bestetik, atentzioa eta estresa leheneratzen dira, atentzio hobetuz eta estres mailak gutxituz, hauek leheneratze *(restoration)* taldean jasotzen dira. Azken taldearentzako Hartig-ek kontzeptu bat garatu zuen: *"instoration"* (T. Hartig, 2016), honela definituz:

"A family of processes engaged in encounters with particular environments that involve the acquisition of new resources; a person may for example become more self-reliant or self-confident, acquire new skills, or gain in physical fitness. The term was introduced into the literature to distinguish restorative effects from effects that do not involve the renewal of depleted resources; not all benefits of environmental encounters are restorative benefit."

Talde honetan ariketa fisiko eta giza kohesioa aurkitzen dira, berrezartzearekin alderatuz, kasu honetan ez da gaitasun bat berrezartzen, garatu baizik.

2.4.2.1. Ingurumen faktore estresagarrien arintzea. Gune berdeek hiri esposizio negatiboak gutxitzeko ahalmena dute (David Suzuki Foundation, 2015). Aire kutsadura, zarata eta beroaldiak dira hiru esposizio negatiboak, zeintzuk, osasunean eragin negatiboa duten.

Gune berdeek aire kutsadura mailak txikitzen dituzte hainbat arrazoi direla medio: jalkitze, dispertsio edota aldatzearen bitartez. Jalkitzeari dagokionez, kutsatzaileak hostoetan jalkitzen dira aire kutsadura mailak gutxituz (David Suzuki Foundation, 2015; Escobedo & Nowak, 2009; Kroeger et al., 2014), dispertsioz berriz, landaredia hesi modura jokatuz kutsatzaileen norabidea eta abidadura aldatzen ditu dispertsatuz, honela jalkitzea erraztuz. Azkenik, aldatzea, partikularen konposizioa modifikatzeko ahalmenaren bitartez, pisu aldaketa, konposizio aldaketa edota kontzentrazio aldaketak eman daitezke partikuletan, berriro ere jaulkitzea erraztuz (Diener & Mudu, 2021). Edozein gune berdek gutxitu dezake aire kutsadura, izan eraikin bateko teilatuko landaredia zein hirian aurkitzen den baso zabal bat. Hala ere, landarediz betetako fatxada eta teilatuek aire kutsadura gutxitzeko ahalmen gutxiago dute beste edozein gune natural batekin alderatuz (David Suzuki Foundation, 2015). Gainera, gune berdeetan trafiko gutxiago dago eta beraz, aire kutsadura mailak baxuagoak dira (Su et al., 2011).

Zaratari dagokionez, gune berdeek zarata maila gutxitzeko bi mekanismo dituzte, batetik eta aire kutsadura mailaren jaitsieran gertatzen den moduan, gune berdeak egotea trafikoaren jaitsierarekin lotua dago, beraz, trafikoa gutxituz zarata maila ere jaitsi egiten da (Markevych et al., 2017). Bestetik, gune berdeek zarata uhinak difraktatu, xurgatu edota suntsitu ditzakete, zarata gutxituz (Van Renterghem et al., 2015).

Gune berdeek ere hirietan ematen diren beroaldiak ekidin ditzakete ebapotranspirazioaren bitartez, baita albedoa handitzen duelako. Gainera, landarediak eguzki irradiazioa xurgatu dezake (Bowler et al., 2010; Markevych et al., 2017; Saaroni et al., 2000). Honetaz gain, zuhaitzek itzala ematen dute tenperaturak jaitsiz (Escobedo et al., 2011).

2.4.2.2. Leheneratzea. Gune berdeek osasun mentalean bi mekanismo leheneratzeren bitartez eragin dezakete. Bi teoria hauen arabera estresa gutxitu eta atentzioa berrezartzen da. *Stress Reduction Theory*ren (SRT) arabera, gune naturalak estimulu lasaigarri eta ez erasokorren iturri dira gizakiontzako eta hortaz, estres psikosoziala murrizten du (Ulrich et al., 1991). Bigarren teoriari dagokionez, *Attention Restoration Theory* (ART), gune berdeek leheneratze kognitiboak errazten ditu, naturak edozein atentzio karga ezabatzeko duen ahalmenaren bitartez. Teoria honen arabera, gizakiak gaitasun kognitibo mugatuak ditu, esaterako, atentzio zuzen mugatua, gainera, atentzio zuzena lehenago agortzen da arreta jarrita daukagun horretan interesik ez badago. Bada, ingurune leheneratzaileei esker, atentzio ez-borondatezkoa aktibatzen da eta bitarte horretan atentzio zuzena leheneratu egiten da, atentzio zuzena berrezarriz (R. Kaplan & Kaplan, 1989; S. Kaplan, 1995). Hortaz, gune berde batean atentzio ahalmena lehenerazi eta estres maila jaisten da.

2.4.2.3. Gaitasunen garatzea (Instoration). Gune berdeek ariketa fisikoa egitera bultzatzen dute espazio atsegin, erakargarri eta seguruak eskainiz (Almanza et al., 2012; Mytton et al., 2012), gainera, espazio hauek bizilagunen arteko elkar ezagutza bultzatzen dute komunitate identitatea sortuz eta giza kohesioa bultzatuz (Forrest & Kearns, 2001; Holtan et al., 2015; Kemperman & Timmermans, 2014; Kuo et al., 1998). Gune berdeak aire librean eta naturarekin kontaktuan egoteko aukera eskaintzen dute, honela, jendearekin beste lekuetan emango ez diren kontaktuak suertatuz (Jennings & Bamkole, 2019). Bai ariketa fisikoa eta giza kohesioa bitartekari bezala ulertzen dira lan honetan eta ez nahasle bezala. Izan ere, aire kutsadura eta zarata prozesu natural baten ondorio bezala ikusten ditugun moduan, jarduera fisikoa egitea eta giza kohesioa handitzea ez dira prozesu natural baten ondorio, baina bai giza jokaera edo portaera baten ondorio (de Vries et al., 2003).

2.4.2.4. Sistema immunea. Gizakiak naturarekin daukan hartu-emanari esker, gizakion mikrobiota aberastu egiten da, eta ondorioz, erantzun inmunitarioak emateko gaitasuna garatu egiten da

(Hanski et al., 2012; Rook, 2013). Ikusi da burmuinaren garapenaren harreman zuzena duela immunoregulazioak eta aldi berean, makro zein mikroorganismoetara esposatuak egoteak immunoregulazioarekin. Horregatik, gune berdetara esposizioa hobetzeak immunoregulazioa hobetuko duen mikrobiotaren sarrera erraztuko du, burmuinaren garapen hobea bultzatuz, are eta garrantzi gehiago edukiz haurtzaroan zehar, epe oso zaurgarria baita (Rook, 2013; Rook et al., 2013, 2015).

2.4.3. Bitartekarien eta osasunaren arteko harremana

Gune berdeek osasun arazo ezberdinetan eragiten dute modu ezberdinean eta bitartekari ezberdinen bitartez. Gune berde eta osasun mentalaren arteko harremana da ikertuena izan den osasun ondorioa. Bestetik, ariketa fisikoa eta aire kutsadura dira bitartekari bezala gehien aztertu direnak (Dzhambov et al., 2020). Lan honetan ugalketa osasunarekin eta osasun mentalarekin harremandutako osasun emaitzak landu dira, hala ere, atal honetan gune berdeek beste osasun emaitzetan eduki ditzaketen eragina ere gainbegiratu da.

2.4.3.1. Ugalketa osasuna. Haurdunaldi prozesuan zehar ematen diren osasun emaitzek eragin zuzena dute jaioberriaren osasunean eta biziraupenean. Jaiotza pisua eta goiztiarra izatea dira gehien aztertu diren bi osasun erantzunak, izan ere, jaiotza-pisu eskasa izatea haur morbilitate eta hilkortasunarekin harremandu da; bestetik, goiztiarra izateak ere eragina du etorkizuneko osasunean, hala nola, garapen neurologikoaren desgaitasunekin (Behrman & Butler, 2007; EPA, 2013; García Baños, 2012). Haurdunaldi asterako txikia izateak alde batetik osasun fisikoko hianbat arazorekin erlazionatu da. Esaterako, pubertaro aurreratuarekin, II. motako diabetesarekin, obesitatearekin, gaixotasun kardiobaskularrarekin edota sindrome metabolikoarekin. Bestalde, osasun mentalean ere eragin dezake, hala nola, errendimendu psikologiko eta intelektualean eragin negatiboa izanik (Hong & Chung, 2018; Milovanovic et al., 2014; van Wassenaer, 2005; Verkauskiene et al., 2013). Haurdunaldi asterako handia izateak, ordea, sorbalden distozia, jaioberriaren hipogluzemia edota ospitaleko estantzia luzatzea ekar dezake epe motzera, epe luzera izan ditzakeen osasun ondorioen inguruan, aldiz, ez dago adostasunik (Khambalia et al., 2017; Weissmann-Brenner et al., 2012).

Gune berdeek osasunean duten eragina aztertzen duen metanalisi baten arabera jaiotza goiztiarraren eta haurdunaldi asterako txikia izateko arriskua txikiagoa da gune berdetara esposizio altua dutenentzako (Twohig-Bennett & Jones, 2018). Akaraci et al.ek (2020) garatutako metanalisi baten arabera, NDVI indizeak haurraren jaiotza pisua igo eta haurdunaldi asterako txikia izateko arriskua gutxitzen du. Tel Aviven egindako ikerketa batean berdetasunaren handitzea jaioberriaren pisuaren igoera batekin harremandu zen eta jaiotze pisu baxua (<2500 g) izateko arriskuaren jaitsiera batekin (Agay-Shay et al., 2014). Hystad et al.ek (2014) ere NDVIaren igoerak jaioberriaren pisua igotzen zuela baieztatu zuen, baita, haurdunaldi asterako txikia eta goiztiarra izateko arriskua txikitu ere, modeloa aire kutsadura eta zarata esposizioekin doitu zen eta asoziazioa sendoa izaten jarraitu zuen.

Hogeita bost ikerketekin egindako metanalisi batek dioenez, gune berdetara esposizioa edukitzeak jaiotze pisuaren igoerarekin eta jaiotzerako pisu baxua izateko arriskua gutxitzearekin lotu dira. Nahiz eta, gune berdetara esposizioa hobe neurtu behar dela eta bitartekaritza bideak aztertzea beharrezkoa dela azpimarratzen den (Hu et al., 2021).

2.4.3.2. Haurren atentzioa. Osasun mentalak desgaitasun psikosozialak, kognitiboak eta intelektualak jasotzen ditu, besteak beste. Hala ere, osasuna hobetzeko egiten diren esfortzuen artean ahaztua dago osasun mentala (WHO, 2019). Funtzio exekutiboak prozesu kognitiboak aurrera eramateko arduradunak dira eta haien artean atentzioa aurkitzen da (Bausela Herreras, 2014; Miyake et al., 2000). Bada, gune berdeen eta osasunaren arteko ikerketan aztergai nagusiena bilakatu da osasun mentala azken urteetan; berrikuspen sistematiko baten arabera gune berdeek atentzio eza hobetzen dute, nahiz eta, ikerketa gehiago eta hobeen beharra eta gune berdeak neurtzeko metodologiaren homogenitate eza azpimarratzen duten (de Keijzer et al., 2016; Luque-García et al., 2022; Vanaken & Danckaerts, 2018).

Gune berdeek atentzioan duten eragina aztertu duten ikerketak bi taldetan banatu daitezke: epe motzera eta epe luzerako azterketak. Epe motzeko azterketak, azterketa experimentalak izaten dira, edo hobe esanda, kuasi-experimentalak, non interbentzio taldea dugu alde batetik, eta interbentzio ez den taldea, bestetik. Gune berdeei lotutako azterketa experimentaletan, interbentzio taldea gune berde batera eramaten da denbora epe batez, interbentzio taldea ez denari berriz, gune berdea ez den leku batera eramaten zaio denbora epe berdinez.

Azterketa kuasi-experimentalak dira ugarienak gune berdea eta atentzioa aztertzen duten ikerketen artean (de Keijzer et al., 2016). 7-12 urte arteko biztanleriarekin egindako ikerketa batean, gune berde batean 20 minutuz egon zirenek puntuazio hobea lortu zuten atentzioan, denbora bera hiri gune batean egon zirenekin alderatuta (Taylor & Kuo, 2009). Aldiz, Naestved, Danimarkan bataz besteko 12 urte zituzten nerabeekin egindako beste antzeko ikerketa batek 30 minutuko ibilaldi batean ikusi zuen atentzioaren hobekuntza bat egon zela gune naturaletan egon zirenetan hiri gunean ibili zirenekin alderatuta (Stevenson et al., 2019). 22-24 urteko partaideekin Michiganeko (AEB) unibertsitatean garatutako hirugarren ikerketa batek 55 minutuko ibilaldiarekin ikusi zuen atentzioaren hobekuntza naturan ibili zirenen artean (Berman et al., 2008). 4-8 urte arteko haurrekin egindako diseinu bereko beste ikerketa batek ere hobekuntza bat ikusi zuen gune berdeko taldean, 20 minutuko ibilaldia eginez (Schutte et al., 2017), aitzitik, beste ikerketa batek ez zuen ezberdintasunik ikusi atentzioaren hobekuntzan gune naturaletara eta hiri guneetara joan ziren taldeen artean, kasu honetan 20-30 urte inguruko partaideekin egin zen ikerketa (Terry Hartig et al., 1991).

Azterketa experimentalak ez direnen artena, badaude zeharkakoak edota longitudinalak direnak. Bien arteko desberdintasunak hurrengoak dira; zeharkako azterketek esposizioa eta efektua momentu berean aztertzen dute eta longitudinaletan berriz, esposizioa efektuaren aurretik neurtzen da, kausalitatearen irizpide garrantzitsu bat bermatuz. Bi azterketa mota hauen esposizioa leku ezberdinetan neurtu daiteke, izan etxebizitzan, izan eskolan edota batetik bestera egindako bidean. Bi ikerketen arabera, etxebizitzaren inguruan berdetasun maila altuagoa zutenek atentzioan puntuazio hobea lortu zuten, bata Bartzelona, Espainiako 7-10 urteko laginarekin eta bestea Wuhan, Txinako 4-5 urteko laginarekin egin zirenak (Amoly et al., 2015; Liao et al., 2020), Alemanian egindako beste ikerketa batean, aldiz, gune berdetara irisgarritasuna ez zutenek atentzio okerragoa zutela ikusi zen (Zach et al., 2016).

Jada aipatu bezala, esposizio luzeko azterketa gutxi daude. Momentura arte, dakidala, lau dira haurretan gune berde eta atentzioaren artean egin diren jarraipen ikerketak. Lehenak, etxebizitzaz aldatutako 7- 12 urte arteko lagin batean aztertu zuen ea etxebizitza berrian gune naturalagoak zituzten haurrek atentzioa hobetzen zuten, hala ikusi zuten, nahiz eta, lagina 17 pertsonakoa soilik izan (Wells, 2000). Bigarrenak, Bartzelonako (Espainia) 7-10 urteko haurrei egindako 12 hilabeteko jarraipen baten bitartez, etxebizitzan, eskolan eta etxetik eskolara edo eskolatik etxerako ibilbidean gune berdetara zuten esposizioak atentzioan izan zezakeen eragina aztertu zuen, horretarako 3 hilero atentzioa neurtuz. Emaitzen arabera, eskola barneko eta eskola inguruko berdetasunak eta bai eskola, bai etxebizitza eta bai ibilbideko berdetasun orokorrak eragina du atentzio ezaren murriztean (Dadvand et al., 2015). Hirugarrenean, aurreko autore berdinak, jaiotza kohorte (Sabadell eta Valentzia, Espainia) bati jarraipena eginez 4-5 eta 7-8 urteko haurren etxebizitzako berdetasuna eta atentzioa alderatu zituen, berdetasun gehiago zutenek atentzio hobea zutela ikusiz (Dadvand et al., 2017). Azken ikerketak ere, berdetasunaren igoera atentzio puntuazioaren jaitsiera batekin erlazionatu zuen Erromako (Italia) 7 urteko haurren lagin batekin (Asta et al., 2021).

2.4.3.3. Beste osasun emaitza batzuk.

Tesi hau gune berdeek ugalketa osasunean eta atentzioan duten eraginean oinarritu bada ere, gune berdeek beste osasun emaitzen duten eragina ere ikertu da. Ikertuenak izan diren osasun emaitzen artean, obesitatea, asma eta alergia, osasun kardiobaskularra, eta morbilitatea eta hilkortasuna daude.

Esaterako, Bartzelonan egindako ikerketa baten arabera, gune berdetara irisgarritasunak obesitatea edukitzeko arriskua gutxitu zuen, hala ere, asoziazioan ez zen aire kutsadura eta ariketa fisikoaren bitartekaritzarik ikusi (O'Callaghan-Gordo et al., 2020). Berrikuspen sistematiko baten arabera, berdetasun maila altuagoak edukitzeak etxebizitza inguruan gehiegizko pisua edota obesitatea edukitzeko arriskua gutxitzen du, ez ordea parke kopuru gehiago edukitzeak (Luo et al., 2020). Obesitatea izateko arriskua gutxitzeaz gain II motako diabetesa edukitzeko arriskua ere gutxitzen dute gune berdeek (De la Fuente et al., 2020). Asmari dagokionez, hainbat autoreen lanak ikusirik oraindik ez dago argi gune berdeak onuragarriak ote diren ala ez asmarentzat (Andrusaityte et al., 2016; Dadvand et al., 2014; Lovasi et al., 2013; Pilat et al., 2012). Gainera, hiriko berdetasunaren handitzea metatutako bakardade inzidentziaren gutxitzearekin lotu da, efektua handiago izanik bakarrik bizi direnentzako (Astell-Burt et al., 2021). Gune berdeak morbilitatean eragina duela ikusi da, baita hilkortasunean ere (Maas et al., 2009; Yuan et al., 2021). Laburbilduz, aterki gisako berrikuspen baten arabera, gune berdetara esposizioa edukitzeak onurak ekar ditzake hilkortasunean, morbilitate kardiobaskularrean, faktore kardiometabolikoetan, osasun mentalean, jaiotze-pisu baxuan, ariketa fisikoan, loaren kalitatean eta hiriko krimenean (B.-Y. Yang et al., 2021).

3. Hipotesiak eta helburuak

Tesi honek hipotesi nagusi (HI.x) ezberdinak ditu, hipotesi hauek tesian zehar egindako ikerketetan baieztatzen saiatu da doktoregaia:

- Gune berdek eragin positiboa dute ugalketa osasunean (HI.1)
- Gune berdeek eragin positiboa dute ugalketa osasunean ingurumen faktoreen gutxitzearen, leheneratzearen eta gaitasunen garatzearen bitartez (HI.2)
- Gune berdeek epe laburreko esposizio batean eragin positiboa dute atentzioan (HI.3)
- Gune berdeek epe luzeko esposizio batean eragin positiboa dute atentzioan (HI.4)

Lan honetan, hipotesiak baieztatze aldera hauek dira helburu orokor (H.O.x) eta espezifikoak (H.E.x):

- Gune berdeek ugalketa osasunean eragiten duten aztertzea (H.O.1)
- Gune berdeek atentzioan eragiten duten aztertzea (H.O.2)
- Gune berdeei onurei buruz dibulgazioa egitea (H.O.3)
- Gune berdeen eta ugalketa osasunaren arteko bitartekarien papera aztertzea (H.E.1)
- Gune berdetara esposizio laburrak 7 urteko haurren atentzioan eragina duen aztertzea (H.E.2)
- Gune berdetara epe luzeko esposizioak 8 eta 11-13 urteko haurren atentzioan eragina duen aztertzea (H.E.3)

4. Aztertutako lanak

Hurrengo atal honetan eranskinetan aurkitzen diren lanen sarrera bat egingo da. Honetaz gain, lan bakoitzak zein hipotesi eta zein helburu bete dituen ere azalduko da. Lehenik, lan bakoitzean aztertu den biztanleriaren aurkezpena egingo da, ondoren gune berdeak neurtzeko zein metodologia erabili den aipatuko da, jarraian zein osasun adierazle neurtu den eta nola neurtu den azaltzeko eta azkenik, erabilitako metodo estatistikoak azalduko dira.

4.1. Aztertutako biztanleria

Tesi honek bi biztanleri izan ditu aztergai; emakume haurdunak eta 14 urte baino gutxiagoko haurrak. H.E.1 burutzeko Donostia eta Bartzelonako emakume haurdunen lagin bat hartu zen, UGARE deritzon proiektuaren bitartez. H.E.2 burutzeko berriz, Zarautzko eta Donostiako eskolako 7 urteko umeekin egin zen eta azkenik, H.E.3 burutzeko INMA proiektuko haurrak erabili dira.

4.1.1. UGARE (Urban Green Activity and Reproductive Effects)

6 irudia. UGARE proiektuaren logoa

UGARE proiektua emakume haurdunen jarraipen ikerketa bat da, hau da, aurrera begirako kohorte azterketa bat da. Proiektu honen helburu nagusia hiri guneek emakume haurdunen jarduera fisikoan eta jaiotza emaitzetan duen eragina aztertzea da. Horretarako bi hiri ezberdinetako emakume haurdunak bildu ziren, Donostialdea eta Bartzelona. ESI Donostialdea eta "Hospital del Mar"-en eragin eremuko emakume hardunak bildu ziren. Lehen ekografia egiterako momentuan jartzen ginen kontaktuan beraiekin, lehenik proiektua azaldu eta ea parte hartu nahi zuten galdetzen zitzaien, erantzuna baiezkoa bazen baimen informatua sinatu eta proiektuaren partaide bihurtzen ziren. Ikerketan parte hartzeko irizpideak hurrengo hauek ziren: 18 urte baino gehiago eduki, ernalketa prozesuei lotu gabeko haurdunaldia eta euskara, gaztelania edota katalana (baita ingelesa ere) ulertzeko ahalmena, tokian tokikoa.

Nahiz eta berezko hiria Donostia izan, hiri egitura jarraia hartu dugu kontuan inguruko herriak ere kontuan hartuz, hala nola, Astigarraga, Hernani, Errenteria, Lasarte-Oria, Lezo, Oiartzun, Pasaia eta Usurbil.

UGARE proiektua Donostialdea eta Bartzelonako emakume haurdunek osatu arren, tesi honetan eranskin (Artikulua 1) modura dagoen artikuluan Donostialdeako lagina soilik dago aztergai.

Ikerketa honek Eusko Jaurlaritzako Osasun departamenduko Ikerkuntza Batzorde Etikoaren onespena dauka (Onespen etikoaren zenbakia: PI2018108). Finantzaketari dagokionez, berezko funtsaren bitartez garatu da.

4.1.2. Zarautzeko ikastoletako haurrak

Lagin hau Kutxa Fundazioak finantzatutako proiektu bati esker martxan jarri zen ikerketa batean barnean kokatzen da. Proiektua bi barne ikerketetan banatzen zen, baina ikerketa taldearen esku ez zegoen gertaera baten ondorioz ikerketa bat bertan behera uztea erabaki zen. Bigarren ikerketa, tesian zehar argitaratutako bigarren artikulua (Artikulua 2), Zarautz herriko 3 ikastetxe eta Donostiako beste ikastola batekin eraman zen aurrera. Donostiako ikastola, Jakintza ikastola izan zen, Antigua auzoan kokatutakoa eta Zarautzeko eskolen antzekoa, maila sozioekonomikoari dagokionez. Zarautzeko eskolak hurrengoak izan ziren: La Salle Zarautz Ikastetxea, Orokieta Herri Eskola eta Salbatore Mitxelena Ikastola. Ikerketan 7 urteko gelako haurrak hartu zuten parte, lehen hezkuntzako bigarren maila alegia. Eskola guztien oniritzia jaso ondoren baimen informatua banatu zitzaien guraso edo tutoreek sinatu zezaten. Frogaren egunean baimen informatu sinatuak jaso ziren eta esperimentua hasi genuen, inor ez baztertze aldera baimen sinatua ekarri ez zutenek ere froga egin zuten, baina beraiek datuak ez ziren bildu. Erabaki hau eskolako tutoreekin batera hartu zen. Atentzio arazoren bat edota zailtasun kognitiboren bat zuten partaideen datuak ezin ziren ikerketan kontuan hartu, kasu hauek eskoletako irakasleengatik informatuak izan ziren.

Lehen esan bezala, ikerketa hau Kutxa Fundazioak Aitana Lertxundi Manterola ikertzaile eta doktoregaiaren zuzendaria denari emandako laguntza bati esker garatu da (KUTXA18/001). Ikerketa honek Eusko Jaurlaritzaren Osasun departamenduko Ikerkuntza Batzorde Etikoaren onespena lortu zuen ikerketa hasi baino lehen (PI2018037).

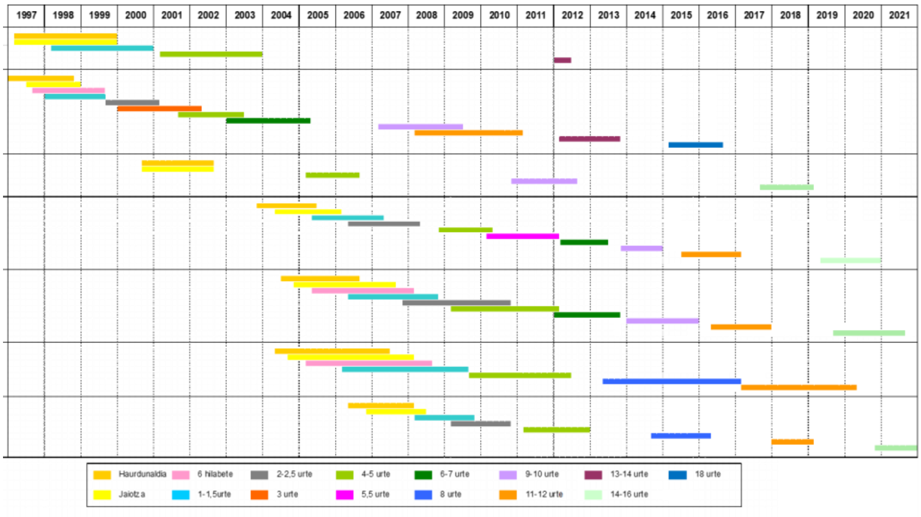
4.1.3. INMA proiektua

7 irudia. INMA proiektuaren logoa

INMA (Infancia y Medioambiente – Haurtzaroa eta Ingurumena) proiektua aurrera begirako kohorte ikerketa bat da, zeinen helburua, haurren osasun eta garapen fisiko zein psikologikoan ingurumen kutsatzaileek eduki dezaketen eragina aztertzea da. Ikerketa 7 azpi kohortetan banatzen da (Ribera d'Ebre, Menorca, Granada, Valentzia, Sabadell, Asturias eta Gipuzkoa), azpi kohorte bakoitza, bere erreklutamendu epeekin. Ikerketan parte hartzeko hurrengo inklusio-irizpideak bete behar ziren: azterketa eremuan bizitzea, gutxienez 16 urte izatea, haur bakarreko haurdunaldia izatea, laguntza bidezko ugalketarik jarraitu ez izana, erditzea erreferentziazko ospitalean izatea eta komunikatzeko arazorik ez izatea (Guxens et al., 2012).

Behin proiektuari buruzko informazioa jasota eta kontsentimendu informatua sinatuta proiektuaren partaide bilakatzen ziren. Urteetan zehar, jarraipen fase ezberdinetan informazio ugari bildu izan da partaideei (guraso eta haurrari) buruz iturri ezberdinen bitartez, lagin biologikoak, galdeketak, test neuropsikologikoak, historia klinikoak eta azterketa fisikoak, besteak beste. Gainera, ingurumen neurketak ere egiten ziren jarraipen fase bakoitzean, aire kutsadura, ura, zarata, kutsatzaile iraunkorrak etab. partaideen inguruak ezaugarrituz (Guxens et al., 2012).

Esan bezala, kohorte bakoitzak bere momentuan egin zuen erreklutamendua, baina jarraipen faseak denek adin berdinetan egin zituzten, protokolo berdinak jarraituz. Lan honetarako Asturias eta Gipuzkoako kohortetako 8 eta 11-12 urteetako datuak erabili dira.



8 irudia. INMA proiektuaren jarraipen faseak. proyectoinma.org (euskaratua)

Ikerketa honek Eusko Jaurlaritzaren Osasun departamenduko eta Asturiaseko Printzerriko Eskualde Klinikaren Ikerkuntza Batzorde Etikoaren onespena lortu zuen ikerketa hasi baino lehen (29/2003, 07/2005, 24/2009, 09/2010, 56/2016, PI2013164, PI2018059). Ikerketa hau Instituto de Salud Carlos III (Red INMA G03/176, CB06/02/0041, FIS-PI04/2018, PI06/0867, FIS-PI09/00090, FIS-PI09/02311, FIS-PI13/02187, FIS-PI13/02429, FIS-PI18/00909, FIS-PI18/01web237 eta FIS-PI18/01142 FEDER finantzaketa barne), Eusko Jaurlaritzako Osasun departamenduari (2005111093, 2013111089, 2015111065 eta 2018111086), Gipuzkoako Foru Aldundiari (DFG06/002 eta

DFG15/221), ikerketa eremuko udalerrien urteroko laguntzei (Zumarraga, Urretxu, Legazpi, Azkoitia, Azpeitia eta Beasain), CIBERESP, Obra Social Cajastur/Fundación Liberbank eta Oviedoko Unibertsitateari esker finantzatu da.

4.2. Gune berdeetara exposizioa ezaugarritzeko aztertutako neurriak

Atal honetan tesi hau osatzen duten lanetan gune berdearekiko kalkulatutako esposizioak azalduko dira. Esan beharra dago, lehenengo lanean eta hirugarren lanean kalkulatutako esposizio batzuk berak direla. Bi taldetan banatu ditzazkegu lan hauetan erabilitako esposizio hauek, pertsona bati esleitutako esposizioen bitartez edo interbentzio baten bitartez, talde bati esposizio zehatz bat ezarriz.

4.2.1. Gune berdeetara esposizioa lehenengo artikuluan

Lehenengo lan hau aurreko lerroetan aipatutako lehen taldean kokatuko genuke, pertsonari esleitutako esposizioetan, alegia. Horretarako lan honetan lehenik eta behin partaideak beraiek emandako etxeko helbidea geolokalizatzen da, gerora gainerako esposizioak puntu horrekiko esleitzeko. Behin partaideak geolokalizatuta hurrengo esposizioak esleitu zitzaizkien:

- NDVI (300 metrotan)
- Gune berdeen (5.000m^2) disponibilitatea 300 eta 500 metrotan
- Gune berdetara (5.000m^2) distantzia.

4.2.2. *Gune berdeetara esposizioa bigarren artikuluan*

Bigarren lan hau hasieran aipatutako bigarren talde horretan kokatuko genuke. Izan ere, lan honetan partaide talde bat lehenago zehaztutako gune berde batera eraman zen, beste taldea gune gris edo hiri gune batera eraman zen bitartean.

4.2.3. *Gune berdeetara esposizioa hirugarren artikuluan*

Azken lanean esposizio pertsonalak kalkulatu ziren berriro ere, kasu honetan haurren etxebizitzetan. Partaide bakoitzaren berdetasun maila ezaugarritzeko hurrengo aldagaiak erabili ziren:

- NDVI (100, 300 eta 500 metrotan)
- VCF (100, 300 eta 500 metrotan)
- Gune berdeen (5.000m^2) disponibilitatea 100, 200 eta 300 metrotan
- Gune berdetara (5.000m^2) distantzia

4.3. Aztertutako osasun adierazleak

4.3.1. *Ugalketa osasuna*

Aztertutako ugalketa osasun adierazleak UGARE proiektuaren baitan aurkitzen dira. Adierazle hauek haur jaio berrien datu ezberdinek osatzen dituzte, lehenago esan bezala, Donostialdeko emakume haurdunak soilik hartu dira kontuan. Adierazle hauek Donostia Unibertsitate Ospitalean jaso ziren.

Hauek dira jaio berriari buruz bildu ziren datuak:

- Jaiotze pisua: Haurra jaio zen momentuko pisua, gramoetan.
- Haurdunaldi astea: Haurra jaio zen momentuko haurdunaldi astea, aste kopuruetan.

Behin adierazle hauek izanik hurrengo aldagaiak sortu ziren:

- Jaiotze pisu baxua: Jaiotze pisua 2500 gramo baino baxuagoa denean
- Jaiotze goiztiarra: Haurdunaldi astea jaiotzean 37 aste baino gutxiago denean
- Haurdunaldi asterako txikia: Haurraren jaiotze pisua 10 pertzentilaren azpitik egotea jaiotze haurdunaldi astean.
- Haurdunaldi asterako handia: Haurraren jaiotze pisua 90 pertzentilaren gainetik egotea jaiotze haurdunaldi astean.

Azken bi aldagai hauek (haurdunaldi asterako txikia eta haurdunaldi asterako handia) kalkulatzeko 2013-2015 artean Gipuzkoan jaiotako 19167 (9682 mutil eta 9485 neska) haurren jaiotze astea eta pisua erabili genituen 10 eta 90 pertzentila ateratzeko, ondoren gure laginean haurdunaldi asterako txikia eta haurdunaldi asterako handia aldagaiak kalkulatu ahal izateko.

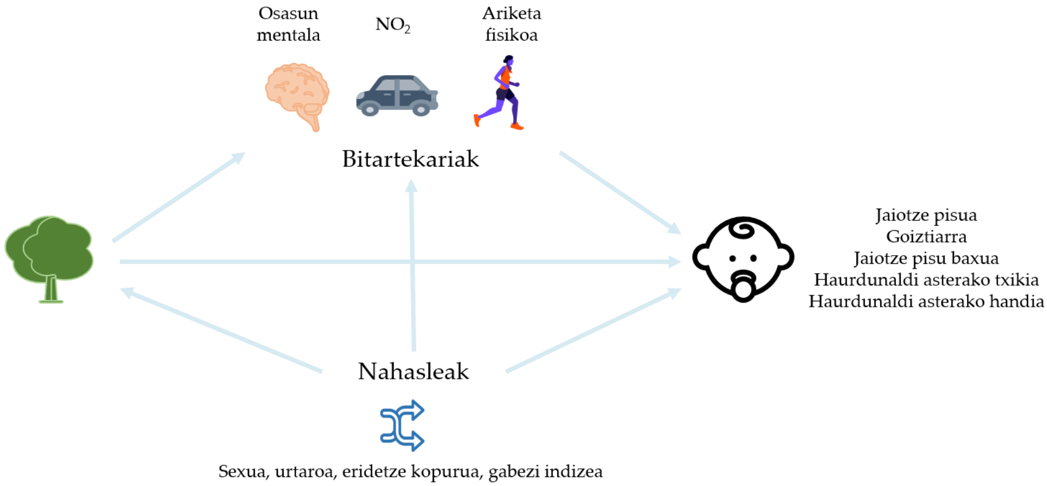
4.3.2. Atentzioa

Haurren atentzioa erreminta berarekin neurtua izan da azken bi artikuluetan (Artikulua 1 eta 2), ANT (*Attentional Network Test)* ordenagailuko testarekin (Fan et al., 2002; Rueda et al., 2004). Esan bezala, partaideek ordenagailuan egindako froga da, non, pantailan 5 gezi ikusiko dituzten, independienteki bakoitza ausazko norabidean. Partaideen zeregina, erdiko geziak zein norabidetara (eskuin ala ezker) begiratzen duen adieraztea da, horretarako, teklatuko geziak erabili beharko ditu. Asmatuz gero, errefortzu auditibo bat jasoko du (Woo hoo!) (Suades-González et al., 2017). Partaideek guztira 128 ataza egin beharko dituzte eta hauek 4 bloketan banatuak egongo direnak. ANTaren bitartez, hainbat aldagai jaso ahal izango dira: puntuazio zuzena, zehaztasuna, erreakzio denbora eta erreakzio denboraren errore estandarra, azken honek, markatzen du gehien bat atentzio eza (Dadvand et al., 2017; Pozuelos et al., 2014; Suades-González et al., 2017).

4.4. Azterketa estatistikoak

4.4.1. Lehenengo artikulu zientifikoan landutakoa metodo estatistikoak (Artikulua 1)

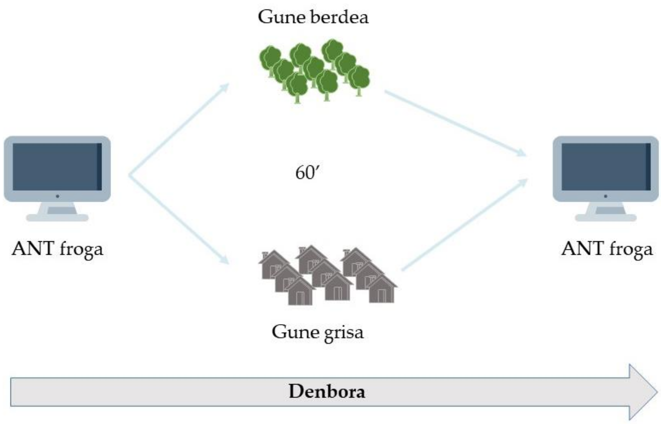
Lehenengo lan honetarako aztertu zen eredu estatistikoa 9. irudian ikus daiteke. Bertan, gune berdeek ugalketa osasunean modu zuzenean eta bitartekarien kontuan hartuz erlazioa aztertzea zen helburu. Horretarako, mediazio analisiak garatu genituen *natural effects models* (Lange et al., 2012) teknikaren bitartez R programaren *medflex* paketearen bitartez (R Core Team, 2019; Steen et al., 2017).



9. irudia. Lehenengo artikuluaren DAG modeloa

4.4.2. Bigarren artikulu zientifikoan landutako metodo estatistikoak (Artikulua 2)

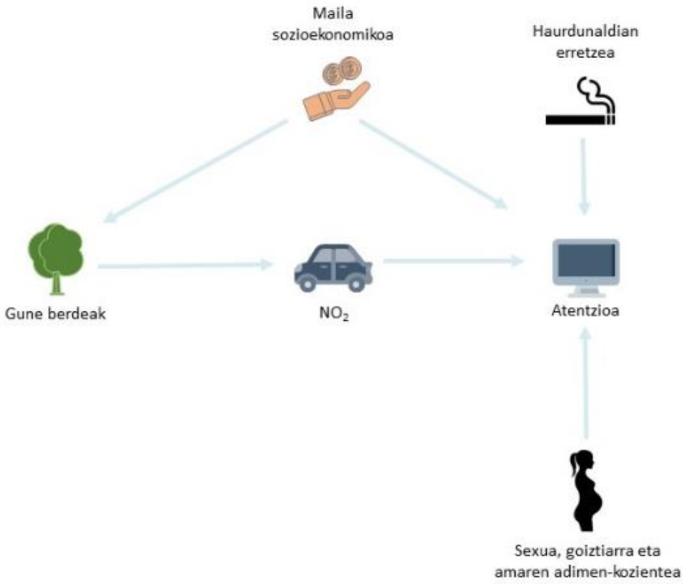
Bigarren lanean, ikerketa kuasiexperimental bat egin zen. Horretarako, bi taldetan banatu ziren partaideak, talde bat gune berdeetara bidali zen, beste taldea, aldiz, gune gris batera bidali zen. Gune berde edo grisera abiatu aurretik eta bertatik itzultzerakoan atentzioa neurtzeko ANT froga egin zuten. Lehenengo frogatik bigarren frogara egon zitezkeen aldaketak neurtze aldera eskola bakoitzerako egiantz handien mugatua erabiliz aztertu ziren efektu mistoen eredu linealen kontextuan (Bolker et al., 2009; José Pinheiro & Bates, 2000). Analisi estatistikoak egiteko R programaren (R Core Team, 2020) *nmle* paketea erabili zen (J Pinheiro et al., 2018).



10. irudia. Bigarren artikuluaren laburpen grafikoa

4.4.3. Hirugarren artikulu zientifikoan landutako metodo estistiskoak (Artikulua 3)

Hirugarren eta azken lanean, bi analisi mota garatu ziren paraleloki. Batetik, zeharkako analisiak egiteko, eredu lineal orokorrak erabili ziren, bestetik, luzerako analisiak egiteko efektu mistoen eredu lineala erabili zen. Lehenak atentzioaren neurketa bakarra zuelako partaideko eta bigarren analisiak, berriz, bi neurketa partaideko. Analisiak aurrera eramateko R programa erabili zen beste behin (R Core Team, 2020), lehenengo analisietarako *stats* paketeko lm() funtzio erabili zen eta bigarrenerako lme() funtzioa *nlme* paketetik (J Pinheiro et al., 2018).



11. irudia. Hirugarren artikuluaren DAG eredua

5. Emaitzen laburpena eta eztabaida

5.1. Emaitzen laburpena. Hipostesietan oinarrituz

Atal honetan, tesian egin diren hiru artikuluen emaitzak azalduko dira lehenago azaldu diren helburuekin bat eginez. Lehen artikuluari dagokionez (Artikulua 1), haurdunaldi asterako handi izateko babesle bezala azaldu da, nahiz eta estatistikoki marjinalki bakarrik harremandun den (HI.1 hipotesia baieztatuz) (H.O.1). Bestetik, etxebizitzatik 300 metrotara gune berde bat edukitzea jaiotze pisuaren jaitsierarekin erlazionatu da, harreman hau estatistikoki esanguratsua izanik (HI.2 hipotesiaren aurka). Azkenik, ez da inolako bitartekaritza erlaziorik ikusi (H.E.1), erlazio zuzena aurkitu dugu baina, ez erlazioa ez zuzena.

Bigarren artikuluari dagokionez (Artikulua 2), ez da HI.3 hipotesia bete, ez baita inongo hobekuntza esanguratsurik ikusi partaideen atentzioan jarduera gune berdeetan egiten zutenen artean, gune grisean egin zutenenik alderatuta (H.O.2 eta H.E.2).

Hirugarren artikuluan berriz (Artikulua 3), HI.4 hipotesia bete da, izan ere, atentzioaren hobekuntza bat ikusi da etxebizitzatik 300 metroko itzulinguruan NDVI maila altuagoa zutenen artean 11 urteko partaideen artean, bai Asturiasen eta bai Gipuzkoan (H.O.2 eta H.E.3). Hortaz gain, nahiz eta esanguratsua ez izan, erlazio gehienak esperotako norabidean agertu dira.

5.2. Eztabaida

Tesi honetan hiru ikerketa ezberdin eraman dira aurrera. Batak gune berdeek ugalketa osasunean duten eragina aztertu zuen eta beste biek gune berdek haurren atentzioan duten eragina, batek epe motzeko esposizioarekin eta besteak, ordea, epe luzeko esposizioarekin. "*Testing the Multiple Pathways of Residential Greenness to Pregnancy Outcomes Model in a Sample of Pregnant Women in the Metropolitan Area of Donostia-San Sebastián*" izenburua duen lehenengo lanean (Artikulua 1) ez da ikusi gune berdeek ugalketa osasuna hobetzen dutenik. Bigarren lanean, "*Is Brief Exposure to Green Space in School the Best Option to Improve Attention in Children?*", ez dago atentzioan hobekuntzarik gune berdeko taldean egon zirenen artean gune grisekoekin alderatuta. Azkenik, hirugarren lanean ("*Effects of Residential Greenness on Attention in a Longitudinal Study at 8 and 11-13 years*") bai ikusi dela atentzioaren hobekuntza bat NDVI 300 metrotan berdetasun mailarekin erlazionatuta.

5.2.1. Gune berdeen eta ugalketa osasunaren arteko emaitzen eztabaida

Gune berdeek ugalketa osasunean duten eragina aztertu duten metanalisi eta berrikuspen sistematiko ezberdinen arabera, gune berdeek eragin positiboa izan dezake ugalketa osasun adierazle ezberdinetan, batez ere jaiotze pisuan (Akaraci et al., 2020; Dzhambov et al., 2014; Hu et al., 2021; James et al., 2015). Tesi honetan garatutako lehenengo ikerketan berriz, berdetasunaren eta jaiotze pisuaren arteko kontrako erlazioa ikusi dugu, nahiz eta, tesi honetan landutako laginarekin ez dugun erlazio estatistikorik aurkitu. Tamalez, ezin izan dugu aurreikusitako hipotesia baieztatu (HI.2), hau da, ezin izan dugu zehaztu gune berde eta ugalketa osasunaren arteko erlazioan zenbat azaltzen duten ingurumen faktoreek, osasun mentalak eta ariketa fisikoak. Jakinik lehenengo artikulua behaketazko azterketa batean oinarritzen dela, ahalegin guztiak egin ziren aldagai nahasleak identifikatze eta jasotze aldera. Honi dagokionez, jasotako aldagai guztiak indibidualak izan baziren ere, maila sozioekonomikoa sekzio zentsaletan jaso genuen MEDEA indizearen bitartez (Duque et al., 2021). Ekologikoki jaso izanak zehaztasuna gutxitzea ekarri zuen ziurrenik eta hau izan daiteke erlazio esanguratsurik aurkitu ez izanaren arrazoietako bat. Honela jasotzea erabaki zen, beste aukera amaren maila sozioekonomikoa erabiltzea litzatekeelako, familiaren maila sozioekonomikoa kontuan hartu gabe, horrela jaso baigenuen galdetegian.

5.2.2. *Gune berdeen eta atentzioaren arteko emaitzen eztabaida*

Argitaratuta dauden gune berdeen eta atentzioaren arteko harremana aztertzen duten berrikuspen sistematikoena arabera, gune berdeek eragin positiboa dute atentzioan (de Keijzer et al., 2016; Luque-García et al., 2022; Vanaken & Danckaerts, 2018). Hori baieztatze aldera bi ikerketa epidemiologiko garatu dira tesi honetan. Literatura zientifikoan aurki ditzazkegun azterketa gehienak kuasi-experimentalak dira eta behakeztazko azterketak berriz gutxiengoak. Tesi honen kasuan, ikerketa kuasi-experimental bat eta behakeztazko azterketa bat egin dira, azken honetan epe luzeko neurketak eginez. Esan bezala, epe motzeko azterketei dagokionez, ikerketa ezberdinek ikusi dute hobekuntza bat eman zela gune berdeetara joan zirenen taldekoen atentzioan, hiri gune batera joan zirenekin alderatuz (Kuo & Taylor, 2004; Schutte et al., 2017; Stevenson et al., 2019), tesi honen bigarren lanean, aldiz, ez da horrelako loturarik ikusi, ezta kontrakorik erez, bat eginik Hartig *et al*.-en (1991) lanarekin. Emaitzetan ez da ezberdintasunik ikusi eta horren arrazoiak desberdinak izan daitezke. Alde batetik, aztertu ziren umeek gune berdeen esposizioa altua dute orokorrean, eta, nahiz eta, gune grisera joan zen taldea interbentzioa gune ez berde batean, bisualki gune berdeen esposizioa zuten. Bestetik, beste arrazoi bat izan daiteke, beste azterketekin konparatuz, aztertu genituen ume gehienak 20000 edo gutxiagoko biztanleko herri batean bizi direla eta beraz, hiriek sortzen duten atentzioaren nekea agian ez dela herrietan horrenbeste gertatzen. Izan ere, hirietan gune berdetara irisgarritasuna zailagoa izan daiteke arrazoi ekonomiko, geografiko edota sozialengatik (Subiza-Pérez et al., 2017).

Epe luzerako azterketei dagokionez, ikerketa gutxi dago (Asta et al., 2021; Dadvand et al., 2015, 2017), gehienak etxebizitzetako esposizioan ardaztu direlarik. Ikerketa guzti hauek atentzioaren hobekuntza bat ikusi dute berdetasun maila handiagoa duten umeetan. Hortaz, bat egiten dute tesi honetan hirugarren artikuluan aurkitutakoarekin. Azken artikuluan, laginaren tamaina beste biekin alderatuz handiagoa da eta bestetik, esposizioaren aldakortasuna ere handiagoa da. Laburbilduz, tesi hau osatzen duten hiru lanek gune berdeek ugalketa osasunean eta atentzioan, epe motzean eta luzean, duten eragina aztertzen dute. Orokorrean, lortutako emaitzek planteatutako hipotesi batzuk baieztatu dituzte, beste batzuk, ordea, ezin izan dira egiaztatu. Salbuespen modura, esan daiteke azken lanean bai ikusi dela hobekuntza esanguratsu bat atentzioan, esan beharra dago ere, ikusitako gainontzeko erlazio guztiak hipotesietan plazaratutako ideiaren bat egiten dutela. Nahiz eta, hauek estatistikoki esanguratsuak ez izan. Hau honela, artikulu bakoitzean aipatutako ahuldadeez gain, bada orokorragoa izan daitekeen beste bat: gune berdeak neurtzeko metodologia. Izan ere, nahiz eta, azken urteetan teknologiaren aurrerapenari esker esposizioa kalkulatzeko hainbat metodo garatu diren (Nieuwenhuijsen, 2015), badira oraindik ere ahultasun batzuk (Luque-García et al., 2022).

Gune berdeak edota berdetasuna neurtzeko metodologia ezberdinak daude, klasifikazio nagusi bat eginez, objektiboak eta subjektiboak leudeke, bakoitza bere alderdi positibo eta negatiboekin. Metodo objektiboek gune berdeak modu kuantitatiboago batean neurtzen dituzte, aitzitik, subjektiboek modu kualitatibo batean neurtzen dituzte. Halaber, metodo objektiboek gune berdeak 2 dimentsiotan ezaugarritzen dituzten bitartean, metodo subjektiboak gizakiaren ikuspegitik egiten du, hau da, 3 dimentsioetan (Leslie et al., 2010). Honek, errealistagoa egiten du gune berdeen ezaugarritzea. Dena dela, azken urteetako literaturan biztanleriak berdetasunera duten esposizio ahalik eta errealena esleitzeko hainbat teknologia garatu edo txertatu dira metodo objektiboan. Alde batetik, GNSS (Global Navegation Satellite System) teknologiari esker, pertsonen joan-etorriak monitorizatu daitezke, honela, etxebizitzan edo lantokian izan daitezkeen esposizioa ezaugarritzeaz gain, eguneroko esposizioa ere kontuan hartuz (Nieuwenhuijsen, 2016). Bestetik, GIS-aren bitartez distantziak marra zuzen baten bitartez kalkulatu ordez, kaleen sarearen bitartez kalkulatu daitezke, distantzia errealagoak lortuz (McCormack et al., 2008; Witten et al., 2008). Honetaz gain, puntako beste bi teknologia berri txertatu dira, LiDAR (Light Detection and Ranging) eta GSV (Green Street View). LiDAR teknologiak laser eskanerraren bitartez puntu-hodei bat sortzen du eskaneatutakoa 3 dimentsioetan sortuz (Casalegno et al., 2017; Vierling et al., 2008), honela metodo objektiboak 2 dimentsioetan ezaugarritzeko ahulezia ezabatuz. GSV-ari dagokionez, Googleko Street View-eko irudiak erabiliz berdetasuna kalkulatzen duen teknologi bat da. Honek, pertsona bakoitza egon den, kalean noski, puntu bakoitzaren 360ºko ikuspegia eskaintzen du, ondoren espektro ikusgaiko banden konbinazioaren bitartez berdetasuna kalkulatuz (Li et al., 2015).

Tesi honetan jorratutako lanetara itzuliz, lan bat batean ere ez da lehenago aipatu diren teknologia berririk erabili, hortaz, esan daiteke, kalkulatutako esposizioak ez direla kalkulatu zitezkeen zehatzenak.

Hala ere, azken teknologia hauek oraindik ez dira hainbeste erabili ikerketa epidemiologietan, honen arrazoietako bat hauen kostua izan daitekelarik.

Tesia osatzen duten hiru lanetatik bik ez dute gune berde eta osasun emaitzen arteko loturarik ikusi. Honetaz gain, gune berdeen eta osasunaren arteko erlazioan bitartekariek duten eragina ere aztertu da lehenengo lanean, izan ere, autore ezberdinen arabera, gune berdeek bitartekari ezberdinak direla medio dute eragina osasunean (Terry Hartig et al., 2014; Kihal-Talantikite et al., 2013; Markevych et al., 2017), baina lortutako emaitzek ez dute inongo erlazio esanguratsurik erakutsi. Hala ere, literatura zientifikoan aurki ditzazkegun berrikuspen sistematikoekin bat eginez (Gascon et al., 2016; James et al., 2015; Luque-García et al., 2022; McCormick, 2017), hirugarren lanean ikusi da gune berdeek eragina dutela atentzioan.

Hortaz, literatura zientifikoan orain arte ikusi denaren arabera esan daiteke gune berdeek paper garrantzitsu bat jokatu beharko luketela hiri plangintzan, izan ere, hiritarren osasuna hobetu dezakete. Hirietan garatu daitekezken naturan oinarritutako estrategiek osasun publikoan eragina dute (van den Bosch & Ode Sang, 2017). Gainera, jakina da gune berdeek osasunean dituzten onurak indartsuagoak direla maila sozioekonomiko bajuagoetan bizi direnenetzako, bizi baldintzako txarragoak dituztenentzako, alegia (Rigolon et al., 2021). Hau oso puntu garrantzitsua izan daiteke, baliabide urriko jendea osasun txarragoa izaten dutenak izan ohi direlako. Beraz, biztanleri talde honen egoera hobetzeko aukera bat izan daiteke. Tesi honetan ordea, hirugarren lanean, nahiz eta hasierako helburua ez izan, mediazio analisi bat eraman zen aurrera, aire kutsadurak gune berde eta atentzioaren artean zuen eragina neurtzeko asmoz. Analisi hauetan kontuan hartu zen gabezi indizea, maila sozioekonomikoa neurtzeko erabiltzen den indize bat. Bertan, aire kutsaduraren mediaziorik ikusi ez bazen ere, bai antzeman zela maila sozioekonomiko altuagoa zutenek atentzio hobea zutela, beraz, kasu honetan ez zen baieztatu aurretik aipatutakoa. Hau ikerketa eremuan gune berdeetara dituzten esposizio maila jada oso altuak direlako izan daiteke. Hala ere azpimarratu behar da maila sozioekonomiko baxukoentzat onuragarriagoak direla gune berdeak, horregatik, kontu handiz kudeatu behar dira naturan oinarritutako interbentzioak, izan ere, estrategia hauek garatu izan direnean *green paradox* fenomenoa gerta daiteke. Hau da, hiriko zonalde bat hobetzen denean, bertako etxebizitzen eta alokairuen prezioaren igoera bat ematen eta bertan bizi den jendea, azkenean, prezio horiek ordaindu ezinda lekuz aldatu behar da, zonalde txiroagoetara mugituz. Horregatik, hirietan horrelako interbentzioak egiten direnean beste neurri batzuekin batera egin behar direla kontuan hartzea garrantzitsua da (Cole et al., 2017).

Hirietan berdeguneak gehitzerakoan kontuan eduki behar dira eremuan sor ditzakeen aldaketak, lehenago aipatutakoak kasu. Hala ere, beharrezkoak dira hirietan geroz eta ugariagoak diren natura bidezko soluzioak. Izan ere, hiriko gune berdeek aldaketa klimatiko edota larrialdi klimatikoaren aurkako borrokan oso lagungarriak izan daitezke, lehenago aipatutako onurez gain, karbono dioxidoaren bahiketaren, biodibertsitatearen kontserbazioaren eta aire kalitatearen hobekuntzaren bitartez, esaterako (EEA, 2021).

Horrenbestez, esan dezakegu, gune berdeek geroz eta garrantzi gehiago eduki beharko luketela gure hirietan eta ondorioz, hiriaren plangintzan edota diseinuan parte hartzen duen orok kontuan hartu beharko lukeela, ez soilik erabilera paisajistiko bat bezala, baita hiritarren osasunean duen eragin positiboagatik ere.

Tesi honen bitartez, jada literatura zientifikoan aurki daitekeen ebidentzia zabaldu nahi izan da. Lehen artikuluaren bitartez, gune berde eta ugalketa osasunaren arteko harremanean eragin dezaketen bide ezberdinei buruzko jakinduria zabaldu nahi izan da. Bestetik, bigarren lanean, gune berdearen eta atentzioaren arteko ikerketa experiemental nahikoa lan egon arren, kasu honetan, hasiera egoera ezberdin batean gune berdeek eragina duten ala ez aztertu da, hau da, ea berez gune oso berdeak diren lekuetan gune berdeetara edo gune grisetara doazen partaideen artean ezberdintasunak dauden aztertu da. Azkenik, hirugarren lanean, gune berde eta atentzioaren arteko azterlan longitudinalen ebidentzia zabaldu nahi izan da. Jada askotan aipatu den moduan, oso urriak dira mota honetako azterlanak, hortaz, azken lan honen bitartez, literatura zientifikoa zabaldu nahi izan da ebidentzia sendoago bat sortze aldera.

6. Dibulgazioa

Tesian zehar egindako lanak aurkezturik eta ebidentzia zientifikoari ekarpen txiki bat eginez hurrengo pausoa ikusi eta ikasitakoa gizartera zabaltzea zen, H.O.3 helburua betetzea.Hau da, lortutako emaitzak dibulgatzea eta bide batez, pertsonen jakin-mina sustatzea eta hauek iritzia garatu ahal izatea (Sánchez & Roque, 2011). Horretarako, 5-7 urteko haurrentzat gune berdeek osasunean duten eragin positiboa azaltzeko bideo bat prestatu zen, hurrengo QR-an ikusgai dagoena (*12 irudia*).

12 irudia. Gune berdeak bideora lotura

Ikusentzunezkoaz gain, Ekaia aldizkarian gune berdeek osasunean duten eraginari buruzko artikulu bat argitaratu zen (Artikulua 4). Hizkuntza ulergarri eta modu sinple batean ordura arte literatura zientifikoak zioen laburbilduz, jendarte guztiari zuzendua.

II. atala: Ondorioak eta erreferentziak

7. Ondorioak

Tesi honen helburu nagusia hiriko gune berdeek emakume haurdunen ugalketa osasunean eta haurren atentzioan eragina duten aztertzea izan da. Lehenengo eta bigarren lanek ez dute erakutsi gune berdeek ugalketa osasuna eta atentzioa hobetzen dutenik, hurrenez hurren. Horrez gain, lehenengo lanean ez da aurkitu gune berde eta ugalketa osasunaren arteko erlazioan bitartekaritza erlaziorik. Hirugarren lanean, ordea, gune berdeek haurren atentzioan hobekuntza eragiten dutela erakutsi da. Garrantzitsua litzateke datozen ikerketetan gune berdeak neurtzeko dauden teknologia berrien erabilera gehitzea, hauetara eduki daitekeen esposizio errealago bat bilatzea dela helburu. Era berean, gomendagarria litzateke partaideen maila sozioekonomikoa ondo jasotzea, izan ere, oso aldagai garrantzitsua da gune berdeak aztergai dituzten ikerketetan. Azkenik, ahalegin bat egin beharko litzateke zientzian sortzen den ebidentzia guztia gizarteratzeko, baita informazio hau hirigintzan eta lurralde planteamenduan lan egiten duten politiko zein teknikariei ere iristeko, gerora administrazioek hartzen dituzte erabakietan kontuan har daitezen.

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III. atala: Eranskinak. Argitaratutako lanak, kongresuetan aurkeztutako lanak eta egonaldiak

9. Argitaratutako lanak

9.1. Artikulu bilduma bidezko tesia osatzen duten lanak

1.artikulua: *Testing the Multiple Pathways of Residential Greenness to Pregnancy Outcomes Model in a Sample of Pregnant Women in the Metropolitan Area of Donostia-San Sebastián*

2.artikulua: *Is Brief Exposure to Green Space in School the Best Option to Improve Attention in Children?*

3.artikulua: *Effects of residential greenness on attention in a longitudinal study at 8 and 11-13 years*

4.artikulua: *Hiriko gune berdeak eta osasuna*

1.artikuluaren material osagarria

2.artikuluaren material osagarria

3.artikuluaren material osagarria

1.artikulua

Artikuluaren izenburua: *Testing the Multiple Pathways of Residential Greenness to Pregnancy Outcomes Model in a Sample of Pregnant Women in the Metropolitan Area of Donostia-San Sebastián*

Autoreak: *Asier Anabitarte, Mikel Subiza-Pérez, Jesús Ibarluzea, Kepa Azkona, Gonzalo García-Baquero, Carme Miralles-Guasch, Jon Irazusta, Kristina W. Whitworth, Guillem Vich eta Aitana Lertxundi*

Aldizkariaren izena: *International Journal of Ennvironmental Research and Public Health (ISSN: 1660-4601)*

DOI: *10.3390/ijerph17124520*

Argitaratze data: *23/06/2020*

Inpaktu-faktorea: *3.390 (JCR 2020)*

Q1: Public, Environmental & Occupational Health (SSCI)

Q2: Public, Environmental & Occupational Health (SCIE)

Q2: Environmental Sciences (SCIE)

International Journal of
Environmental Research and Public Health

MDPI

Article

Testing the Multiple Pathways of Residential Greenness to Pregnancy Outcomes Model in a Sample of Pregnant Women in the Metropolitan Area of Donostia-San Sebastián

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Received: 22 May 2020; Accepted: 19 June 2020; Published: 23 June 2020

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Abstract: Residential greenness may positively impact diverse human health indicators through the reduction of air pollution, the improvement of psychological health, and the promotion of physical activity. Previous studies indicate a weak but positive association with pregnancy outcomes. Our aim was to test the multiple pathways from residential greenness to pregnancy outcomes model, using residential NO_2 concentrations, psychological health, and moderate-to-vigorous physical activity (MVPA) during the first trimester of pregnancy, in a sample of 440 pregnant women residing in Donostia, Spain. Three metrics of residential greenness were calculated around each participant's home address: normalized difference vegetation index (NDVI) within 300 m, and green space (>5000 m^2) availability within 300 and 500 m. Residential NO_2 concentrations, psychological health, and MVPA were explored as mediators of the associations between these metrics and the following pregnancy outcomes: birth weight (BW), low birth weight (LBW), prematurity, small for gestational age (SGA), and large for gestational age (LGA). Educational attainment, parity, and body mass index (BMI) were treated as covariates. Counterfactual mediation analyses showed very low to null statistical support for an association between any of the greenspace metrics and pregnancy outcomes in the full sample. Green space availability (300 m) was associated with lower BW and showed a marginal protective effect against LGA.

Keywords: mediators; maternal health; natural effects models; urban exposures; GIS

1. Introduction

Green infrastructure, which encompasses urban forests, parks, green roofs, street trees, and flowers, provides a wide array of ecosystem services that are of great interest for human health [1]. It has been proposed that greenness's salutogenic effects may arise from three complementary pathways [2], namely the mitigation of harmful exposures, the recovery from attentional fatigue and stress, and the encouragement of physical activity (PA) and social interactions. Current evidence supports the benefits of greenness (measured as availability of green spaces and/or normalized difference vegetation index (NDVI) near the residence), including, among others, improving cardiovascular (CV) health and reducing CV-related mortality [3], reducing obesity rates [4], increasing physical and mental health [5,6], and reinforcing social cohesion [7]. Besides, international urban planning strategies and policies point at the value green areas and infrastructures in the achievements of healthier cities [8].

Researchers are also aware of the impact of greenness on pregnancy outcomes [9], which are of utmost importance due to their association with cognitive development, medical conditions, and morbidity and mortality in later stages of life [10–12]. The literature in this area suggests that residential greenness weakly but significantly reduces the risk of small for gestational age and preterm birth and increases birth weight [13–19]. Evidence of the possible influence of green spaces on large for gestational age is scarce. To our knowledge, there is only one previous study of this question, in which support for this association was not found [20]. In a large exposome study on birth weight [21], residential greenness measured via NDVI within 100, 300, and 500 m from the mother's residence was positively associated with birth weight and was protective against term low birth weight. However, evidence is equivocal and most of the studies cited above report significant effects on some but not all the considered pregnancy outcomes (i.e., birth weight, low birth weight, prematurity, and small for gestational age). In addition, some studies have shown negative effects of residential greenness on pregnancy outcomes [22,23].

Kihal-Talantikite et al. [9] suggested that residential green space might have a positive effect on newborns' health through the improvement of maternal physical and psychological health and the reduction of exposure to contaminants such as air pollution. The main objective of our study was to test the model presented in Figure 1, which is an adaptation of the one developed by Markevych et al. [2], focused on the possible effects of residential greenness on pregnancy outcomes (i.e., prematurity, birth weight, low birth weight, small for gestational age, and large for gestational age). We expect to observe a positive effect of greenness on these outcomes and expect that they will be mediated through three different pathways: (1) the reduction of exposure to air pollution, (2) the improvement of psychological health, and (3) the promotion of PA. Finally, it is also possible that residential greenness may have a positive influence on outcome variables through other pathways not considered in this study.

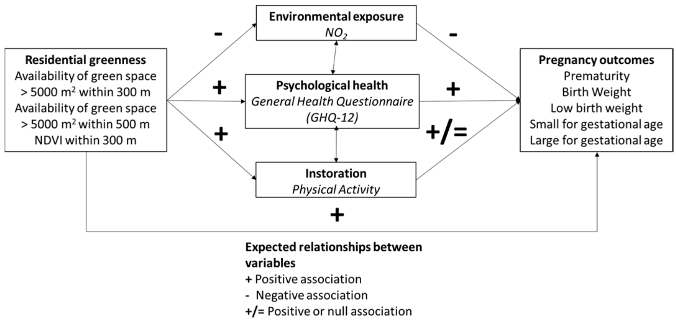

Figure 1. Proposed multiple pathways of residential greenness to pregnancy outcomes (MPRGPO) model and associations linking residential greenness to pregnancy outcomes in the study sample.

1.1. Previous Evidence Supporting the Multiple Pathways of Residential Greenness to Pregnancy Outcomes (MPRGPO) Model

We briefly review current literature on (1) the association of residential greenness and the three proposed mediators and (2) the association between those mediators and the pregnancy outcomes selected for this study (Figure 1).

First, residential greenness may mitigate air pollution. For example, vegetation removes atmospheric particles by dry deposition onto their surfaces and absorbing gaseous pollutants through their stomata [24]. In Strasbourg (France), it was estimated that urban trees absorb 7% of PM_{10} emissions in the city [25], and, according to Nowak [26], tree canopy is responsible of the absorption of 8% of NO_2 emissions. Cai, Zhuang, and Ren [27] emphasize the ability of well-designed and interconnected green spaces in the reduction of $PM_{2.5}$ and NO_2 air levels, although the potential of green spaces to mitigate ozone concentrations is much more limited. Residential green space and green elements may also foster improved psychological health through the recovery from cognitive fatigue and emotional distress [28,29], and evidence points to the positive influence of residential greenness on psychological health [5,19,30]. Hence, if residential greenness enhances psychological health during pregnancy, it may subsequently have a positive effect on pregnancy outcomes (please see Epigraph 1.2.2). Indeed, in a study analyzing data from over 7000 singleton pregnancies, researchers found that residential greenness (in the form of NDVI) and a lower distance to green spaces exerted a protective role against depressive symptoms during pregnancy [31]. Finally, residential greenness (using both metrics of NDVI and availability of greenspace within 300 m of the home) has been positively associated with self-reported MVPA in European adults [30]. This effect is also apparent in other studies of green space availability and PA [32] and is likely due to the fact that green spaces promote PA by providing room for activities (e.g., walking, running, playing sports, etc.) that might not be easily performed in other settings [33].

The current literature also provides rich evidence of the connection between the proposed mediators (Figure 1) and pregnancy outcomes. Numerous studies, including systematic reviews and meta-analyses, support associations between multiple air pollutants (e.g., NO_2, $PM_{2.5}$, and PM_{10}) and pregnancy outcomes, including those related to alterations in birth weight and gestational age [34,35]. Additionally, given remarkable changes in the biological, behavioral, and social spheres that occur during pregnancy, there has been increasing interest in studying psychological health in pregnancy. For instance, between 7–20% of pregnant women may have depressive symptoms [36–38]. Some studies indicate a more delicate psychological state during pregnancy than in other moments of life [39], although there is also evidence that psychological health does not vary—in statistical terms—between the pre-pregnancy or postpartum periods, or between pregnant and non-pregnant women [40]. Regardless, psychological health during pregnancy may be an important determinant of pregnancy outcomes. In a meta-analysis of eight cohort studies, Lima et al. [41] reported that high maternal stress during pregnancy increased the odds of low birth weight but not preterm delivery.

Finally, while it is well established that PA promotes physical and psychological health [42,43] for the general population, until recently, pregnant women have been advised to limit their PA [44]. However, a review by Schlüssel and colleagues [44] concluded that, in fact, PA during pregnancy reduces the risk for pre-eclampsia and gestational diabetes and failed to detect consistent adverse effects on miscarriage, low birth weight, or cesarean deliveries. More recently, a meta-analysis of randomized clinical trial and cohort studies did not detect any negative association between exercise during pregnancy and pregnancy outcomes [45]. A similar picture was obtained in two other meta-analyses [46,47]. In a study with greater than 97,000 participants, low PA patterns were associated with higher odds of preterm birth and cesarean delivery, with no effect detected for highly active women [48].

1.2. Blue Spaces and Health: Similarities to Green Spaces

The literature about the effects of greenness on human health is wide and well-consolidated. However, less attention has been paid to the salutogenic potential of blue spaces (e.g., rivers, sea, lakes, and other superficial water bodies), which have been frequently included in the "green space" category [49]. Apparently, some of the positive effects detected for greenness appear also in relation to blue spaces. Some studies have found positive associations between exposure and use of blue spaces and both general physical and psychological health [50–52] and increased PA [51,53]. Nevertheless, the question of whether exposure to blue spaces is positively associated with pregnancy outcomes has not been addressed to date [22].

The objective of this study was to test the Multiple Pathways of Greenness to Pregnancy Outcomes Model by analyzing the direct association of residential greenness with pregnancy outcomes and the indirect associations via the proposed mediators. Moreover, we aimed to test this model with the availability of walkable green and blue spaces, to see whether the effects of blue exposure could be comparable.

2. Materials and Methods

2.1. Study Sample and Procedure

We recruited 441 pregnant women (mean age 33.52; SD = 4.88) living in the metropolitan area of Donostia-San Sebastián (Spain). This area, located in the Northeastern region of the Basque Country, is composed by the municipalities of Astigarraga, Donostia-San Sebastián, Errenteria, Hernani, Lasarte-Oria, Lezo, Oiartzun, and Pasaia y Usurbil (Figure 2). All of these municipalities compose the functional area of the main city of the region (Donostia-San Sebastián) and maintain a semi-continuous urban scene.

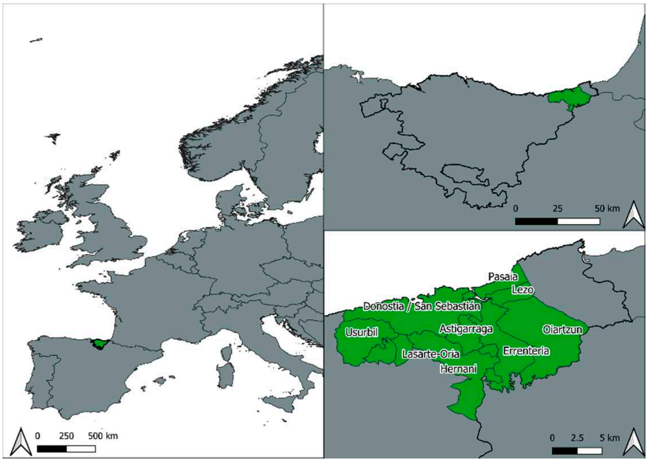

Figure 2. Location map of the study area.

Participants were recruited from among all women who attended the gynecological health service for the 12th week echography that is routinely conducted in the Basque Health Service (Osakidetza). Women residing in the study area, being able to adequately communicate in Basque or Spanish, and not having been identified with a high-risk pregnancy, were invited to take part in the study. If interested, they were led to a private room, where a researcher provided them with further information about the study, including an explanation of the implications of taking part in the study and administered informed consent. After consenting, participants were administered the study questionnaire and provided with an accelerometer (ActiGraph GT3X-BT; ActiGraph LLC, Pensacola, FL, USA). They were instructed to wear the accelerometer for one week, starting on the day of recruitment, and given information on how to return the device after its use. By the 20th week of pregnancy, and before attending the second echography, participants were contacted again and invited to wear the accelerometer for one week more. They were also given, in person, a short questionnaire. Birth information was obtained via the medical birth records in Osakidetza. 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 (Ethical Approval Number: PI2018108).

2.2. Study Instruments and Variables

2.2.1. Residential Greenness

We calculated three residential greenness metrics (availability of green space with area > 5000 m^2 within 300 or 500 m of the woman's home and NDVI within 300 m of the home) for each of the study participants, using the geocoded of each participant's home at the time of her recruitment. NDVI (Equation (1)) is a residential greenness metric commonly used in previous studies that indicates the level of greenness of a given area and which is calculated through the combination of the near infrared (NIR) and the red band based on satellite imagery with a 30 × 30 m resolution in the maximum vegetation period (03.08.2019) [54]. The value of the NDVI ranges from −1 to +1, with 1 being the maximum level of greenness [55]. As mentioned, we separately calculated residential NDVI within 300 and 500 m buffers of each participant's home.

$$NDVI = \frac{(NIR - Red)}{(NIR + Red)} \tag{1}$$

Availability of residential greenness was operationalized, using a dichotomous indicator of the presence (or absence) of a green space of area >5000 m^2 within a 300 or 500 m buffer of the residence and accessibility by the estimation of the minimum distance (in a straight line) with a green space of the former dimensions. For both green space availability variables, we used a local layer obtained from GeoEuskadi, the spatial data service of the Basque Country.

Availability of walkable green space (of area >5000 m^2) and blue space (the sea and main rivers) within 300 m of the residence was also calculated for the subsample of participants (n = 256) residing in the city of Donostia-San Sebastián. The term "walkable" means, here, those green and blue settings that are accessible and often used by citizens to walk and run (among other activities). The inclusion of spaces in the walkable category was collectively defined by three of the authors' (AA, MS-P, and JI), who research and live in the city. This variable was only created for women who live in the municipality, as a result of the limited knowledge of the authors about the use patterns of use of green and blue spaces in the rest of the study area.

2.2.2. NO_2 Exposure Assessment

We assessed air pollution exposures by using estimates of residential NO_2 concentration from land-use regression (LUR) models previously developed [56], which accounted for the spatial variability expected among participants. The variables included in the LUR model were (1) road length in 1000 m buffer, (2) main road length in 25 m buffers, and (3) area of low residential density in 5000 m buffers. In contrast to the original authors, we obtained the road network from the Basque Country's IDE (Spatial Data Infrastructure in its Spanish acronym) and residential density from the CORINE 2018 Program (Coordination and Information on the Environmental Programme; CLC 2018 accessed in https://land.copernicus.eu/pan-european/corine-land-cover/clc2018), initiated by the European Commission. Once participants were assigned a LUR-based NO_2 exposure level, we applied a time correction to account for seasonal changes. To do so, we gathered daily air-quality data from eight air-quality stations from the Basque Government Air Quality Network's stations in the study area. Each participant was assigned to the station closest to her residence. Individual LUR values were divided by the average value of all the stations during the study period (October 2018–February 2020) and then multiplied by the daily value of the corresponding station. Hence, an individual daily value adjusted for spatial and time variation was obtained for each participant. Finally, we calculated individual average value for the whole pregnancy by compiling the exposure scores meeting the pregnancy dates.

2.2.3. Physical Activity

Objective PA was determined based on the accelerometer (Actigraph wGT3X-BT set at 30 Hz) worn by the participants for two separate one-week periods during pregnancy (once in the first trimester and once during the second trimester). Participants' PA data were used in the analyses if they had worn the device a minimum of three days of at least 10 h of use per day in each sampling period. Sleeping hours (23:00–06:00) were not taken into account, and Freedson 1987's thresholds were used to calculate the minutes of light, moderate, and vigorous activity. This allowed us to estimate the number of minutes of sedentary behavior, as well. For the analyses, we built a composite measure reflecting MVPA by adding registered daily minutes of moderate and vigorous physical activity. Self-reported PA was also assessed through a single question in which participants were asked to define themselves as sedentary, scarcely active, moderately active, quite active, or very active [57,58] in each of the sampling periods.

2.2.4. Psychological Health

Participants' psychological health status during the first trimester was measured with the Spanish version of the General Health Questionnaire [59]. This scale comprises 12 items reflecting diverse psychological symptoms and daily functioning issues, using a 0–4 scale in which the respondent is asked to indicate whether she is experiencing them and to what degree. The sum of the answers provides a score ranging from 0–36, with higher scores indicating worse psychological states or higher amounts of stress. The internal consistency of the scale for this study was good (α = 0.75).

2.2.5. Pregnancy Outcomes

The outcome variables defined for this study were birth weight, preterm birth, low birth weight (LBW), small for gestational age (SGA), and large for gestational age (LGA). We defined preterm birth as birth <37 completed weeks of gestational age and low birth weight as <2500 g. SGA and LGA were defined as sex-specific birthweight less than the 10th percentile (SGA) or greater than the 90th percentile (SGA) for gestational age, based on the distribution of birthweights for 19,000 births in Gipuzkoa, during the period 2013–2015.

2.2.6. Covariates

We also obtained a list of adjustment variables. Sex of the newborn, participant's parity, and season of the birth were obtained from medical records. Socioeconomic status (SES, in the form of a district privation index developed for the MEDEA project-http://www.proyectomedea.org/-) was assigned to each participant, based on their residential district. Finally, body mass index (BMI) before and during pregnancy, based on the WHO classification, was calculated from self-reported data [60].

2.3. Data Analysis

The events of being born small for gestational age (SGA) or large for gestational age (LGA) give rise to two of the five newborn traits used as response variables in the subsequent mediation analysis. We classified newborns in the present dataset as either SGA, LGA, or normo-type. For this purpose, we first employed a second dataset, obtained from 9682 boys and 9485 girls born in Gipuzkoa during 2013–2015, to compute the 10th and 90th percentiles (i.e., 0.1th and 0.9th quantiles) for the sample distributions of newborn weights (g) at each of the gestational weeks, 25–42 (Supplementary Table S1). To estimate these quantiles, the median-unbiased estimator (<sample quantiles type 8> in Reference [61]) was used, as implemented in the R function quantile() of R software v. 3.6.1 (R Foundation for Statistical Computing, Vienna, Austria) [62]. This estimator not only is defined independently of underlying probabilistic distributions, but also Hyndman and Fan [61] found that it possesses most of the required properties of (sample) quantile estimators. Once computed by using the abovementioned second dataset, we then used the said quantile estimates to classify newborns in the present dataset as SGA or LGA if the observed weight was below the 10% threshold or above the 90% threshold, respectively; otherwise, they were considered as normo-type (i.e., neither SGA nor LGA).

In order to address the study's objective, we used data from the whole study population to apply mediation analysis [63]. For these analyses, we used objective MVPA during the first trimester of pregnancy instead of the self-reported estimation (for accuracy reasons) or MVPA during the second trimester, as only a half of the sample participated in the second data-collection period. First, we analyzed associations between each of the primary study variables (exposures, mediators, and outcomes) with the adequate statistical procedures for each pair of comparison (Yule's phi coefficient, Welch's F, and chi-squared test). Mediation analysis allowed us to explore whether effects of residential greenness on the pregnancy outcomes under study (i.e., birth weight, LBW, preterm birth, SGA, and LGA) are mediated by maternal psychological health, MVPA during pregnancy, or residential NO_2 exposure, once that we condition them on a priori covariates (i.e., sex of the newborn, season in which the neonate was born, maternal parity, and family privation index). In each pathway, we decomposed total effects into natural (also called pure) direct and indirect effects [64] via the mediation formula [65] as implemented in the R package medflex [62,66]. Total effects were thus decomposed within the framework of counterfactual outcomes [64], into natural direct and indirect effects via the mediation formula [65]. The advantage of this approach is that it allows the extension of mediation analysis to include a large class of models [67,68] that encompasses both numerical and categorical responses and exposures, as well as numerical and categorical mediators. More explicitly, we fitted imputation-based [69] natural effect models [70] to test mediation hypotheses concerning the general question whether either maternal psychological health, maternal physical activity, or residential NO_2 exposures experienced during pregnancy act as mediators (M) of the effect of exposure (X) to neighborhood greenness (Figure 3) on any of the five newborn traits (Y) (i.e., birth weight, prematurity, SGA, LGA, and LBW), conditioned on the covariates (C) (i.e., sex of the newborn, season of birth, maternal parity, and family privation index). The sampling distributions of model parameters were approximated by using nonparametric bootstrap with 1000 replications, and these sampling distributions were then used for statistical inference (hypothesis testing).

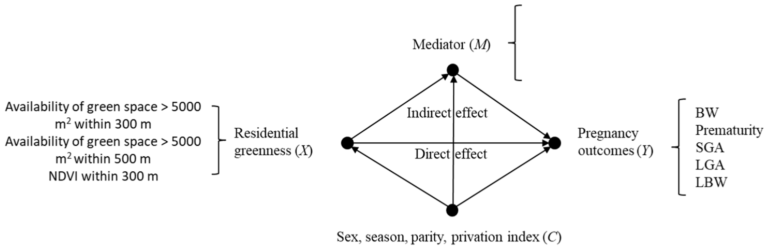

Figure 3. Directed Acyclic Graph representing the hypotheses tested in this research work for the whole study population. These mediation hypotheses concern the questions whether each of three variables experienced during pregnancy, namely GHQ, MVPA, and NO_2 exposure, can be considered as intermediate mechanisms (M) through which neighborhood greenness (X) exerts its influence on each of the five newborn traits (Y), namely birth weight, prematurity, small for gestational age (SGA), large for gestational age (LGA), and low birth weight (LBW), once that it has been conditioned on the covariates (C), namely sex of the newborn, season in which the neonate was born, maternal parity, and family privation index.

We also computed population-average effects, together with 95% C.I., for the natural-effects models reported (Supplementary Material Table S5 and Supplementary Material Table S6).

Additionally, as mentioned, we also used data from the subsample of the study population who resided in the municipality of Donostia-San Sebastián, to assess, using the same statistical technique, whether the same variables (i.e., psychological health, MVPA, or NO_2 exposure) mediate the effect of either exposure to walkable blue space availability (within 300 m), walkable green space availability (within 300 m), or the union of both exposures, on each of the aforementioned five newborn traits, once we take into consideration the said covariates (see Supplementary Materials Figure S1).

In the first case (Figure 3), since there are three potential mediators (psychological health, MVPA, and NO_2), five response variables (birth weight, prematurity, SGA, LGA, and LBW), three exposures (availability of green space >5000 m^2 within 300 and 500 m and NDVI within 300 m), and only one set of covariates, there are sixty ($4 \times 5 \times 3$) hypotheses to be tested. In the second case (Supplementary Figure S1), there also are sixty additional hypotheses. A description of the variables involved in this research is given in Table 1.

Table 1. Description and distribution of study variables ranged by role in the analyses.

Role in the Analyses	Variable	Type	*n*	*n* Missing	Condition Is Met	Minimum	Maximum	Mean	SD	Median	Q1	Q2	IQR
Exposure	Green space availability within 300 m	Binary	435	1	325 (74.7%)	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
	Green space availability within 500 m	Binary	435	1	384 (88.3%)	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
	Neighborhood greenness (NDVI) within 300 m	Quantitative continuous	435	1	N/A	0.07	0.5	0.21	0.09	0.2	0.14	0.26	0.11
Mediator	Mental health	Quantitative discrete	373	63	N/A	0	29	10.8	4.07	10	8	13	5
	Average NO_2 during the whole pregnancy	Quantitative continuous	400	36	N/A	11.3	226	46.7	22.36	40.2	33	56	23
	MVPA during the first trimester	Quantitative continuous	338	98	N/A	4	124	39.9	21.65	36.3	24.1	53.4	29.35
Response	Birth Weight	Quantitative continuous	400	36	N/A	1600	4900	3350	488.62	3340	3060	3640	580
	Prematurity	Binary	398	38	13 (3.3%)	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
	SGA (small for gestational age)	Binary	397	39	37 (9.3%)	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
	LGA (large for gestational age)	Binary	397	39	58 (14.6%)	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
	LBW (low birth weight)	Binary	400	36	19 (4.8%)	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
Covariate	Parity	Quantitative discrete	400	36	N/A	0.00	10.00	0.71	0.89	1.00	0.00	1.00	1.00
	Privation Index	Quantitative discrete	435	1	N/A	1.00	5.00	2.42	1.28	2.00	1.00	3.00	2.00
					♀	♂	Spring	Summer	Autumn	Winter	N/A	N/A	N/A
	Sex	Binary	401	35	196 (48.9%)	205 (51.1%)	N/A	N/A	N/A	N/A	N/A	N/A	N/A
	Season	Nominal	398	38	N/A	N/A	82 (20.6%)	135 (33.9%)	127 (31.9%)	54 (13.6%)	N/A	N/A	N/A

Note: SD—standard deviation; Q1—quartile 1; Q2—quartile 2; IQR—interquartile range; ♀—Female; ♂—Male.

3. Results

3.1. Testing the Multiple Pathways of Residential Greenness to Pregnancy Outcomes Model in the Study Sample

Participants were 33.52 years old on average (SD = 4.48). A total of 50.44% of the participants had no currently living children previous to the ongoing pregnancy, 36.87% had one previous child, and the rest of the sample had two or more other children. A 66.67% of the women which participated in the study were normal-weighted, 16.22% were overweight, and 6.78% were obese, according to the BMI classification system. Around two-thirds of the sample had completed tertiary education (64.60%) and were working at the time of data collection (79.94%). The sociodemographic profile of the study participants and further data on their characteristics can be found elsewhere [71].

Around three-quarters and nine-tenths of the participants lived within 300 m and 500 m of a green space with area >5000 m^2, respectively (Table 1). NDVI scores (mean = 0.21; SD = 0.09) converge with what might be expected in urban built settings with grassland sections, street trees, and other usual elements of urban greenery. The study of mediator variables reveals that participants experienced low-to-moderate levels of psychological stress and exercised, on average, above the international PA recommendations. With regard to NO_2, average concentration values in the study area (mean = 46.7 $\mu g/m^3$; SD = 22.36) were higher than the average annual value in the Basque Country (mean = 22–30$\mu g/m^3$) [71]. In relation to outcome variables, 9.3, 14.6, 4.8, and 3.3% of the births were categorized as SGA, LGA, LBW, or premature, respectively. The average birth weight was 3350 g, with a standard deviation of 500 g.

Our initial analyses did not reveal statistically significant associations between the three exposure variables and most of the mediators or outcomes (data not shown). The exceptions were a statistically significant differences in average BW by green space availability within 300 m of the residence (F = 4.91, $p < 0.05$; not found at the 500 m level) and in average residential NO_2 concentrations by green space availability within 500 m of the residence (F = 7.20, $p < 0.01$), and a negative correlation between NDVI within 300 m and MVPA minutes (rho = −0.179, $p < 0.001$). These results indicate that participants living in the vicinity of a green space of more than 5000 m^2 delivered children with lower average birthweights and were exposed to lower NO_2 concentrations, and those living in greener environments performed less activity at moderate-to-vigorous intensities per day. We also found that participants who delivered LBW children were less active than the rest of the sample (F = 7.20; $p < 0.05$).

The main results of the natural effects mediation models are shown in Table 2. Overall, the data did not confirm the existence of either a direct link between residential greenness with the pregnancy outcomes selected for this study or an indirect association between the former and the latter through the three proposed mediators. The only statistically significant effect we observed was a negative direct effect of green space availability in 300 m on BW, which was observed in the model using NO_2 as mediator. This means that participants living close to green spaces delivered children weighing, on average, 140 gless at birth than participants living further from green spaces. The direct effect in the models using the other two mediators was only marginal ($p < 0.10$). Another marginal negative direct effect of green space availability in 300 m was detected for LGA when GHQ was used as a mediator. More extensive information about Table 2 can be seen in Supplementary Material Table S2.

Table 2. Direct and indirect natural effect coefficients and SE by residential greenness metric, mediator, and outcome.

Exposure	Prematurity			SGA			LGA			LBW			BW		
	NO$_2$	**GHQ**	**MVPA**	**NO$_2$**	**GHQ**	**MVPA**	**NO$_2$**	**GHQ**	**MVPA**	**NO$_2$**	**GHQ**	**MVPA**	**NO$_2$**	**GHQ**	**MVPA**
Green availability 300 m															
Direct effect	−0.1 (2.69)	−0.71 (3.10)	−0.32 (2.61)	0.68 (0.55)	0.46 (0.56)	0.42 (0.79)	−0.52 (0.32)	−0.64 † (0.38)	−0.48 (0.37)	0.39 (2.35)	−0.20 (2.48)	0.06 (2.31)	−138.65 * (60.35)	−107.87 † (65.39)	−110.63 † (66.90)
Indirect effect	−0.17 (0.15)	0.06 (0.23)	0.01 (0.17)	−0.02 (0.06)	<0.01 (0.03)	<0.01 (0.04)	0.03 (0.04)	0.01 (0.03)	−0.012 (0.04)	−0.12 (0.11)	0.05 (0.08)	−0.016 (0.12)	6.62 (5.26)	−1.24 (4.54)	−2.06 (6.23)
Green availability 500 m															
Direct effect	0.99 (8.27)	0.02 (8.49)	0.27 (8.28)	1.12 (5.10)	1.01 (5.19)	0.95 (4.89)	−0.11 (0.54)	−0.20 (1.59)	−0.25 (0.77)	0.46 (5.76)	−0.26 (5.80)	−0.10 (6.03)	−137.35† (81.96)	−123.87 (86.26)	−133.9 (86.98)
Indirect effect	−0.50 (0.38)	0.11 (0.19)	0.01 (0.26)	−0.05 (0.14)	<0.01 (0.04)	<0.01 (0.07)	0.05 (0.08)	0.03 (0.05)	−0.02 (0.07)	−0.31 (0.25)	0.04 (0.09)	−0.01 (0.15)	15.39 (12.95)	−2.44 (5.43)	−3.97 (9.20)
NDVI 300 m															
Direct effect	−0.34 (0.38)	−0.5 (0.70)	−0.14 (0.49)	0.14 (0.18)	0.01 (0.19)	0.12 (0.20)	−0.05 (0.15)	0.02 (0.18)	−0.03 (0.17)	−0.07 (0.20)	−0.11 (0.25)	−0.12 (0.25)	−6.15 (22.28)	4.26 (23.12)	−4.75 (23.88)
Indirect effect	0.19 (0.14)	0.01 (0.07)	0.02 (0.08)	>−0.001 (0.02)	<0.01 (0.01)	<0.01 (0.05)	<0.01 (0.02)	<0.01 (0.01)	−0.01 (0.03)	0.08 (0.09)	<0.01 (0.03)	0.08 (0.06)	0.42 (0.60)	0.85 (2.14)	−3.46 (4.73)

Note: Coefficients are beta coefficients per units increase of each of the residential greenness metrics and the standardized mediators. SE—standard error; †—$p < 0.10$; *—$p < 0.05$; NO$_2$—individual NO2 residential concentrations; GHQ—General Health Questionnaire; MVPA—moderate-to-vigorous physical activity; SGA—small for gestational age; LGA—large for gestational age; LBW—low birth weight (<2500 g); BW—birth weight.

3.2. Testing the Pathways from Residential Greenness or Blueness to Pregnancy Outcomes in a Study's Subsample

As reported in Section 2.3., we also included an indicator of exposure to blue spaces (availability of a walkable blue space within a 300 m radius of the residence), to check whether it showed significant direct or indirect effects on the study outcomes. Of the 256 participants included in this secondary analysis, only 77 (30.1%) lived within 300 m of a walkable blue space. Separately, none of the models using green and blue space availability (Supplementary Material Table S3) showed statistically relevant direct or indirect effects on the outcomes, with the sole exception of a marginally significant increase of 36 g (p = 0.066) in BW in children delivered by mothers with green-space availability in 300 m in the model using NO_2 concentrations as mediator (Supplementary Material Table S4). We also built the corresponding mediation models, in order to test the combined effects of having a walkable green space or blue space, and the condition was met by less than half of the sample (107, 41.8%). None of the coefficients, which are shown in Table 3, reached statistical significance. More extensive information about Table 3 can be seen in Supplementary Material Table S4.

Table 3. Direct and indirect natural effect coefficients and SE of green/blue availability in 300 m by mediator and outcome.

	Prematurity			SGA			LGA			LBW			BW		
	NO_2	GHQ	MVPA	NO_2	GHQ	MVPA	NO_2	GHQ	MVPA	NO_2	GHQ	MVPA	NO_2	GHQ	MVPA
Green/blue availability 300 m															
Direct effect	−0.28 (5.10)	−0.48 (9.06)	−0.72 (6.42)	0.12 (1.48)	0.12 (0.89)	0.39 (1.71)	−0.20 (0.45)	−0.01 (0.54)	−0.35 (0.50)	−1.34 (6.81)	−1.58 (7.26)	−1.45 (6.52)	51.47 (68.73)	107.19 (72.73)	80.41 (81.38)
Indirect effect	−0.07 (2.70)	0.04 (9.77)	−0.01 (1.93)	−0.03 (0.11)	<0.01 (0.07)	−0.05 (0.13)	−0.02 (0.07)	>−0.001 (0.06)	0.06 (0.10)	−0.14 (0.45)	0.01 (1.22)	−0.10 (0.83)	21.81 (14.60)	−3.02 (12.05)	9.62 (13.91)

Note: Coefficients are beta coefficients per units increase of each of the residential greenness metrics and the standardized mediators. SE—standard error; NO_2—individual NO_2 residential concentrations; GHQ—General Health Questionnaire; MVPA—moderate-to-vigorous physical activity; SGA—small for gestational age; LGA—large for gestational age; LBW—low birth weight (<2500 g); BW—birth weight.

4. Discussion

This study tested the Multiple Pathways of Greenness to Pregnancy Outcomes model (adapted from [2,9]). According to this model, and congruently with recent research (e.g., [15,21]), we expected that residing near green spaces to (1) reduce exposure to ambient NO_2, (2) strengthen psychological health, and (3) promote PA, all of which would exert positive direct and/or indirect effects on a set of pregnancy outcomes in a sample of 441 pregnant women in the metropolitan area of Donostia-San Sebastián. However, the results of our analyses provided little support for this model.

None of our three metrics of residential greenness (i.e., availability of green space of area >5000 m^2 within 300 or 500 m of the residence, and NDVI within a 300 m radius of the residence) showed consistent or significant associations with the mediators and outcomes included in our model. Our data showed some relevant links (e.g., green space availability in 300 m with NO_2 concentrations and lower PA patterns in participants delivering LBW children), but, on the whole, they do not support the MPGRH model. Indeed, only a single direct effect coefficient was found to be statistically significant (at an alpha level of 0.05), indicating that participants living within 300 m of a green space delivered children with birthweights, on average, 140 g less than their counterparts, a result opposite of the evidence gathered by James et al. [54] that showed a positive association between residential greenness (NDVI) and birth weight.

Finally, we conducted a secondary analysis among the subsample of participants living in the city of Donostia-San Sebastián, including availability of blue spaces as additional exposure variable. In these mediation models, we also added a measure of walkable green or blue space, meaning that the spaces should be frequently used by the citizenship. However, the results of this secondary analysis were largely unchanged from the main analyses (apart from a marginally significant effect of greenness on birth weight).

4.1. Interpretation of Results in Context of Available Evidence

First of all, it should be taken into account that, even though the theoretical assumptions of the relationship between residential greenness and pregnancy outcomes are solid (e.g., greenness reduces air pollution, and this, in turn, reduces prematurity), even the studies with supporting evidence do not show a clear and consistent pattern in all the exposure types and pregnancy outcomes examined. In our study, and contrary to previous evidence [13–19,21,54], green space availability was negatively and significantly associated with birth weight. The only previous study (to our knowledge) to examine greenness with LGA [20] did not find an association, though we did find that green space availability marginally reduced the odds of LGA in our sample. The fact that we have not found any statistically significant direct connection between NDVI and pregnancy outcomes might lie, partially, on the NDVI values. Studies showing such links had sample average NDVI levels greater than ours—0.5 ± 0.1 in 300 m and 0.546 (0.089) (Median (IQR)) in 500 m [21,23], which double the ones in this study (0.21 ± 0.1). Similarly, results from other pregnancy cohorts also report NDVI values higher than these in the 300 m radius (0.42 ± 0.1 and 0.51 ± 0.1) [72]. This means that our sample not only lived in less green areas than samples in other studies, but the variability between participants' scores is also low. There is at least one study reporting a protective effect of greenness on pregnancy outcomes with lower NDVI values [13]; however, it is plausible that those effects may appear only above a certain NDVI threshold. This is, that residential environments might not only need to have some greenness but need to be green enough to strengthen the pregnancy outcomes of their inhabitants. For instance, negative associations between residential NDVI and MVPA have been observed, and that may happen because large green spaces might be placed in locations with lower building densities and mixed uses. Hence, residents in those areas may have lower access to services and destinations by foot and then resort to less active means of transport. Finally, our sample was also very homogenous in terms of the green space availability metrics; 75% of participants lived within 300 m of a >5000 m^2 green space, and 88% in 500 m, which might have also limited our ability to find statistically significant effects.

Regarding our findings dealing with indirect effects, NO_2 concentrations assigned to participants in our study are higher than in other studies [21,23,73]. This might be due to the use of another source of information to determine the roads and create the LUR model in our study. Beelen's [56] LUR model was calculated by using a dataset that was no longer available at the time we had to calculate NO_2 exposure levels. Thus, we calculated road-related variables by using local information layers. The average assigned NO2 value (46.70 ± 22.36) in our study strongly differs from the annual average NO2 value reported by Basque Government authorities in 2018 [74]. In addition, LUR models developed in the European Study of Cohorts for Air Pollution Effects (ESCAPE) project are reliable in terms of detecting inter-individual variability, but they might overestimate NO_2 concentration values, which may also affect our estimations, even though the use of the Government's air quality network values to estimate temporal variability may have partially reduced overestimation. The effects of greenness on pregnancy outcomes are expected to be protective, whereas air pollution is negatively associated with pregnancy outcomes.

In the analyses with the subsample of residents in the main city of the study area, we saw a marginal effect of walkable green space availability in 300 m on birth weight. In comparison to the full sample analyses, we only included green spaces that are frequently used by the city residents, due to the relevance of not only the actual availability of green spaces but their user-oriented design and their use, as well [75]. Even so, we believe the inclusion of walkable green space in the model might provide a more accurate characterization of the effects of greenness on pregnancy outcomes.

4.2. Strengths and Limitations

There are several strengths to this study. First, MVPA was objectively measured by using an accelerometer as opposed to self-reports, which correlate only moderately to weakly with objective measures [76,77]. Indeed, we have previously shown, using data from this same research project [71], that objectively measured and self-reported MVPA during the first trimester of pregnancy were only moderately correlated ($r = 0.44$). The reasons for the limited association between both measurement modalities are described in that work. Secondly, we have used three metrics of exposure to residential greenness: availability of a green space of size >5000 m^2 within 300–500 m of women's residence and NDVI within a 300 m radius of women's residence. We have also advanced a possible way of increasing the validity of the measures in availability by considering only the spaces that are frequently used by citizens. An important limitation of Geographic information system (GIS)-based greenness analyses is that participants can live objectively near a park, garden, or green lot but may not fully benefit from it due to use restrictions (e.g., private property and insecurity). This lack of relevant contextual information has been identified as one of the flaws of GIS-based methodologies by Gidlow et al. [78], and this solution might contain its possible deleterious effects.

Given we found no evidence against the null hypothesis that psychological health, air pollution, and physical activity experienced during pregnancy do not mediate the effect of neighborhood greenness on birth weight, prematurity, SGA, LGA, and LBW, readers might ask whether our results arise from pervasive error in our hypothesis testing, i.e., whether systematic type II error occurred. Likewise, readers might question our results by suggesting that these results might have arisen from model misspecification [79] in our counterfactual-based mediation analysis.

The issue of model misspecification has been dealt with elsewhere, so here we only discuss the possibility that systematic type II error occurred in our data analyses. Type II error occurs when one does not reject a null hypothesis when this hypothesis is in fact false. In general terms, for a given statistical technique and a fixed probability of type I error, α (which, in our case, was set at the traditional level of 0.05), the probability of type II error, β (or, complementarily, the statistical power, $1 - \beta$) when testing for an effect of a certain size depends on sample size [80]. Thus, the first of the hypothetical objections that a reader might pose boils down to ask whether we used samples of sufficient size. To evaluate whether our study results might arise from insufficient sample size, we used results from theoretical simulations, as follows. Loeys et al. [81] used sample sizes ranging from $n = 25$

to just n = 200, to estimate statistical power under a variety of simulated mediation analysis scenarios. They found that, under unfavorable scenarios, power for detecting the most-difficult-to-detect cases of indirect effects could be as low as approximately 0.45% when sample size was as large as n = 200, though (still under unfavorable scenarios) power was in most cases substantially higher (between 70–90%). By contrast, power for detecting the most-difficult-to-detect cases of indirect effects under scenarios now more favorable was at least c.70% when sample size was n = 200, though, under those favorable scenarios, power was in most cases substantially higher (between 95–99%). For those reasons, given that most of our cases fall not within the category of the most-difficult-to-detect cases (since the prevalence of most outcomes is greater than circa 5%), and also because our analyses used samples of substantially higher sizes (n = 256 in the case of the analysis limited to Donostia-San Sebastian; n = 436 in the case of the more general analysis), we believe it unlikely that our results arise from pervasive type II error (except in the case of the outcome prematurity, which had a prevalence of about just 5%).

Besides, in a simulation study comparing both the relative RMSE (root-mean-square error) and the relative bias of imputation-based [79] natural effect models [70] fitted with the R package medflex [66], which are the kinds of models used in the research here presented, to RMSE and bias obtained by means of other approaches fitted via several other packages and software systems (such as the R package mediation SAS macros), Lange and Starkopf [82] found that, for sample sizes comprising 250–500 subjects, imputation-based natural effect models achieved minimum levels of both relative bias (which, in fact, was nearly null) and relative RMSE (between 0.5–0.25).

Nevertheless, this study is also affected by several limitations. We are not aware of the distribution of NDVI scores and green and blue space availability for the Basque population, and therefore we cannot estimate whether our sample is representative in those terms. Besides, according to registered MVPA levels [78], we can conclude that our sample is very active. The inclusion of both PM (2.5 and 10) and noise would have strengthened our study due to the known associations between those and pregnancy outcomes [16,83–88]. However, NO_2 is correlated with other specific air pollutants (e.g., particulate matter) and is often used as a marker of traffic-related air pollution and noise pollution [16,89], and it was the only available indicator of air pollution, so this limitation is relatively controlled. According to official data, 6.89% of children delivered in the Basque Country are LBW and a 6.36% are delivered preterm [90]. Our data show lower proportions of LBW and preterm infants (4.8 and 3.3%, respectively), and this might be indicative of a self-selection bias and might suggest that our results are not generalizable to the target population (only 33.77% of the contacted women decided to take part in the study). Finally, another limitation that may have affected our study is that participants might have performed PA in places far from their residence [91]. If so, urban greenness could have had a positive effect on pregnancy outcomes which we have been unable to detect. This issue could be solved by using data from the Global Navigation Satellite System (GNSS).

Future studies on the multiple pathways of residential greenness to pregnancy outcomes could overcome these limitations by imputing to participants more adjusted NO_2 values or even better measuring direct personal exposure with ad hoc devices (as done in Reference [92]). Widening the set of air pollution variables would also help to determine greenness contribution to its containment and subsequent potential positive effects on pregnancy outcomes. Finally, identifying which are the most-used green settings might assist for the correct weighting of the effects of interest here. Apart from our initiative for the analyses with the subsample (relying on authors' knowledge), surveys or interviews might be key to get this information. In this line, the use of GNSS devices might enlighten this line of research by providing us with real information about the use of green spaces in residential contexts.

5. Conclusions

We could not find support to the hypotheses underlying the Multiple Pathways of Residential Greenness to Pregnancy Outcomes model, as our data failed to show significant direct or mediated associations between diverse measures of both residential greenness and pregnancy outcomes in the whole study sample. Analyses with a section of the sample, and using an improved GIS-based determination of green space availability, showed a promising trend effect of the former in birth weight through NO_2 concentration levels. Nevertheless, and in view of the results reported by other researchers in the area, it is greatly needed to keep exploring the role of greenness in pregnancy outcomes and possible mediators involved.

Supplementary Materials: The following are available online at http://www.mdpi.com/1660-4601/17/12/4520/s1. Table S1: Descriptive statistics, together with 10th and 90th percentiles, for the sample distributions of newborn weights (g) at gestational weeks 25–42 in Gipuzkoa. Table S2: Direct and indirect natural effect coefficients and SE by exposure, mediator, and outcome. Table S3: Direct and indirect natural effect coefficients and SE of Green/Blue availability in 300 m by mediator and outcome. Table S4: Direct and indirect natural effect coefficients and SE by exposure, mediator, and outcome for the study subsample (n = 256). Table S5: Population-average effects for the natural effects models reported in Table 2, applicable to a typical individual in the population. Table S6: Population-average effects for the natural effects models reported in Table 3, applicable to a typical individual in the population. Figure S1: Directed Acyclic Graph representing the hypotheses tested in this research work for only a fraction (San Sebastián/Donostia) of the whole study population. The model is similar to that used for the whole population, except that the exposures (X) now studied are blue space availability within 300 m, green space availability within 300 m, and the union (but not the intersection) of the two former exposures (i.e. whether either a blue area, or a green area, or both, is available for the mother within 300 m around her home)

Author Contributions: Conceptualization, J.I. (Jesús Ibarluzea) and K.W.W.; methodology, A.A., M.S.-P., J.I. (Jesús Ibarluzea), G.G.-B., and A.L.; formal analysis, G.G.-B. and A.L.; investigation, M.S.-P. and K.A.; data curation, M.S.-P. and G.G.-B.; writing—original draft preparation, A.A. and M.S.-P.; writing—review and editing, A.A., M.S.-P., J.I. (Jesús Ibarluzea), K.A., G.G.-B., C.M.-G., J.I. (Jon Irazusta), K.W.W., G.V., and A.L.; project administration, A.A. and M.S.-P.; funding acquisition, J.I. (Jesús Ibarluzea) and A.L. All authors have read and agreed to the published version of the manuscript.

Funding: This research was funded by Diputación Foral de Gipuzkoa (the Gipuzkoan Provincial Council), grant number 105/19 within their call "Programa Red Guipuzcoana de Ciencia, Tecnología e Innovación 2019" (Network Gipuzkoan Program for Science, Technology and Innovation 2019).

Acknowledgments: The authors of this paper want to show their great gratitude to all the professionals in the District Health Centers of Donostialdea, the obstetric service located at the Gros Health Center and the midwifes working at Donostia Hospital for their kind involvement and support, which made it possible to conduct this study. Special thanks also to all the participants who took part in the study. AA would like to thank the Department of Education, Language Policy and Culture of the Government of the Basque Country for a predoctoral research training grant.

Conflicts of Interest: The authors declare no conflict of interest.

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Artikuluaren izenburua: *Is Brief Exposure to Green Space in School the Best Option to Improve Attention in Children?*

Autoreak: *Asier Anabitarte, Gonzalo García-Baquero, Ainara Andiarena, Nerea Lertxundi, Nerea Urbieta, Izaro Babarro, Jesús Ibarluzea eta Aitana Lertxundi*

Aldizkariaren izena: *International Journal of Ennvironmental Research and Public Health (ISSN: 1660-4601)*

DOI: *10.3390/ijerph18147484*

Argitaratze data: *13/07/2021*

Inpaktu-faktorea: *3.390 (JCR 2020)*

Q1: Public, Environmental & Occupational Health (SSCI)

Q2: Public, Environmental & Occupational Health (SCIE)

Q2: Environmental Sciences (SCIE)

International Journal of
Environmental Research and Public Health

MDPI

Article

Is Brief Exposure to Green Space in School the Best Option to Improve Attention in Children?

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Citation: Anabitarte, A.; García-Baquero, G.; Andiarena, A.; Lertxundi, N.; Urbieta, N.; Babarro, I.; Ibarluzea, J.; Lertxundi, A. Is Brief Exposure to Green Space in School the Best Option to Improve Attention in Children?. *Int. J. Environ. Res. Public Health* **2021**, *18*, 7484. https://doi.org/10.3390/ijerph18147484

Academic Editor: Riikka Puhakka

Received: 31 May 2021
Accepted: 12 July 2021
Published: 13 July 2021

Abstract: The positive effects of Green Spaces on health are thought to be achieved through the mechanisms of mitigation, instoration and restoration. One of the benefits of Green Spaces may be the restoration of attention and so the objective of this research is testing empirically whether exposure to a green environment improves attention in school children. For so doing, we first used a split-unit statistical design in each of four schools, then combined the primary results via meta-analysis. The Attention Network Test (ANT) was used to measure attention before and after exposure and a total of 167 seven-year-old students participated in the experiments. Overall, our experimental results do not support the hypothesis that students' exposure to activities in green vs. grey spaces affected their performance in ANT. This was so despite the fact that neither age nor gender biases have been detected and despite that our experiments have been proved to be sufficiently statistically powerful. It would be advisable to consider air pollution and noise. We also recommend that participants attend the experiment with mental exhaustion to maximize the ability to detect significant changes.

Keywords: attention network test; natural spaces; mental health; ReML

1. Introduction

In an increasingly urban world, with almost 75% of the European population living in urban areas [1], urban planners and public health professionals need to work together [2] since various environmental exposures and lifestyles detrimental to health can be found in cities [3]. Natural spaces such as parks, gardens, urban trees, etc. are becoming increasingly important for improving the quality of life and health of citizens [4,5] and according to the World Health Organization (WHO), Urban Green Spaces are beneficial for health [6]. Therefore, and with the sustainable development goals set by the UN (SDG3 and SDG11), it is important that the contributions of Green Spaces to cities are taken into account [7].

According to scientific evidence, the mechanisms that explain the positive effects of Green Spaces on health are through mitigation, instoration and restoration. Different authors agree that Green Spaces can have positive effects on health through mitigation, instoration and restoration [8,9]. They mitigate air pollution and noise levels [10–12] and are able to regulate temperature by preventing possible heat waves [13,14]. In addition, their instoration role comes from the contribution of new resources because Green Spaces promote physical activity [15–17] and the relationship between neighbours by strengthening social cohesion [18,19]. In regards to the restorative role, there are two theories: on the one hand, the stress reduction theory (SRT) and, on the other hand, the attention restorative theory (ART). The SRT states that Green Spaces are a source of positive emotions while blocking negative emotions and therefore reducing stress levels [20,21]. According to ART, Green Spaces offer a space to attract and recover attention effortlessly and suppress neurocognitive load [22,23]. ART suggests that natural spaces would stimulate involuntary attentional processes and therefore voluntary attentional processes would be restored. Living in environments that reduce the restorative capacity of attention, mainly in childhood, would negatively affect learning, the academic process and the development of social functions [24,25]. Those are the reasons why it is important to provide young students with care restoration areas [26].

There are few observational studies on the potential effect of Green Spaces in urban environments and their effect on attention. Depending on the type of exposure, two types of studies have been carried out: observational studies with long time exposure and interventional studies with brief exposure. Among the first ones, we will mention the study of Dadvand et al. [27] carried out with 2593 children between 7 and 10 years old living in the city of Barcelona. They focused on the beneficial role of green environments in cognitive functions, including attention. Specifically, they wanted to analyse the effects Green Spaces' exposure had on superior working memory and attention. They found that the greater the amount of green space exposure both at home and at school, and the lower the levels of air pollution, the better the children's cognitive performance. Additionally, also in Barcelona Amoly et al. [28], analysed the greenness of the city's school yards and the environment of 2111 school children's (7–10 years) homes and found a statistically significant inverse relationship between playtime in Green Spaces and inattention scores. Several authors point out as a limitation the lack of existence of a large number of longitudinal studies and therefore, that one cannot speak of an association [27–29].

Interventional studies related to Green exposure perform the analysis using brief exposure instead of long time exposure. One of the first studies was by Kuo and Faber [30], in which they exposed 452 children of 5–18 years of age with ADHD (Attention Deficit and Hyperactivity Disorder) symptomatology to an activity in nature, observing an improvement in ADHD symptoms in those who performed the activities exposed to Green Spaces several times compared to those who performed the activities in an indoor or outdoor built space.

Schutte et al. [31] found improvements in attention and working memory tasks for those who took a nature walk in a sample of 33 children aged 4–5 and 34 children aged 7–8. According to the results of the study by Stevenson et al. [32], performed with 33 Danish students aged 12, walking 30 min in a natural environment—compared to walking a similar time in an urban environment—is beneficial for children's attention, being associated with faster and more stable responses on the ANT (Attention Network Test) test. However, Hartig et al. [33] observed no difference between the group exposed to natural environments and the control group, exposed to urban spaces, for restoration of attention.

The present study aims to assess whether 60-min of exposure, involving a short walk, an activity and having a mid-morning snack, to a green environment improves attention compared to another environment (grey spaces) in the general population of seven-year-olds.

2. Materials and Methods

2.1. Type of Study

This work has a quasi-experimental analytical epidemiological design. The exposure was defined as the environment where a programmed activity takes place: green space and grey space (a space without green environment). The assignment of the environment to each classroom (green/grey) was made randomly in each school. Green Spaces consist of an open green space with trees bigger than 5000 m^2, while grey spaces are paved squares or schoolyards.

This study was carried out after obtaining the approval of the Ethical Committee of the Department of Health of the Basque Government as well as with the approval of the schools and with the signed informed consent of the parents or guardians of the children.

2.2. Study Area

The study area focuses on schools located in two coastal municipalities of Gipuzkoa, Zarautz and Donostia-San Sebastian, Basque Country, northern Spain. These municipalities are located 20 km from each other. Donostia-San Sebastian is the capital of Gipuzkoa, while Zarautz is the fifth largest municipality in the province by population, 23,223 inhabitants in Zarautz and 186,665 inhabitants in the capital (INE, 2018). They are two municipalities with a very defined urban network; Donostia-San Sebastian being the capital, has very important road axes in addition to urban traffic. At the same time, two busy roads cross the municipalities of Zarautz and Donostia, the AP-8 highway, which connects Donostia-San Sebastian with the other two provincial capitals of the Basque Country with an average daily traffic intensity of 44,890 vehicles in Zarautz and 49,244 vehicles in Donostia, and, on the other hand, the N-634 road, which crosses the entire coast of Gipuzkoa with an average daily traffic intensity of 7235 vehicles at the closest seating station to Zarautz [34].

Of the four schools, two of the schools (School 1 and 2) have a green space less than 300 m away, as recommended by the WHO [6], while the other two (School 3 and 4) have a green space more than 300 m away.

2.3. Sample

The participants were 167 children of 7 years old ($\bar{x}$ = 6.8, SD = 0.3) distributed in 4 schools, 3 in Zarautz and 1 in Donostia-San Sebastián. The four schools have similar characteristics in terms of the socioeconomic level of the students, all above the MEDEA 4–5 deprivation index, which allows them to be classified as areas of a high socioeconomic level (http://www.proyectomedea.org, accessed on 18 August 2020). None of the study participants had a previous diagnosed ADHD symptomatology. Among the participants, 7 children had to be excluded from the study because they did not meet the criteria for inclusion in the test of care used (a score of less than 90 in the test scores variable) (proyectoinma.org accessed on 10 July 2020).

2.4. Attention Network Test (ANT)

Attention was evaluated using the children's version of the neuropsychological Attention Network Test (ANT) [35]. The children's version of ANT [36] was designed to measure attention in children aged 6 to 10. To make it more user-friendly, the arrows in the adult version were replaced with fish with an arrow inside. Children should look at the fish in the middle of a row of 5 fish and use the arrows on the keyboard to indicate the same direction as that fish. For each correct hit the children will have a positive hearing reinforcement (¡Woo-hoo!) [25]. This test has been used in several studies measuring the effect of Green Spaces on the attention of children of similar ages to the sample above [32,37,38].

The test was conducted in the children's usual classroom. Computers were distributed in such a way that participants did not disturb each other and they were provided with headphones to listen to the auditory stimulus when responding correctly and to avoid possible sound discomfort.

Each classroom had 3–4 instructors and 19 children on average. All participants received the same instructions, which were agreed upon by all instructors. The first time-block was always for training and once the instructors checked that each child had understood how to do the test, the training ended and the test started, which consisted of 4 blocks of 32 tests each (128 tasks in total).

Five different variables were obtained through the test. The variable "test scores" represents the score of the hits obtained; "accuracy" defines the accuracy, calculated as accuracy = test scores/(errors + test scores). The variable "Reaction time" marks the median time that the participants took to answer each test. One of the most interesting variables of the test, along with that of the scores, is the variable "Reaction time variability", which indicates the variation in response time between the different tests of each participant. This variable has been related to inattention [37]. Finally, the "impulsivity" was calculated as (impulsivity = (Reaction time in correct responses − Reaction time in incorrect responses)), which is interpreted as the higher value being the less impulsive. This test does not allow us to know whether voluntary attention processes have been deactivated during the activity, but we understand that significant reductions in reaction time variability could be compatible with this change in the attentional system (voluntary-involuntary).

2.5. Procedure

Four schools were contacted and all of them gave their approval to carry out the study within their premises. The project started after obtaining the signed consent of the principals. First, the school was visited in the early morning to prepare the necessary material and to set up the computers. Then, participants entered classrooms at the time they normally start lessons, at 9 a.m., and each subject was placed in their respective computer with the ID assigned to them. The informed consent forms, signed by the parents or legal guardians and distributed earlier by the school, were collected and the explanation began. The participants were not informed in advance of the test they were to take. Only data belonging to those who gave their informed consent were analysed.

Once all the students were in place, it was explained to them how they should proceed for the correct realization of the practice. The ANT (Attention Network Test) was carried out for 20 min. Once the whole class finished the exercise (pre-intervention test), they went out to the school playground or street. Then, the class was divided into two groups: one went to a green space and the other to a grey space to perform the activity (Figure 1).

Figure 1. Participants in the green and grey spaces.

All the groups performed the same playful activity which consisted of playing a game and then having a mid-morning snack; altogether the activity lasted 60 min. Afterwards, they returned to the class and each participant went back to the same computer where they first performed the test, in order to repeat it. After the second test, the group's experiment was concluded.

2.6. Power Analysis

A power analysis was carried out in order to calculate the sample size required for each outcome of the study. For this purpose, the R package BDEsize: Efficient Determination of Sample Size in Balanced Design of Experiments [39] was used. The defined parameters were: alpha = 0.05, effect size (exposure × time interaction) = 15%, obtaining statistical power of 85%. The sample size was different for each outcome: total score (n = 4 for each group), accuracy (n = 3 for each group), reaction time (n = 16 for each group) and reaction time variability (n = 22 for each group) and impulsivity (n = 664 for each group). In the case of impulsivity, due to its variability, a large sample size would be required. Therefore, the results obtained in the experiment should be interpreted with caution.

2.7. Description of the Experiments

A basic experiment was carried out in each of four schools, namely School 1, School 2, School 3 and School 4 (Supplementary Table S1), to test for the effect of the exposure to activities in green vs. grey spaces on the school students' performance in multiple-choice computer-based tests (128 questions). Students (random factor <Subject>) were randomly assigned to each of two levels of the fixed factor <Exposure>, that is <grey> and <green> spaces. Five univariate responses were recorded in two occasions on each subject, one before applying the exposure (level <before> of the fixed factor <Time>) and another after applying the exposure (level <after> of the fixed factor <Time>). Student's sex and age were also recorded.

2.8. Repeated Measures: Statistical Design and Model

Each basic experiment is to be understood as a split-unit (or split-plot) statistical design [40], where subjects represent the whole units, exposures represent the whole-unit treatments and time represents the split-unit treatment. The two measurements of each response taken on each subject are correlated although, there being just two repeated measures, we may assume equicorrelation [40] and, therefore, Cochran's theorem [41] is satisfied, with the final consequence that F-tests are valid. This specific type of split-unit design is known as a repeated-measurement design and the corresponding statistical model may be written as follows [40–42]:

$$Y_{ijk} = \mu + \tau_i + \varepsilon_{ij} + \gamma_k + (\tau\gamma)_{ik} + \delta_{ijk}, \quad (1)$$

Equation (1). where Y_{ijk} is a given response to Exposure i (= 1, . . . , t) of subject (whole unit) j (= 1, . . . , r) at Time k (= 1, . . . , g); μ is the overall mean effect; τ_i is the effect of Exposure i (i.e., the whole unit treatment: Subjects in Exposure); ε_{ij} is the effect of Subject j in Exposure i (i.e., the whole unit error), where ε_{ij} is independently and identically distributed as N(0, σ2ε); γ_k is the effect of Time k (i.e., the split unit treatment); $(\tau\gamma)_{ik}$ is the interaction between Exposure i and Time k; and δ_{ijk} is the experimental error (i.e., the split unit error: Time x Subjects in Exposure), where δ_{ijk}, which is independent of ε_{ij}, is assumed to be independently and identically distributed as N(0, σ2δ). Since Exposure has two levels (green and grey spaces) and since Time has two levels (before and after), t = 2 and g = 2; since different numbers of subjects were used in each school, r varies in each basic experiment as specified in Supplementary Table S1.

Thus, the effect of the exposure under a repeated-measurements design is measured by the term $(\tau\gamma)_{ik}$ in Equation (1), i.e., by the interaction between Exposure i and Time k. Since the goal of each of our basic experiments was to test for the effect of the exposure to activities in green vs. grey spaces on the school students' performance in multiple-choice tests, we focused our analysis on said term.

2.9. Linear Mixed Effects Modelling: The Analysis of the Basic Experiments

Univariate responses from experimental settings may be analysed using the ANOVA approach [40], but we preferred the Restricted Maximum Likelihood (ReML) approach within the framework of linear mixed effects modelling [42,43]. This was so because the flexible ReML approach yields unbiased estimates for random terms in mixed models (such as the terms ε_{ij} and δ_{ijk} in Equation (1). Hence, for the purpose of analysing (i.e., for hypothesis testing and parameter estimation) all the responses in our basic experiments, according to Equation (1), we used function lme() of R package nlme [44] in R software v. 4.0.0 (R Foundation for Statistical Computing, Vienna, Austria) [45]. Model assumptions, as made explicit in Equation (1), were checked for each fitted model and variance function structures [46] were introduced, when needed, through the argument weights of lme().

2.10. Meta-Analysis: Combining the Results of the Basic Experiments

Once we quantified the effect of the exposure levels in each basic experiment (as measured by the term $(\tau\gamma)_{ik}$ in Equation (1), we combined the available evidence from School 1, School 2, School 3 and School 4 experiments using the meta-analysis methodology [47]. For this purpose, we used the function metagen() of the R package meta [48], applying the generic inverse variance method [49] for pooling the available data of each of the five response variables.

For more information about the methods, see Supplementary Material.

3. Results

As can be seen in Table 1, the maximum score obtained in score was 128, and on average the children failed eight (120 on average in score), with a minimum score of 91. The average value of the accuracy of the test was high, close to 1. As for the reaction time, in ms, the average was 924 ms and the standard deviation was 194 ms. A similar coefficient of variation is observed in both variables, c. ~23% variation around the mean.

Table 1. Descriptive statistics (mean of pre-post) for the five responses considered in this research work.

Schools 1, 2, 3 and 4									
Variable	n	Minimum	Maximum	Mean	StDev	Median	*Q1*	*Q3*	*IQR*
Test score	319	91.0	128.0	119.7	6.6	121.0	117.0	124.0	7.0
Test accuracy	319	0.823	1.000	0.967	0.032	0.976	0.957	0.992	0.035
Reaction time (ms)	319	527.0	1584.0	923.9	194.2	898.0	789.8	1044.5	254.8
Impulsivity (ms)	319	−1593.5	1406.0	117.2	447.9	71.5	−106.3	247.3	353.5
Variability in reaction time (ms)	319	112.4	485.1	329.5	73.6	336.8	287.2	375.6	88.4

Because neither age nor gender biases were detected (Supplementary Table S1), we concluded that the randomization of students to exposure levels was correct. The only strong correlation between responses occurred between test score and accuracy (0.603) (Supplementary Table S2), which is logical.

The Exposure × Time interaction effect (Table 2), the focus of our inference, was not found to be significant for any combination of response and school. Thus, we did not find evidence that students' exposure to activities in green vs. grey spaces affected their performance in multiple-choice tests. The same is true for the main effect corresponding to Exposure (Table 2), which, again, suggests that, in our repeated-measures designs, the randomization of students to exposure levels was correct. By contrast, the main Time effect was significant in most schools for reaction time and variability in reaction time (Table 2). These main Time effects are negative, indicating that students' reaction time was lower after being exposed to activities in green and grey spaces than before, regardless of the exposure. More information about the results can be found in Supplementary Material, Figures S1–S5.

The estimates of the Exposure × Time interaction effect for each response obtained in the different schools were combined via meta-analysis. The results (Figures 2–6) were found to be unbiased despite the small number of studies (Supplementary Table S3). However, they do not support the idea that students' exposure to activities in green vs. grey spaces affected their performance in attentional multiple-choice tests, for each confidence and prediction interval includes the value zero. Besides, because in every case $\tau_2 = 0$, the fixed effects model was found to be sufficient, thereby suggesting that the observed variability in the schools' estimates can be explained simply by the expected estimator variance. Information about the funnel plots can be found in Supplementary Material, Figure S6.

Table 2. Hypothesis testing for the five response variables considered in the experiment.

Response is Test Score			**School 1**		**School 2**		**School 3**		**School 4**	
Source	**df (num)**	**df (den)**	***F*-value**	***p*-value**	***F*-value**	***p*-value**	***F*-value**	***p*-value**	***F*-value**	***p*-value**
(Intercept)	1	40	15611.40	<0.001	26003.36	<0.001	22164.02	<0.001	22581.18	<0.001
Exposure	1	40	0.05	0.834	0.64	0.431	0.56	0.456	0.40	0.534
Time	1	40	0.86	0.360	0.12	0.737	5.01	0.029	4.18	0.051
Exposure × Time	1	40	0.03	0.864	0.49	0.490	2.65	0.109	0.03	0.876
Response is accuracy			**School 1**		**School 2**		**School 3**		**School 4**	
Source	**df (num)**	**df (den)**	***F*-value**	***p*-value**	***F*-value**	***p*-value**	***F*-value**	***p*-value**	***F*-value**	***p*-value**
(Intercept)	1	40	42300.24	<0.001	95594.79	<0.001	83821.45	<0.001	49778.72	<0.001
Exposure	1	40	0.44	0.509	1.34	0.257	0.98	0.326	0.59	0.448
Time	1	40	0.04	0.833	1.35	0.255	2.11	0.151	11.07	0.003
Exposure × Time	1	40	0.01	0.910	0.31	0.584	1.50	0.226	0.14	0.712
Response is reaction time			**School 1**		**School 2**		**School 3**		**School 4**	
Source	**df (num)**	**df (den)**	***F*-value**	***p*-value**	***F*-value**	***p*-value**	***F*-value**	***p*-value**	***F*-value**	***p*-value**
(Intercept)	1	40	1132.50	<0.001	737.58	<0.001	1733.15	<0.001	1210.86	<0.001
Exposure	1	40	0.64	0.429	1.48	0.234	0.02	0.896	0.68	0.416
Time	1	40	51.67	<0.001	22.50	<0.001	16.38	0.000	17.84	<0.001
Exposure × Time	1	40	0.02	0.900	1.87	0.182	0.50	0.484	0.36	0.555
Response is impulsivity			**School 1**		**School 2**		**School 3**		**School 4**	
Source	**df (num)**	**df (den)**	***F*-value**	***p*-value**	***F*-value**	***p*-value**	***F*-value**	***p*-value**	***F*-value**	***p*-value**
(Intercept)	1	40	3.05	0.088	10.98	0.003	5.89	0.018	0.95	0.339
Exposure	1	40	1.47	0.233	1.88	0.181	0.01	0.908	2.69	0.113
Time	1	40	2.81	0.101	7.07	0.013	1.51	0.224	0.88	0.357
Exposure × Time	1	40	0.68	0.415	0.78	0.386	0.05	0.818	1.36	0.254
Response is reaction time variability			**School 1**		**School 2**		**School 3**		**School 4**	
Source	**df (num)**	**df (den)**	***F*-value**	***p*-value**	***F*-value**	***p*-value**	***F*-value**	***p*-value**	***F*-value**	***p*-value**
(Intercept)	1	40	1500.11	<0.001	633.75	<0.001	1457.69	<0.001	892.34	<0.001
Exposure	1	40	0.05	0.824	0.38	0.543	2.15	0.148	0.21	0.649
Time	1	40	3.27	0.078	1.88	0.181	8.15	0.006	4.29	0.048
Exposure × Time	1	40	0.04	0.849	0.60	0.444	0.22	0.643	0.56	0.462

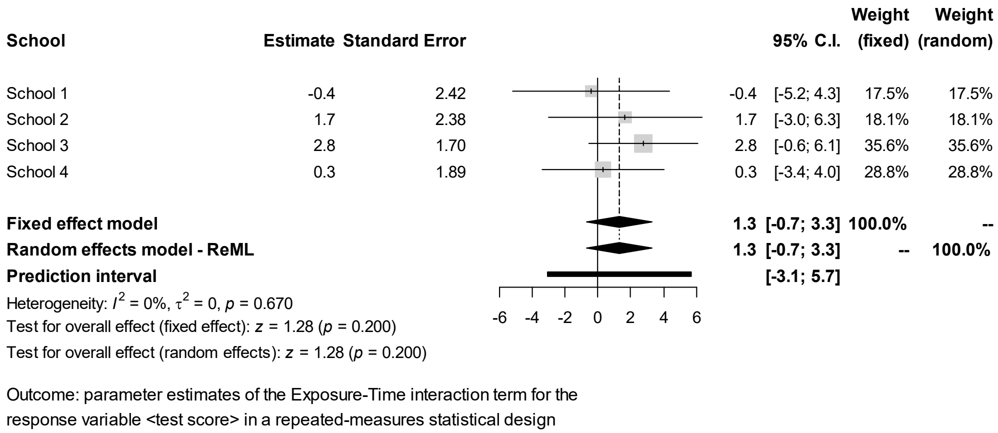

Figure 2. Meta-analysis for test response test score.

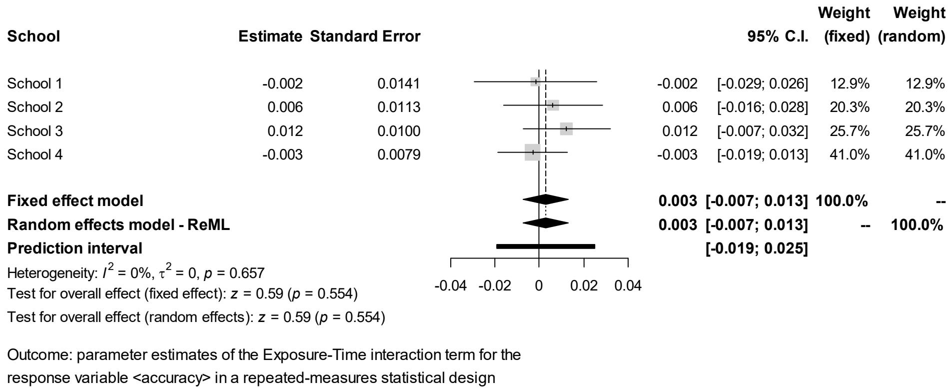

Figure 3. Meta-analysis for test response accuracy.

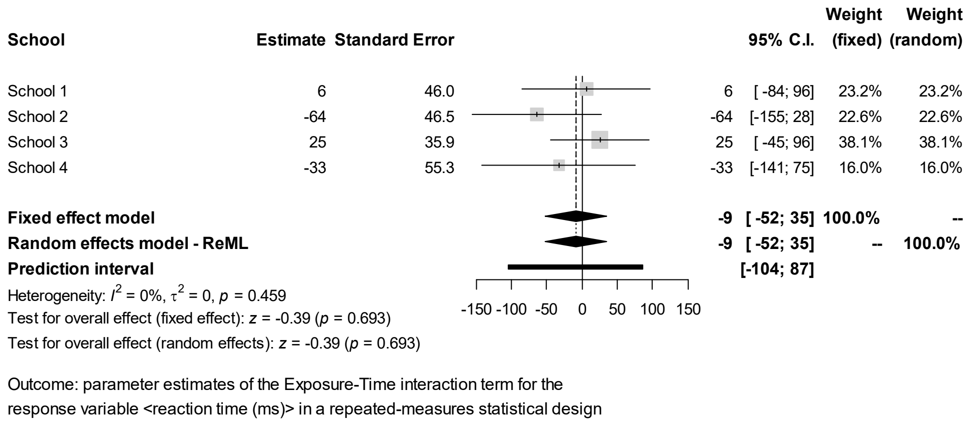

Figure 4. Meta-analysis for test response reaction time.

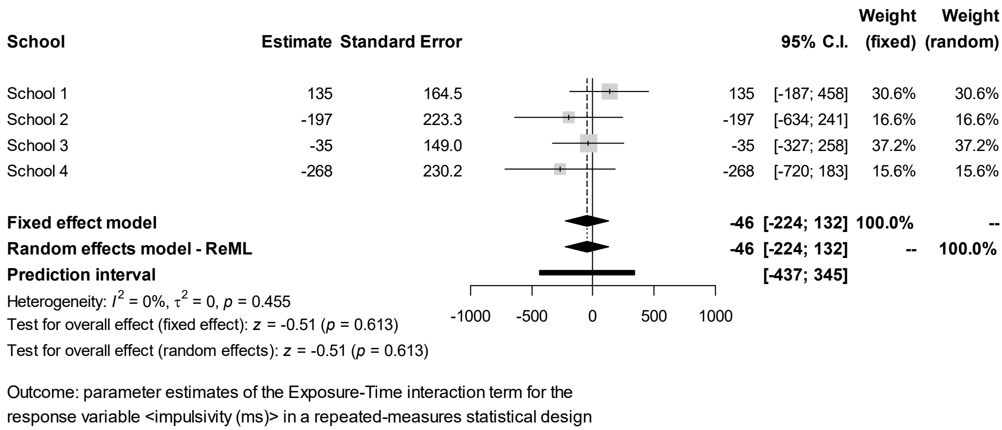

Figure 5. Meta-analysis for test response impulsivity.

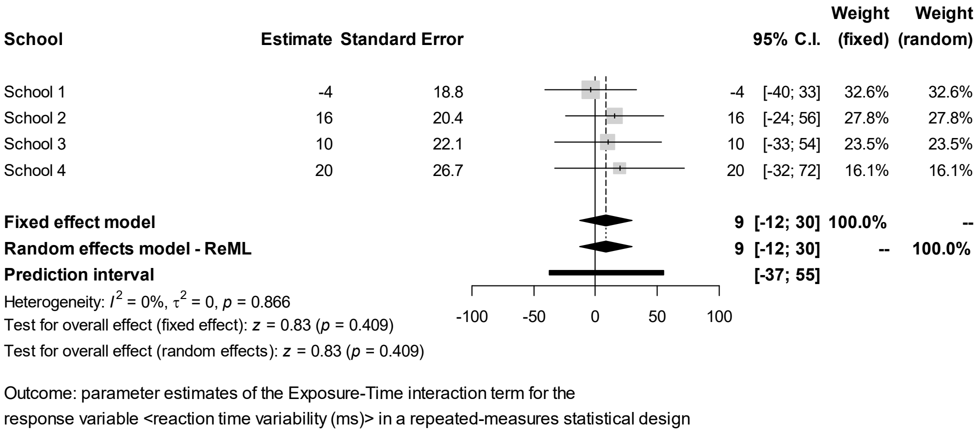

Figure 6. Meta-analysis for test response reaction time variability.

4. Discussion

The aim of this work was to study the relationship between carrying out an activity in a short period in a green space and the restoration of attention in seven-year-old children. Although no interaction was found between exposure and time, after the activity—regardless of exposure—student responses improved in reaction time and reaction time variability. Previous studies have shown that long time exposure to green space can influence restoration of attention [37]; however, this study examined the effect that green space can have on restoring attention but found no effect. This result may be due to the fact that the study area is located in very green areas itself, as a consequence of being in the Atlantic climate: a temperate-humid climate, showing moderate temperatures and being very rainy without a dry season. This combination favours the proliferation of vegetation [50]. In contrast, Dadvand's [37] study area is a Mediterranean climate zone, with hot and dry summers and mild and rainy winters. In conclusion, there are fewer green areas compared to the Atlantic climate zones. In addition, other studies have found that more urbanised areas or city centres benefit more from the health effects of Green Spaces compared to rural areas, which may be due to the increased pace of life and stress that can occur in large cities [51,52]. Our study area consists of Zarautz, a town of around 23,000 inhabitants and Donostia, a city of around 186,000 inhabitants, which is small and surrounded by mountains.

Regarding the meta-analysis, no significant results were found for the test answers. No differences were found between the groups that performed the activity in the green space near the school and those that performed it in the grey space near their school. It should be noted that inter-individual variability could explain a great part of the variance, in many cases exceeding 50%. Although in the present study information was collected about gender and the same protocol was followed when carrying out the intervention to avoid variability in the estimates, it is estimated that, even so, the inter-individual weight is very high.

In addition, schools are usually located next to roads with heavy traffic [53]; this reality also exists with the four schools in the study. This makes it difficult to select noise-free spaces to develop the experiment in an environment free of negative exposures; therefore, results may be influenced by some environmental stressors such as noise, since all schools are located in noise zones that are higher than those dictated by legislation [54], which could interfere with the participants' ability to restore the attention, since according to the literature noise has a negative influence.

Some studies have linked the presence of Green Spaces with decreased noise levels, although there is not yet consistent evidence [55]; noise has been observed to have a causal relationship in inattention and affect cognitive development [56]. A study around Munich airport found a cause–effect relationship between environmental noise and cognitive skills among children. In the same study, groups exposed to an airport (old and new Munich airport) were compared with control groups, groups not exposed to aerial noise and with the same sociodemographic characteristics as the groups of those exposed. The groups exposed to airport noise have a longer reaction time in the attention test. When the old airport was closed, the group that had experienced such exposure improved in reading and long-term memory scores. In addition, the exposed group had worse reading scores two years after the new airport became operational, compared with scores one year after the new airport became operational, suggesting that there may be a cumulative effect of noise exposure [57].

In another study, Zhang, Kang, & Kang [58] analysed the restorative capacity of an urban natural environment but compared different groups exposed to three sound scenarios. They found that the group exposed to an urban natural environment with a natural sound environment had a greater restorative capacity than those exposed to traffic noise.

The idea that noise, as well as air pollution, interferes with restoring attention and that Green Spaces mitigate these exposures follows the model of Markevych et al. [9] and Hartig et al. [8]. With what was mentioned before, it can be concluded that not measuring exposure to noise as well as not considering more individual variables has been a limitation of this study.

Finally, an hour of activity in the Green Spaces may not have been enough time to appreciate improvements in attention and, therefore, the minimum time to consider in relation to attention is something to take into account in future studies. Several studies claim to see differences between exposed and unexposed groups with activities or walks of 20–30 min [32,59,60], however, a review of minimum time in nature for a positive impact found only three studies related to attention; all three studies designed time periods in Green Spaces of 50 min. One of them observed an improvement in attention, another observed no association and the last one observed worse scores in the attention test [61].

5. Conclusions

According to the results obtained, the main hypothesis that carrying out a short-term activity in a green space is restorative of attention is not fulfilled. However, it is recommended to continue analysing the relationship between Green Spaces and restoration of attention, taking into consideration for the analysis variables such as noise and air pollution as well as individual variables.

Supplementary Materials: The following are available online at https://www.mdpi.com/article/10.3390/ijerph18147484/s1, Table S1: Summary of the experimental layout, together with the number of subjects employed in each experiment (school). Table S2: Kendall's rank correlation tau across schools, together with tests of the null hypothesis that (true) tau is equal to 0. Table S3: Egger's test. Figure S1: Test score before and after experimental exposure to activities in grey and green spaces (fitted relationship). Figure S2: Test accuracy before and after experimental exposure to activities in grey and green spaces (fitted relationship). Figure S3: Reaction time (ms) before and after experimental exposure to activities in grey and green spaces (fitted relationship). Figure S4: Impulsivity (ms) before and after experimental exposure to activities in grey and green spaces (fitted relationship). Figure S5: Reaction time variability (ms) before and after experimental exposure to activities in grey and green spaces (fitted relationship). Figure S6: Funnel plots for the meta-analysis reported in Figures 1–5.

Author Contributions: Conceptualization, A.L. and N.L.; methodology, A.A. (Asier Anabitarte), A.L., N.L., A.A. (Ainara Andiarena) and J.I.; software, A.A. (Asier Anabitarte) and G.G.-B.; validation, G.G.-B., A.L. and J.I.; formal analysis, G.G.-B.; investigation, A.A. (Asier Anabitarte), A.A. (Ainara Andiarena), N.L., N.U., I.B. and A.L.; resources, A.A. (Asier Anabitarte), A.A. (Ainara Andiarena), N.L. and A.L.; data curation, A.A. (Asier Anabitarte) and A.L.; writing—original draft preparation, A.A. (Asier Anabitarte); writing—review and editing, A.A. (Asier Anabitarte), G.G.-B., A.A. (Ainara Andiarena), N.L., N.U., I.B., J.I. and A.L.; visualization, A.A. (Asier Anabitarte) and G.G.-B.; supervision, N.L., J.I.

and A.L.; project administration, N.L., A.A. (Ainara Andiarena) and A.L.; funding acquisition, A.L. All authors have read and agreed to the published version of the manuscript.

Funding: This research was funded by KUTXA FUNDAZIOA, grant number KUTXA18/001.

Institutional Review Board Statement: The study was conducted according to the guidelines of the Declaration of Helsinki and approved by the Institutional Review Board (or Ethics Committee) of Department of Health of the Basque Government (PI2018037; 12/09/2018).

Informed Consent Statement: Informed consent was obtained from all subjects involved in the study.

Data Availability Statement: Not applicable.

Acknowledgments: The authors of this paper want to show their great gratitude to all the participants who took part in the study. A.A. would like to thank the Department of Education, Language Policy and Culture of the Government of the Basque Country for a predoctoral research training grant.

Conflicts of Interest: The authors declare no conflict of interest.

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Artikuluaren izenburua: *Effects of residential greenness on attention in a longitudinal study at 8 and 11-13 years*

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Aldizkariaren izena: *Environmental Research (ISSN: 0013-9351)*

DOI*: 10.1016/j.envres.2022.112994*

Argitaratze data: 25/02/2022

Inpaktu-faktorea: *6.498 (JCR 2020)*

Q1: Public, Environmental & Occupational Health (SCIE)

Q1: Environmental Sciences (SCIE)

Environmental Research 210 (2022) 112994

Contents lists available at ScienceDirect

Environmental Research

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

Effects of residential greenness on attention in a longitudinal study at 8 and 11–13 years

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ARTICLE INFO

Keywords:
Longitudinal study
Inattention
NDVI
INMA
Children

ABSTRACT

In an urbanizing world, with 55% of the population living in cities, it is essential to design friendly and healthy ones. An emerging body of evidence has associated greenspace exposure with improved cognitive development, including attentional function; however, the longitudinal studies looking at the association with attentional function are still scarce. Therefore, the objective of this study was to analyze the association of the exposure to greenspace and attention in school children. This study was based on 751 participants at 8 years and 598 at 11–13 years of two sub-cohorts of the INMA cohort study in Gipuzkoa and Asturias, Spain. Greenspace exposure at home was characterized using four indicators: (i) average of Normalized Difference Vegetation Index (NDVI) and (ii) Vegetation Continuous Field (VCF) in buffers of 100 m, 300 m, and 500 m around the residential address, (ii) availability of a green space within 300 m from the residential address, and (iv) residential distance to green spaces. Participants' attention was characterized twice at ages of 8 and 11 years, using the computerized Attentional Network Test (ANT). General linear models were used for the cross-sectional analyses and linear mixed effects model for the longitudinal analyses. Our cross-sectional analyses showed a statistical significant protective association between average NDVI at 300 m and inattentiveness (−7.20, CI 95%: 13.74; −0.67). In our longitudinal analyses, although we generally observed beneficial associations between greenspace exposure and attention, none attained statistical significance. No statistically significant indirect effect were seen for NO_2. Our findings add to the emerging body of evidence on the role of green spaces in neurodevelopment, which can provide the evidence base for implementing intervention aimed at promoting neurodevelopment in urban children.

1. Introduction

The industrialization accelerated the process of rural exodus to the city in search of better living and working conditions (Delgado Viñas, 2019). This urbanization process has occurred mostly due to wealth creation and economic growth in cities (Bettencourt and West, 2010). Even so, this progressive increase of the population in cities had led the scientific community to evaluate whether current urban environments are healthy for people's well-being (WHO, 2010).

Current urban environments often promote an unhealthy lifestyle such as lack of physical activity and stress and higher exposures to environmental hazards such as air pollution, noise, and heat that are detrimental to health (Nieuwenhuijsen and Khreis, 2019). From a public health and urban planning perspective, in order to ensure people's

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https://doi.org/10.1016/j.envres.2022.112994
Received 20 October 2021; Received in revised form 17 February 2022; Accepted 19 February 2022
Available online 25 February 2022

wellbeing, it is necessary to design healthier and more resilient and sustainable cities (Duhl and Sanchez, 1999; WHO, 2008). Above all, greater emphasis needs to be placed on those vulnerable groups for whom the exposure to these environmental factors has the greatest effect on health. The older adult, people with chronic diseases and those with low socioeconomic status are more vulnerable to noise, extreme temperatures, and air pollution exposure than the general population (European Environment Agency, 2018). Children are also considered as a vulnerable group because they have higher respiratory frequency than adults and therefore a higher exposure to air pollutants. In addition, their immune system and organs are not yet mature as they are under development and therefore are more susceptible to the environmental hazards (European Environment Agency, 2018).

Urban greenspaces are defined as land that is partly or completely covered with grass, trees, shrubs, or other vegetation). Greenspace includes parks, community gardens, and cemeteries (United States Environmental Protection Agency, n.d.). According to a recent systematic review, urban greenspaces have potentially positive effects on physical, mental health and well-being of the population (Gianfredi et al., 2021). These health benefits could be in part explained through the ability of greenspaces to mitigate the exposure to the urban-related environmental hazards such as air pollution, heat, or noise and promote social interactions and physical activity (Dadvand et al., 2014; Dadvand et al., 2015a, 2015b; Dadvand et al., 2019; Diener and Mudu, 2021; Markevych et al., 2017; Nieuwenhuijsen and Khreis, 2019; World Health Organization, 2017).

Moreover, according to the Attention Restoration Theory (ART), greenspaces could restore directed attention. Based to this theory, when people enter a natural space, their attention is deactivated and instead, their effortless attention is activated, resulting in the restoration of directed attention capacity (Hartig et al., 2014; Kaplan, 1995; Markevych et al., 2017). It is during childhood and adolescence when cognitive functions such as attention, experience a higher development, the brain develops steadily during the prenatal and postnatal period, being these periods the most vulnerable to the possible effects of environmental pollutants. However it is during childhood and adolescence when cognitive functions such as attention, experience a higher development (Anderson, 2002; Grandjean and Landrigan, 2014).

Earlier quasi-experimental studies evaluated the improvement of attention across two exposure groups: either walking in a natural environment or walking in a non-natural environment in children aged 4–10 years (Anabitarte et al., 2021; Schutte et al., 2017; Stevenson et al., 2019). These studies, evaluating the short-term effect of natural environment on attention were generally supportive of a beneficial association (Kuo and Faber Taylor, 2004; Schutte et al., 2017; Stevenson et al., 2019). Later, epidemiological studies started to evaluate the association of the long-term greenspace exposure on attention in children. Amoly et al. (2015) objectively measured residential exposure to greenspace and assessed, cross-sectionally, its relationship with attention in children at age of 7–10 years concluding that higher residential exposure to greenspace was associated with better attention. Dadvand et al. (2015a, 2015b), evaluated short-term memory and inattention in a Spanish cohort of children aged 7–10 years and found that exposure to greenspace at school was associated with improvements in short-term memory and attention over a period of 12 months. On the other hand, Dadvand et al. (2017) analyzed the association of exposure to greenspace with attention over a longer period of time. These studies found that those children who had more exposure to greenspace had better attention and cognitive development.

There are few studies analyzing the relationship between exposure to greenspace and neurodevelopment during childhood, and few authors have studied this relationship longitudinally. Therefore, this study aimed to evaluate the association of long-term exposure to greenspace with attention using two different approaches: a longitudinal approach including two repeated measurements of attention (8 and 11–13 years old) and a cross-sectional approach taking into account only one measurement of attention (8 or 11–13 years old).

2. Methods

2.1. Study setting and population

The INMA cohort is a well-established population-based cohort aimed at evaluating the role of environmental factors during pregnancy and childhood on the growth and development of children (Guxens et al., 2012). The INMA cohort is conducted in seven centres across Spain, including Sabadell, Granada, Valencia, Asturias, Gipuzkoa, Menorca and Flix. This current study is based on data from Asturias and Gipuzkoa, both located in the north of Spain. They have a temperate climate with mild summers and water availability all over the year (Cfb according to Köppen's classification), so they have high levels of arboreal vegetation (Gobierno de España, 2011).

Pregnant women were informed about the project and recruited during the first trimesters of pregnancy in health centres and hospitals of the public health system. The inclusion criteria were the following: being older than 16 years, having a singleton pregnancy, not having used assisted reproduction techniques, intention to give birth in the reference hospital, and speaking and understanding Spanish or the local language (Basque, in the case of Gipuzkoa). Since recruitment, data have been collected in several follow-up phases: in the first and third trimester of pregnancy, at birth, and when the child was 14 months, 26 months, 4 years, 8 years and 11 years of age. At the beginning of the study (2004–2007 in Asturias and 2006–2008 in Gipuzkoa), 1132 pregnant women were recruited (494 from Asturias and 638 from Gipuzkoa), and 751 participants aged 8 years and 598 participants aged 11–13 years were included in this study (Fig. 1). The ethical committees of the hospitals involved in the regions approved the project and informed consent was obtained from all participants in each wave.

2.2. Exposure to greenspace

To characterize exposure to greenspaces at 8 and 11–13 years of age, four indicators were calculated around participants' home: two of them to characterize greenness surrounding home and the other two to characterize the access to urban greenspaces.

2.2.1. Residential surrounding greenness

Satellite-based Normalized Difference Vegetation Index (NDVI) and the Vegetation Continuous Fields (VCF) were applied to characterize residential surrounding greenspace. The NDVI is an index of the level of the photosynthetically active greenspace of a given area (Tucker, 1979). The index is calculated by the difference of the surface reflectance in the visible wavelength (0.4 μm–0.7 μm) and the near-infrared wavelength (0.7 μm–1.1 μm), the near infrared (NIR) and red band must be

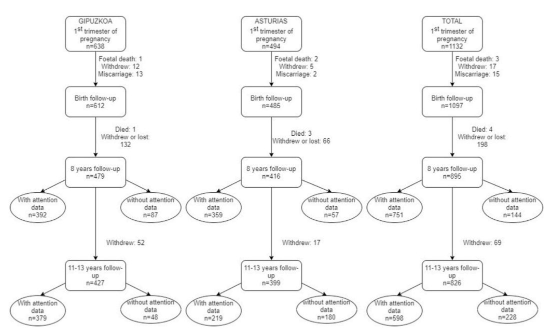

Fig. 1. Number of participants in each follow-up and available data in Asturias, Gipuzkoa and total.

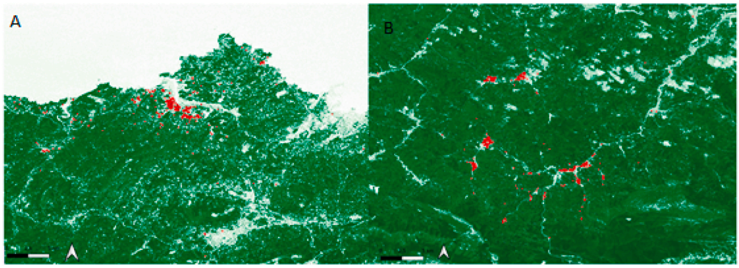

Fig. 2. Vegetation index, NDVI. Asturias (A) and Gipuzkoa (B) study area.

combined (Equation 1). This information was obtained through satellite images from Landsat 4–5 Thematic Mapper (TM) and Landsat 8 Operational Land Imager (OLI) and Thermal Infrared Sensor (TIRS) with a resolution of 30 × 30 m in the maximum vegetation period (Supplementary Materials, Table S1). The index ranges from −1 to +1, with a value of 1 indicating the highest greenspace, negative values in the images have been reclassified to null values previously (James et al., 2015; Weier and Herring, 2000). The imagery had been selected according to the following criteria: i) cloud cover less than 10%, ii) Standard Terrain Correction (Level 1 T) and iii) greenest period of the year.

The VCF indicates the percentage of woody vegetation greater than 5 m in height in each 30 × 30 m pixel. This variable is a product derived from Landsat-5 Thematic Mapper (TM) and/or Landsat-7 Enhanced Thematic Mapper Plus (ETM+) bands (Sexton et al., 2013). To calculate VCF at both follow-ups satellite images of different dates were used in Asturias and Gipuzkoa (Supplementary Material Table S1).

We defined residential surrounding greenspace and tree cover as the average of NDVI and VCF, respectively, across buffers of 100 m, 300 m, and 500 m (Dadvand et al., 2017; Rammah et al., 2021) around the participant's residential address at each follow-up.

2.2.2. Residential access to greenspaces

The residential access to greenspaces was characterized by (i) the availability of an urban greenspace larger than 5000 m^2 (based on WHO recommendation) within, separately, 100, 200, and 300 m (WHO Regional Office for Europe, 2016) from the residential address (yes/no), and by (ii) the residential distance, in meters, to this large greenspace. This information was obtained from Urban Atlas 2012 and EUNIS 2009 (European Nature Information System) for Asturias and Gipuzkoa, respectively.

2.3. Attention

Attention was characterized using the Attention Network Test (ANT) (Fan et al., 2002; Rueda et al., 2004) at the 8 as well as 11-13y follow-ups. This computer test characterizes attention in children older than 6 years (Rueda et al., 2004). Participants have to press the left or right arrows on a keyboard depending on which way the central arrow of the five horizontal arrows on the screen is facing, in case of success participants will receive a positive auditory reinforcement (Woo hoo!) (Suades-González et al., 2017). All participants received the same instructions, which were agreed upon by all instructors. The first time-block was always for training and once the instructors checked that each child had understood how to do the test, the training ended and the test started, which consisted of four blocks of 32 trials each (128 trials in total). Median response time calculated from the response time collected in the 128 trials (Hit Rt median), which could indicate the speed of the participants in answering each test. The higher Hit Rt median hence suggestive of less attention. We also calculated the standard error of the response time (HRT-SE), which indicates the speed consistency in response time between the different tests of each participant. The higher HRT-SE could indicate more inconsistency in responding, hence more inattention (Dadvand et al., 2017; Pozuelos et al., 2014; Suades-González et al., 2017). The test was administered by a person prepared for this purpose in each cohort for each follow-up. The same computer was used for all participants in each cohort and all were given the same explanation.

2.4. Covariates

The sociodemographic variables used in the models for this study were identified through a DAG model designed *a priori* based on the available literature (Supplementary Material Figure S1). The variables sex, prematurity (<37 weeks' gestation), birth weight (continuous), parity (continuous), maternal education (primary or without education, secondary or university), social class based on occupation (1: highest social class to 3: lowest social class) and smoking during pregnancy (yes or no) were collected in the pregnancy follow-up. Type of breastfeeding (maternal breastfeeding, mixed or formula feeding) and nursery (yes or no) were collected during the postnatal 24 months follow-ups. Time spent in sedentary activities (continuous) and maternal IQ were collected in the 4-year follow-up. Maternal scores on the Similarities subtest of the Wechsler Adult Intelligence-Third Edition (WAIS-III) (Wechsler and Kaufman, 2001) were assessed as a proxy for maternal IQ, given that this subtest has been shown to be a good predictor of global IQ (Wechsler, 1997). Time sleeping in hours (continuous) was collected in the 8-year follow-up and hours watching TV per week (continuous) was collected in the 8-year and 11-13-year follow-ups. Finally, the neighbourhood's socioeconomic status was collected through the deprivation index of the MEDEA2011 project for each follow-up, created by the following indicators: manual worker, unemployment, temporary workers and insufficient education overall and in young. This index has been created using the census section, the smallest administrative unit, as the administrative unit. (Domínguez-Berjón et al., 2008). Sex, prematurity and birth weight were collected through the clinical history. Parity, maternal education, social class, smoking during pregnancy, type of breastfeeding, nursery, time in sedentary activities, time sleeping and time watching TV were collected by questionnaire. Not all variables were used for the model adjustment.

2.5. Statistical analysis

First, with the aim of describing the sample, a descriptive analysis of both the characteristics of the sample, and the exposure and effect variables was carried out. The profile of the sample at 8 and 11–13 years of age was evaluated using nonparametric tests ($\chi 2$ for qualitative variables and Mann-Whitney for quantitative variables). In addition to between follow-ups, those who performed the test (included) were also compared to those who did not (excluded) at 8 and 11–13 years of age and in total.

2.5.1. Cross-sectional analyses

Once the variables of interest were identified through performing DAG model (supplementary material Figure S1), we used general linear models (Madsen and Thyregod, 2010) to test for the effect of either greenspace (NDVI/VCF), availability or distance of greenspaces on each of the Hit Rt median and HRT-SE for each follow-up. Date of measurements was introduced in the models as an offset variable. Residuals of each model were evaluated for validation purposes. For this purpose, we used the function lm() of package stats in R software (R Core Team, 2020). The objective of this analysis is to evaluate whether exposure to the green environment has better attentional results in those who are more exposed in comparison to those who are less exposed at home. Although green environment exposure is at 8 years and 11–13 years, it is assumed that most participants have been exposed since birth or at least 3 years ago, because according to the follow-up results, for every 10 participants only 2 changed residence between birth and 8 years and only 9% from 5 to 8 years. Therefore, we can assume that most of them have had a long-term exposure. Nevertheless, a sensitivity analysis was performed with only those who have not moved and with those who were not preterm to assess the consistency of the results obtained. We adjusted the aforementioned models for socioeconomic status, age at the time of attention test, sex, preterm, maternal IQ, maternal smoking during pregnancy and cohort (Table S3).

2.5.2. Longitudinal analyses

Likewise, we used general linear mixed-effects models (Madsen and Thyregod, 2010) to test for the effect of both age and either greenspace (NDVI/VCF), availability or distance of greenspaces on each of the responses Hit Rt median and HRT-SE, once the effect of adjusting variables had been accounted for. Since responses were measured in the same subjects at two different ages (8- and 11-13-year-old), subject (nested within cohort) was fitted as a random factor. The response variables is expressed by the difference between attention measured at 8 and at 11–13 years (Hit Rt median at 8 years – hit rt median at 11–13 years and HRT-SE at 8 years – HRT-SE at 11–13years). To correct the observed within-group heteroscedasticity, a constant variance structure was introduced in the models to allow for different variances according to the levels of cohort and age. These models we adjusted for age at the time of attention test, socioeconomic status, sex, preterm, maternal IQ, maternal smoking during pregnancy and cohort. For this purpose, we used the function lme() of package nlme (Pinheiro et al., 2018) in R software (R Core Team, 2020).

When models were statistically significant, mediation models using NO_2 as mediator were fitted. More information about these mediation models is given in supplementary material.

3. Results

In the first trimester of pregnancy 1132 woman were recruited (494 from Asturias and 638 from Gipuzkoa) in INMA. Longitudinal data up to the 8-year follow-up was available for 66% of the recruited families, being 61% for those from Gipuzkoa and 73% from Asturias. At the 11–13 years follow-up, we collected information from 53% of the recruited families, being 59% for those from Gipuzkoa and 37% from Asturias. In the case of Asturias, the notable decrease in the sample of the last follow-up was due to lockdown measures taken due to the COVID-19 pandemic.

Table 1 shows the characteristics of the study samples at both follow-ups. Women made up 49% of the sample, under 5% of children had the history of preterm delivery, and around 12–13% of the mothers were smoker during pregnancy. The median of mother's IQ was 9.76 of the possible range of 0–14. The neighbourhood socioeconomic status of the participants changed significantly between the two follow-ups. At 8 years follow-up 64% of the had a high socioeconomic level (indexes 1 and 2) while at 11–13 years 72% of the families had these socioeconomic levels. Moreover, children's sleeping time was significantly higher at the 11-13-years follow-up. For the rest of characteristics we did not observe any notable difference between the follow-ups.

Table 1
Description[a] of characteristics of the study participants at 8 and 11–13 years follow-up.

Characteristics	8 years follow-up (n = 751)	11–13 years follow-up (n = 598)	p-value[b]
Sex (female)	0.489	0.507	0.547
Preterm birth(yes)	0.049	0.046	0.965
Age (mean (min-max))	8.10 (7.7–9.7)	11.4 (10.3–13.1)	–
Maternal IQ[c] (0–14)	9.76(3.67)	9.76(3.67)	0.704
Maternal smoking during pregnancy (yes)	0.132	0.121	0.495
Neighbourhood socioeconomic status			0.005
1 Better	0.309	0.370	
2	0.326	0.362	
3	0.186	0.137	
4	0.137	0.102	
5 Lower	0.041	0.029	
Parity			0.978
0	0.590	0.599	
1	0.364	0.350	
2	0.040	0.044	
3	0.005	0.007	
4	0.001	0.002	
Birth weight (gr.)	3290 (545)	3290 (558.75)	0.976
Time watching TV 8y(min.)	60 (60)	60 (75)	0.989
Time watching TV 11-13y (min.)	60 (30)	60 (30)	0.873
Time sleeping (hrs.)	10.29 (0.93)	10.36 (0.68)	0.016
Time spent in sedentary (hrs.)	90.5 (13)	90.5 (12.28)	0.908
Maternal education			0.967
Primary or without education	0.118	0.114	
Secondary	0.401	0.395	
University	0.482	0.490	
Social class			0.802
I- More rich	0.420	0.443	
II	0.227	0.226	
III-Less rich	0.353	0.319	
Type of breastfeeding			0.645
Maternal breastfeeding	0.273	0.283	
Mixed	0.547	0.563	
Formula feeding	0.181	0.153	
Nursery at 24 months(yes)	0.722	0.741	0.487

[a] Categorical variables were described through percentages and for continuous variables, with median and IQR.
[b] p-value of difference between the two follow-ups using chi-squared test for the categorical variables and Mann-Whitney *U* test for the continuous variables.
[c] Similarities subtest.

The characteristics of children and their mothers participating and non-participating at each wave, 8 and 11–13 years of age, are shown in the supplementary material (Table S2), being the main difference that of the mother's IQ.

As shown in Table 2, at the age of 8 years NDVI was higher in Gipuzkoa than in Asturias for the three buffers ($p < 0.05$) and, at the age of 11–13 years, the difference was also observed with NDVI 500 m ($p < 0.05$), but not for the buffers of 100 and 300 m. Regarding the differences between follow-ups, there were statistically significant differences in all NDVI buffers, being greenspace scores higher at 11–13 years. For VCF, significant differences were found between cohorts at both waves, 8 and 11–13 years, at the 100 m and 300 m buffers; differences were also seen between waves at 8 and 11–13, although VCF 300 m difference was marginally significant. Unlike NDVI, the average VCF value was higher in the Asturias than in the Gipuzkoa cohort. No differences in VCF were observed for 500 m, neither between cohorts nor between follow-ups.

Almost all families (97%) lived within 300 m of a greenspace larger than 5000 m^2. The availability a greenspace larger than 5000 m^2 only differed statistically for the 100-m buffer between cohorts at both follow-ups. No differences in the availability of large greenspaces were

Table 2
Description of measures of green exposure measurements (measured at home) at age of 8 and 11–13 years.

Variables	8-y follow-up				11-13-y follow-up				
	Total (n = 751)	Asturias (n = 359)	Gipuzkoa (n = 392)	p-value[a]	Total (n = 598)	Asturias (n = 219)	Gipuzkoa (n = 379)	p-value[a]	p-value[b]
Residential Surrounding greenspace (NDVI) (median(IQR))									
100	0.312 (0.177)	0.298(0.202)	0.319(0.158)	0.027	0.379 (0.185)	0.382(0.221)	0.378(0.159)	0.850	0.000
300	0.389 (0.172)	0.377(0.209)	0.405(0.155)	0.000	0.461 (0.165)	0.457(0.226)	0.462(0.143)	0.504	0.000
500	0.454 (0.148)	0.424(0.175)	0.477(0.137)	0.000	0.514 (0.133)	0.507(0.214)	0.519(0.121)	0.012	0.000
Residential surrounding tree cover (VCF) (%)									
100	9.31 (7.1)	11.44 (5.35)	6.89 (4.89)	0.000	8.59 (6.35)	11.2 (4.93)	6.67 (4.82)	0.000	0.035
300	12.07 (7.48)	13.01 (6.58)	10.97 (7.9)	0.000	11.75 (7.25)	13.01 (6.1)	10.68 (7.89)	0.000	0.087
500	15.62 (8.3)	15.28 (7.6)	16.11 (10.17)	0.300	15.32 (8.71)	14.98 (6.45)	15.76 (10.2)	0.368	0.252
Green availability (>5.000m^2) (%)									
100	62.55	69.16	57.14	0.001	61.990	69.95	57.94	0.007	0.884
200	89.48	89.41	89.54	1	89.14	90.16	88.62	0.679	0.917
300	97.33	97.51	97.19	0.979	96.85	96.89	96.83	1.000	0.726
Distance to a green area >5.000m^2 (m)	73.17 (99.7)	57.42 (84.17)	83.9 (103.04)	0.003	75.62 (102.74)	58.46 (81.74)	83.9 (107.47)	0.004	0.539

Note: p-values are reported for chi-squared test for categorical variables and Mann-Whitney *U* test for continuous variables. For continuous variables, median (IQR) and for categorical variables count (percentage) of each category has been reported. p-value[a] for the difference between children in each cohort. p-value[b] for the difference between children with attention availability data at the 8-year follow-up and at 11-13-y follow-up.

seen between the two follow-ups. The distance to greenspaces of larger than 5000 m^2 was statistically longer between the two cohorts and between waves, being the distance in Asturias smaller than in Gipuzkoa.

3.1. *Cross-sectional association between exposure to greenspace and attention*

As presented in Table 3, for the 8-year follow-up we only observed a marginally significant inverse (i.e. protective) relationship between VCF at 500 m buffer and HRT-SE. Although no other significant relationship was found, NDVI and VCF distance to a greenspace showed an inverse relationship with HRT-SE response and a positive relationship with distance to greenspace. Hit Rt median was not associated with any of the greenspace indicators at this wave.

At 11–13 years follow-up we found an inverse relationship between NDVI (300 m buffer) and Hit Rt median and HRT-SE, being statistically marginally and statistically significant, respectively. Also, a marginal inverse relationship was seen between NDVI (500 m buffer) and HRT-SE. The rest of the residential greenspace indicators did not show any significant association with any of attention measurements.

When repeating the analyses only with those participants who did not change their residence (Supplementary material Table S4-5), and with those that were not preterm, we did not observe any notable change in the aforementioned findings (Data not shown).

3.2. *Longitudinal association between greenspace exposure and attention*

In total, there were 555 children with attention test measurements in the two follow-ups (206 from Asturias and 349 from Gipuzkoa). No significant relationships were observed in the longitudinal analyses between greenspace indicators and attention measurements (Table 4).

No indirect effect between NDVI 300 and NO_2-mediated HTR-SE was found. The results can be found in supplementary material (Figure S3).

4. Discussion

The objective of this study was to analyze the association between exposure to greenspace and attention at the age of 8 and 11–13 years. Our study was based on two well-established and well-characterized

Table 3
Coefficients (together with 95%CI) of the regression models estimating the association between several versions of exposure measurements (NDVI, VCF, green availability, green distance) and two measurements of attention score (Hit Rt median/HRT-SE), once that the effect of the covariates have been accounted for.

	8 years n = 751		11–13 years n = 598	
	Hit Rt median	HRT-SE	Hit Rt median	HRT-SE
NDVI - 100 m buffers	9.69 (−6.24; 25.62)	−0.47 (−7.23; 6.30)	−8.15 (−19.49; 3.19)	−4.18 (−10.83; 2.48)
300m buffers	2.57 (−13.43; 18.57)	−1.03 (−7.82; 5.75)	−10.33 (−21.49; 0.83)	−7.20 (−13.74; −0.67)*
500m buffers	0.69 (−15.59; 16.98)	−2.81 (−9.71; 4.09)	−8.11 (−19.29; 3.08)	−6.56 (−13.10; 0.01)
VCF - 100m buffers	3.49 (−13.26; 20.24)	−0.01 (−7.12; 7.09)	2.13 (−10.00; 14.26)	4.31 (−2.79; 11.41)
300m buffers	−8.08 (−23.79; 7.63)	−4.59 (−11.25; 2.06)	−6.62 (−18.02; 4.78)	−3.48 (−10.17; 3.21)
500m buffers	−10.74 (−26.28; 4.79)	−6.48 (−13.06; 0.09)	−3.66 (−14.85; 7.53)	−3.18 (−9.74; 3.38)
Green availability 100	8.60 (−24.39; 41.59)	5.27 (−8.87; 19.42)	0.04 (−23.44; 23.53)	−1.29 (−14.96; 12.36)
Green availability 200	7.59 (−44.29; 59.46)	−3.57 (−25.81; 18.68)	−6.59 (−44.16; 30.97)	−14.69 (−36.51; 7.12)
Green availability 300	−15.97 (−123.67; 91.74)	7.89 (−38.29; 54.08)	−20.31 (−87.81; 47.19)	−22.48 (−61.71; 16.75)
Green distance	−1.79 (−17.81; 14.22)	−0.49 (−7.36; 6.37)	3.62 (−8.06; 15.29)	3.58 (−3.21; 10.36)

*$p < 0.05$. Adjusted for socioeconomic status, age at the time of attention test, sex, preterm, maternal IQ, maternal smoking during pregnancy and cohort.

Table 4
Coefficients (together with 95%CI) of the regression mixed effect models estimating the association between several versions of exposure measurements (NDVI, VCF, green availability, green distance) and two measurements of attention score (Hit Rt median/HRT-SE), once the effect of the covariates have been accounted for.

	Hit Rt median		HRT-SE	
	Value	p-value	Value	p-value
NDVI – 100m buffers	72.817 (−207.211; 352.846)	0.610	−9.052 (−131.197; 113.093)	0.884
300m buffers	−58.803 (−338.487; 220.880)	0.680	3.585 (−119.127; 126.297)	0.954
500m buffers	−93.634 (−391.159; 203.890)	0.537	−25.755 (−156.792; 105.283)	0.700
VCF – 100m buffers	0.847 (−5.529; 7.223)	0.794	−1.000 (−3.787; 1.786)	0.481
300m buffers	−2.814 (−7.553; 1.924)	0.244	−0.065 (−2.718; 1.428)	0.541
500m buffers	−3.900 (−8.302; 0.504)	0.083	0.949 (−2.880; 0.982)	0.335
Green availability 100	−17.401 (−97.394; 62.593)	0.669	3.909 (−30.770; 38.587)	0.825
Green availability 200	10.606 (−116.171; 137.383)	0.870	22.623 (−32.822; 78.068)	0.423
Green availability 300	−18.206 (−256.378; 219.965)	0.881	80.267 (−22.953; 183.486)	0.127
Green distance	0.087 (−0.399; 0.574)	0.725	−0.049 (−0.262; 0.164)	0.654

*$p < 0.05$. Mixed effects models with random cohort effect adjusted for socio-economic status, age at the time of attention test, sex, preterm, maternal IQ, maternal smoking during pregnancy and cohort, cohort x age and exposure x age.

birth cohorts with repeated assessment of attention using objective computerized tests and a prospectively-collected covariate data since pregnancy. In our cross-sectional analyses we observed a protective association between average NDVI at 300 m buffer around the residential address and HRT-SE (an indicator of inattentiveness) at 11–13 years, which was not seen at 8 years. For the rest of the cross-sectional associations and all longitudinal associations, we generally observed beneficial associations between residential surrounding greenspace and Hit Rt mean and HRT-SE; however, none of these associations attained statistical significance. In general, the cross-sectional and the longitudinal studies within this research work led to similar, consistent, results (in general terms, no significant effects were found). Nonetheless, in the cross-sectional study, and only for the response HRT-SE at 11–13 years of age and exposure NDVI at 300 m buffers, we found one significant effect [−7.20 with 95% C.I. (−13.74, −0.67)]. In the longitudinal study, a nearly significant effect ($p = 0.083$) was found for only for the response Hit Rt median and VCF 500 m buffers [estimate of the effect: 3.900 with 95% C.I. (−8.30, 0.50)]. These findings stayed unchanged after we limited participants to those who did not change their address since 4-year follow-up. Conducted mediation analysis did not revealed NO_2-mediated effects of NDVI 300 m on HTR-SE at 11 years.

Regarding residential greenspace, different levels of greenspace measured by NDVI have shown an association on attention; for example, studies conducted in Mediterranean areas with lower NDVI levels than ours have also observed a relationship between greenspace exposure and attention in children of the similar age (Amoly et al., 2015; Asta et al., 2021; Dadvand et al., 2017). In contrast, we did not observe any association between greenspace measured by VCF and attention, and neither did the only other study that analyzed the relationship between VCF and attention (Dadvand et al., 2017). To our knowledge, only one study besides this one has analyzed the improvement of attention at different ages related to exposure to residential greenspace (Dadvand et al., 2017), this study was also carried out in the INMA project, but in this case in the cohorts of Sabadell and Valencia. Attention data were collected at the 4–5 and 7–8 year follow-ups and the analyses were carried out cross-sectionally. Previous longitudinal studies have found a relationship between greenspace and attention from age 4–10 years, therefore, this study extends the positive results previously observed (Asta et al., 2021; Dadvand et al., 2017; Dadvand et al., 2015a, 2015b; Liao et al., 2020). In our case, no associations were observed at 8 years of age, although the trend was toward reduced inattention.

It should be noted that there are also other studies in which association between exposure to greenspace and Attention-Deficit/Hyperactivity Disorder (ADHD) is investigated. There are studies that have studied the relationship between NDVI and ADHD (Donovan et al., 2019; Markevych et al., 2018; Thygesen et al., 2020; Yang et al., 2019), and also with access to green spaces (Markevych et al., 2014). Some studies have seen an association between NDVI and ADHD diagnosis (Donovan et al., 2019; Markevych et al., 2018; Thygesen et al., 2020) and another, in contrast, with ADHD symptomatology (Yang et al., 2019). Another study saw a relationship between access to urban green spaces and ADHD symptomatology (Markevych et al., 2014). These studies have generally reported that higher greenspace exposure is associated with lower risk of ADHD and its symptomatology. Therefore, this study provides evidence on the effect of residential greenspace exposure on attention.

In our current study, no association was seen between residential surrounding tree cover and attention, except for a marginal association at age 8 with HRT-SE. No effect with higher tree cover was seen in this study either. Unlike the study above mentioned, which was mainly located in a Mediterranean climate and therefore does not have much tree cover higher than 5 m, this current study was conducted in an area with an Atlantic climate in which larger trees predominate. Therefore, in this case, we could expect significant results with the use of VCF. On the other hand, as the participants were in an Atlantic climate with a lot of vegetation, this could lead to almost no variability in exposure to green spaces and it could be that the high exposure to greenspace around the neighbourhood does not lead to significant restoration of attention. Just as the possible restorative effect of different types of greenspace should be studied, it would be interesting to analyze whether those who are more exposed on the day-to-day restore less attention than those who interact with greenspace sporadically.

At 8 years, in an Atlantic climate, we observed higher NDVI levels than in similar studies conducted by Dadvand et al. (2017) in Sabadell and Valencia (Spain) with 7-year-olds and by Asta et al. (2021) conducted in Rome (Italy) also with 7-year-olds in areas with a Mediterranean climate. On the one hand, despite having higher levels of greenspace (measured as the NDVI average) in the Atlantic zone, no associations were observed at 8 years of age. On the other hand, significant associations between average of NDVI in a 500 m buffer around residential address and attention were observed at 7 years in Sabadell and Valencia and Rome. It should be noted that Asta et al. found an association between NDVI at 500 m around the residence and attention with very similar values of this study, but no association was found in our study. We postulate that this may be due to two possible reasons. On the one hand, it could be the different types of vegetation that can be found in different climates and on the other hand, it could be due to our relatively modest sample size that limited our statistical power.

Greenspaces could have an effect on health through three pathways: the mitigation of environmental pollutants such as air pollution or noise, the instoration of social cohesion and physical activity and through the reduction of stress linked to the Stress Reduction Theory (STR), and the restoration of attention linked to the ART theory (Markevych et al., 2017). According to scientific literature, it is not only exposure to greenspaces that can have an effect on attention via ART. According to several studies, exposure to greenspaces can reduce air pollution

(Dadvand et al., 2012; Dadvand et al., 2015a, 2015b) and noise (Van Renterghem et al., 2015), factors that have been linked to poorer attention (Sunyer et al., 2015; van Kempen et al., 2012). In addition, the promotion of physical activity by greenspaces (James et al., 2015) may improve attention (de Greeff et al., 2018), and it may be that the promotion of social cohesion by greenspaces is also an enhancing mechanism for improving attention (Markevych et al., 2017).

With respect to limitations, it should be noted that this study is not free of them. Firstly, due to the COVID-19 pandemic, data collection for the 11–13 years phase in Asturias was suspended and, therefore, only part (approximately 50%) of the total sample of the Asturias cohort could be included. This may be one of the reasons for the differences in socioeconomic status between those included and excluded from this phase in the Asturias cohort. In addition, there may be some variables not collected in the present study like family context or bio-genetic factors that are interfering in the relationship between greenspace exposure and attention. Second, given that we had collected the social class variable individually in the pregnancy follow-up and this measure was probably outdated for the current analyses, we decided to use the MEDEA deprivation index. Despite this latter measure was more recent in time, it is less informative because it is calculated at census section level (smallest administrative unit) so we could lose accuracy. However, it is also true MEDEAs deprivation index comprises several socioeconomic indicators making it more complete than the simple social class variable (Domínguez-Berjón et al., 2008). Third, the possible effect of blue spaces, as a co-exposure with greenspace, has not been taken into account (Amoly et al., 2015). Finally, no measures have been taken for exposure to greenspaces in children's schools, where they spend a relevant part of their time during work days and the quality of greenspaces has also not been measured.

5. Conclusion

The present study provides evidence on a potential beneficial impact of exposure to greenspace on attention in childhood. Specifically, a significant and positive association was found between greenspace measured by NDVI in 300 of the home and attention at 11–13 years of age, but not at 8 years of age. These results highlight both the need for further research on the subject and the need to create healthy spaces in cities, such as greenspaces, as a priority. It would be recommended that future studies take into account the possible exposure of participants to the noise, in order to measure the indirect effect between greenspaces and attention. Including exposure to blue spaces would also be important. Our findings, if confirmed by future studies, could inform policymakers about implementing interventions aimed at improving attention and neurodevelopment in general in urban children.

Funding

This study was funded by grants from Instituto de Salud Carlos III (Red INMA G03/176, CB06/02/0041, FIS-PI04/2018, PI06/0867, FIS-PI09/00090, FIS-PI09/02311, FIS-PI13/02187, FIS-PI13/02429, FIS-PI18/00909, FIS-PI18/01web237 and FIS-PI18/01142 incl. FEDER funds), Department of Health of the Basque Government (2005111093, 2013111089, 2015111065 and 2018111086), Provincial Government of Gipuzkoa (DFG06/002 and DFG15/221), annual agreements with the municipalities of the study area (Zumarraga, Urretxu, Legazpi, Azkoitia, Azpeitia and Beasain), CIBERESP, Obra Social Cajastur/Fundación Liberbank and Universidad de Oviedo.

The ethical committees of the hospitals involved in the regions approved the project and informed consent was obtained from all participants in each wave (29/2003, 07/2005, 24/2009, 09/2010, 56/2016, PI2013164, PI2018059).

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.

Acknowledgments

AA would like to thank the Department of Education, Language Policy and Culture of the Government of the Basque Country for a predoctoral research training grant.

Appendix A. Supplementary data

Supplementary data to this article can be found online at https://doi.org/10.1016/j.envres.2022.112994.

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4.artikulua

Artikuluaren izenburua: *Hiriko gune berdeak eta osasuna*

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Aldizkariaren izena: *Ekaia (ISSN 0214-9753)*

DOI: *10.1387/ekaia.20910*

Argitaratze data: *01/05/2020*

Ekaia, 2020, 37, 45-63
https://doi.org/10.1387/ekaia.20910

ekaia
ZIENTZIA eta TEKNOLOGIA ALDIZKARIA

ISSN 0214-9001 – eISSN 2444-3255

Hiriko gune berdeak eta osasuna

(Urban green spaces and health)

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LABURPENA: Azken urte luzeetan hiritarragoa den mundu batean, hiriguneek sortutako esposizio positibo zein negatiboek osasunean duten eraginak geroz eta gehiago kezkatzen gaitu. Osasunean eragin negatiboa duten esposizioak ikertu dira gehien, baina, hauei aurre egiteko, esposizio positiboak ere badaude, bizimodu osasuntsuago batera eta hortaz osasun maila hobe bat edukitzera bultzatzen gaituztenak. Esposizio positibo hauek gune berde eta urdinak dira. Geroz eta ikerketa gehiagotan aurki daitezke, eta osasun mental, fisiko eta sozialean duten eragin positiboa hainbat ikerketatan aurki daiteke. Artikulu honen helburua gune berde eta urdinak aztertzen dituzten ikerketek diotena aztertzea, esposizio hauek neurtzeko metodologia ezberdinak azaltzea eta osasunean dituzten eragin ezberdinak ikustea da.

HITZ GAKOAK: gune berdeak, berdetasuna, osasun publikoa, NDVI.

ABSTRACT: *Nowadays, living in a world more focused on citizenship, specialists are concerned on the impact produced by cities in the health of our society. This impact, which can be either positive or negative, has been profoundly researched lastly. However, it is important to mention the existence of positive exposures to overcome negative impact. These positive exposures are named green and blue areas, and have the aim of helping society maintain a healthier lifestyle. Recently, more and more research is made concerning green and blue areas; focusing on their positive impact in mental, physical and social health. The aim of this article is to present a compilation of information on green and blue areas in latest investigations, explaining different methodologies used for research and showing the diverse impact these areas might produce in human health.*

KEYWORDS: green spaces, blue spaces, public health, NDVI.

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Nola aipatu / How to cite: Anabitarte, Asier; Ibarluzea, Jesus; Azkona, Kepa; Lertxundi, Aitana (2020). «Hiriko gune berdeak eta osasuna»; *Ekaia*, 37, 2020, 45-63. (https://doi.org/10.1387/ekaia.20910).

Jasoa: 04 ekaina, 2019; Onartua: 21 azaroa, 2019

ISSN 0214-9001 - eISSN 2444-3255 / © 2020 UPV/EHU

1. SARRERA

Landatik hirietara izan den migrazioa, industria iraultzarekin bortizki hasi zena, gaur egun geroz eta hiri jendetsuago eta landa gune hutsagoen emaitza izan da. 1950ean munduko biztanleriaren % 30 hiri guneetan bizi zen; 2018. urtean, ordea, nabarmenki igo zen, eta % 55era iritsi zen. 2020urtean gaude eta pixkat desfasatua geratzen delako. Aurreikuspenen arabera, 2050ean munduko biztanleriaren % 68 hirietan egongo da kontzentratua [1]. Hau horrela izanik, garrantzitsua da hirietan ingurune osasuntsuak sortzea gizakien ongizateari begira [2].

Orokorrean, hirietako bizimoduak osasunean eragin negatiboa du. Nahiz eta hiriek osasunerako onurak ere badituzten, hala nola aukera ekonomiko oparoagoak eta osasun zentro eskuragarriagoak. Hiriguneek ingurumen faktoreen arrisku maila, aire kutsadura eta zarata areagotu eta gune naturaletara irisgarritasuna gutxitzen dute [3].

Gune naturalak osasun eta ongizate fisiko, mental eta sozialerako baliabidetzat ulertu behar dira, gune natural batek pertsonen osasuna hobetu baitezake [4]. Osasuna sustatuko duten jarduerak garatzeko espazio dira gune naturalak. Gainera, atentzioa berreskuratzeko eta estresa gutxitzeko ahalmena dute: ariketa fisikoa egiteko aukera ere eskaintzen dute. Gizarte integrazioa bultzatu eta naturarekin kontaktuan egoteko aukera ematen dute. Aipatutako faktore guztiak onuragarriak dira osasun eta ongizaterako [4].

Hiriguneek osasunarekin duten harremana ikertzen duen zientzietako bat da ingurumen epidemiologia. Aitzindarietako bat John Snow izan zen, zein epidemiologia modernoaren aitatzat jotzen duten, koleraren epidemiaren aurkikuntzari esker. John Snowren kolera epidemiaren aurkikuntzarekin, alde batetik, ingurumen epidemiologia sortu zen, eta, bestetik, mapak osasunean erabiltzea [5]. Ingurumen epidemiologia epidemiologiak erabili ohi dituen prozesu eta metodologia berdinez baliatzen da, baina, kasu honetan, ingurumen faktoreek sortutako efektuak soilik aztertzen dira [6]. Koleraren epidemiaren arrazoia mapa baten laguntzaz aurkitu zuen. Epidemiaren analisi espaziala eginez konturatu zen hildako gehienak iturri intoxikatu baten inguruan kontzentratzen zirela [5]. Egindako mapa proto-GISa dela jo daiteke (GIS: geografia informaziorako sistemak). Gaur egun, osasun publikoan geroz eta garrantzi handiagoa duen tresna da GISa.

GISaren sorrera Roger Tomlinsonen eskutik dator. GISaren aitatzat ezagutzen da; izan ere, berak sortu zuen lehenengo GISa, Kanadako lurren inbentarioa aurrera eraman ahal izateko [7]. GISen garapena dela eta, gune berdeen neurketa objektiboak egiteko adierazle berriak sortu ahal izan dira, osasun berdearen paradigmari erantzuna aurkitzeko asmoz [8]. GISaren bitartez, esposizio ezberdinak eslei dakizkieke pertsonei edota leku edo espazio zehatzei; honela, ingurua osasun arazoekin erlaziona daiteke.

Azken urteetan ingurumen epidemiologiak garrantzi handiagoa hartu du GISari esker. Tresna honen bitartez, gune berdeei buruz eta hauek osasunean duten eraginei buruz gehiago jakin ahal izan da. Gune berdeak diru sarreren ezberdintasunarekin erlazionatuta egon daitezkeela ikertu da, baita diru sarrera urria dutenek eduki ohi dituzten osasun arazo batzuk hein handiago batean hobetzeko ahalmena dutela ere [9]. Horregatik, MOEren (Munduko Osasun Erakundea) gomendioa 5.000 m^2-ko gune berde bat etxebizitzatik 300 metro baino hurbilago edukitzea da [10].

Gune berdeez gain, badira ere hiria jasangarriago eta osasuntsuagoak izaten laguntzen duten espazio naturalak, aldaketa klimatikoaren ondorioak leuntzeko ahalmenak ere dituztenak [11, 12]: gune urdinak, berdeak bezala, onuragarriak izan daitezke hiritarren osasunerako [13]. Gune urdinak lurrazaleko ur eremu guztiek osatzen dituzte; izan itsaso, erreka, ibai, laku etab. [14]. Esan beharra dago oraindik gutxi ikertu dela honen inguruan eta, beraz, lan honetan gune berdeei soilik egingo zaie erreferentzia. Aipatutako guneek biztanle sektore ahulenetan (haurrak, haurdunak, edadetuak…) eduki dezaketen eragin positiboa indartsuagoa izan daiteke, nahiz eta ikerketa gehigarriak beharko lirateke baieztapen hau egiaztatzeko [15].

Artikulu honek gune berdeek osasunean duten eragina azaleratzea du helburu, ikerketa ezberdinetan ikusi diren ondorioak aztertuz. Lan hau «Precautionary principle»-aren barnean dagoela esan daiteke. Printzipio hau Europar Batzordeak babesten duen printzipioa da. Lan honetan, aipatutako printzipioaren arriskuen detekzioa eta ikerketa, eta sortutako kalteen berrezartzearen ideiak lantzen dira [16].

2. GUNE BERDEEN NEURKETA ETA ESPOSIZIOAREN ESLEIPENA

Gune berdeek osasunean eragina dutela jakin ahal izateko, ezinbestekoa da biztanle bakoitzaren esposizioa neurtzea; honela, geroko analisi estatistikoetan ikusi ahal izango da ea harremanik duen ala ez. Gune berdeak neurtzeko, bi iturri objektibo nagusi daude: batetik, NDVI landaredi indizea erabiltzen dutenak [17-21]; bestetik, lurzoruaren erabileren datu basea erabiltzen dutenak [9, 22, 23], iturri batzuk eta besteak bateraezinak izan gabe. Iturri subjektiboari dagokionez, partaideak gune berdeei buruz duen pertzepzioa aztertzen da galdetegien bidez [24].

Ez dago orokorki onartua dagoen definiziorik; definizio gehienek aipatzen dute, ordea, sarbide publikoa izan behar duela eta aisialdirako erabilera baimendua egotea [10]. Europako Ingurumen Agentziaren (EEA) arabera, hiriko gune berde bat aisialdirako erabilera duen gune publiko berde bat da: esaterako, lorategia, zooa, parkeak edota hirigune inguruan diren gune naturalak eta basoak [25].

https://doi.org/10.1387/ekaia.20910

2.1. **Iturri objektiboak**

NDVIa (Normalized Difference Vegetation Index) da landaredi indizerik erabiliena eta landaredi berdea hautemateko errazena. Urruneko multiespektro detekzioaren bitartez lortzen da; espektroaren banda ikusgaiaren (banda gorria-Red) eta infragorri hurbilaren (NIR) datuen konbinazioz sortzen da [26].

$$NDVI = \frac{NIR - Red}{NIR + Red}$$

Esan bezala, NDVI indizea banda gorriaren eta infragorri hurbilaren arteko konbinazioaren bitartez sortzen da; –1 eta 1 arteko balioak lortzen dira: 1etik gertu dauden balioek berdetasun maila altuenak adierazten dituzte [27]. NDVIa sortzeko erabiltzen diren sateliteek 30 × 30 metroko erresoluzioa izan ohi dute [20, 28, 29]. Ikerketa gehienek Landsat sateliteetako datuak erabiltzen dituzte [17, 20, 29]; beste ikerketa batzuek MODIS satelitearen datuak erabiltzen dituzte [30, 31].

Biztanleei NDVIaren esposizioa esleitzeko ikerketa epidemiologikoetan erabiltzen den metodologia zabaldu eta erabiliena Dadvand *et al*. [17], Dzhambov *et al*. [19], Dzhambov [18], Gascon *et al*. [20] eta Grazuleviciene *et al*. [21] autoreek erabiltzen dutena da: lehenik eta behin, ikerketako partaidea geokodetzen da bere ohiko egoitzan; ondoren, neurri ezberdinetako bufferrak[1] kalkulatzen dira etxebizitzaren inguruan. Azkenik, neurri ezberdinetako buffer bakoitzari NDVI indizearen balioaren batezbestekoa esleitzen zaio. Ohikoenak diren bufferrak 100, 300 eta 500 metrokoak dira.

Lurzoruaren erabileren datu baseek lurzorua erabileraren arabera zatikatzen dute; ondoren, bakoitzari klasifikazio ezberdin bat ematen diote. Lurzoruaren erabileren datu basea sortzen duen herrialdearen edo unitate administratiboaren arabera aldatzen dira klasifikazio horiek, eta bai lurraldea zatikatzeko erabiltzen duten erresoluzioa ere. Klasifikazio ezberdinen artean gune berdeei erreferentzia egiten dien bat egotea ohiko da [26].

Gune berdeetarako irisgarritasuna kalkulatzeko, partaideen etxebizitzak abiapuntu harturik sortzen dira 300 metroko bufferrak, MOEren gomendioei jarraituz [10], eta, ondoren, 5.000 m^2 baino gehiagoko gune berderik duen kalkulatzen da. Gune berdeak Urban Atlas (https://land.copernicus.eu/local/urban-atlas/urban-atlas-2012) edo tokiko mapa topografikoetatik lortzen dira. Etxebizitzatik gune berdeetara dagoen distantzia ere kalkulatzen da, berriro ere 5.000 m^2-tik gorako gune berdeak kontuan hartuz [29].

[1] GISaren funtzio bat. Zehaztutako metroen erradioa duen eragin eremua sortzen duena kokapen baten inguruan.

Gune berdeetarako irisgarritasuna, orain arte, distantzia bitartez neurtu da, baina ikerketa berrienak partaideek egiten duten bidea erregistratzen hasi dira, bertako esposizioak esleitu nahiez. Honetarako, ikerketek kokapen sistemak erabili dituzte partaideak nondik ibiltzen diren jakin ahal izateko eta ingurune horien esposizioak kalkulatzeko. Nieuwenhuijsen, M-ek [3] aipatu zuen teknologia berrien erabilerak txikitzen zituela ordura arte esposizioak ebaluatzeko izandako zailtasunak; horietako teknologia bat GNSS (Global Navigation Satellite System) da. Kokapen sistemak partaideari bere esposizio erreala esleitzeko aukera ematen du. Hainbat dira, jada, honelako gailuak erabili dituzten ikerketak [32-35].

2.2. **Iturri subjektiboa**

Partaideek beren ingurua zer-nolako berdea den adierazten dute galdetegi ezberdinen bitartez, eta, ondoren, osasun arazoekin alderatzen. Galdeketak orokorrak izaten dira: aldagai sozioekonomiko eta osasun orokor eta mentalei buruzko galderez gain, bizilekuaren inguruari buruzko galderak ere badaude; hauek dira gune berdeari buruz partaideek duten pertzepzioa ezaugarritzen duten galderak [24, 36].

Honela, hala informazio objektiboa (partaidearen etxebizitza inguruko berdetasun maila, 300 metro inguruan gune berderik duen ala ez, eta gertuena zein distantziatara dagoen) nola partaidearen pertzepzio subjektiboa edukiko ditugu.

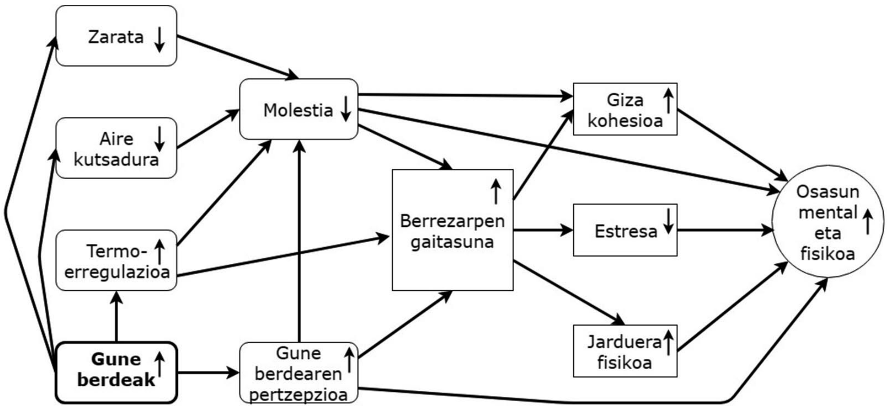
3. **GUNE BERDE ETA OSASUNAREN ARTEKO BITARTEKARIAK**

Aldagai bitartekaria mendeko aldagaiaren eta aldagai independentearen artean modu kausal batean aurkitzen den aldagai bat da [37]. Dakigunez, orain arte ez dago emaitza esanguratsurik aldagai bitartekariek eduki dezaketen pisuari dagokionez.

Gune berdeekiko esposizioak sortatutako mekanismoen bitartez dira onuragarriak natura espazioak osasunean. 1. irudiaren bitartez ikus dezakegu nola jokatzen duten bitartekari hauek eta zein modutan eragiten diote osasunari.

Lau talde nagusitan banatu dira bitartekariak, gune berdeekin duten harremana eta eragiteko modua adierazteko. Bitartekari hauek baitira ondoren osasunean eragin zuzena izango dutenak.

https://doi.org/10.1387/ekaia.20910



1. irudia. Gune berdeek nola eragiten dioten osasunari [36].

3.1. Ingurumenarekiko esposizioa

Gune berdeetarako hiri espazioak handitzeak hiru ingurumen faktoreetan izaten du eragina; batetik, landarediak CO_2-a oxigeno bilakatzeko duen ahalmenagatik [38]; bestetik, gune berdeko espazio horietan trafikorik egongo ez dela ziurtatzen delako eta, hortaz, trafikoaren eraginez sortzen diren aire kutsadura eta zarata arazoak ekiditen direlako [39, 40], eta, azkenik, gune berdeek tenperatura eta hezetasuna erregulatzeko duten ahalmenagatik [41]. Prozesu hauei guztiei esker, osasunean arazo asko prebeni daitezke [26]. Aipatutako asoziazioak 1. grafikoan ikus daitezke.

3.2. Jarduera fisikoa

Hiriek jarduera fisikoa egiteko aukera urriak eskaintzen dituztenez gero, gune berdeek jarduera horiek garatzeko aukerak sortzen dituzte. Gune berdeak etxebizitzatik gertu edukitzeak ariketa fisikoa egitera bultzatzen du [42]. Fong *et al*.-ren arabera, berdetasun maila altuagoak edukitzea jarduera fisikoaren handitze batekin erlazionatua dago [43]. Horregatik, MOEk gomendatzen du 5.000 m^2-tik gorako gune berde bat edukitzea etxebizitzatik 300 metrora gehienez [10]; 1. grafikoan ikus daiteke nola erlazionatzen diren gune berdeak eta jarduera fisikoa.

3.3. Gizarte kohesioa

Hiri eta auzoetan gune berdeak izateak erakargarriago bilakatzen ditu elkarbizitzako guneak [44, 45]; horrek elkartze sozialak errazten ditu [45, 46]. Hortaz, gune berdeek auzoetako giza kohesioa garatzen laguntzen dute; gainera, gune irekiek itxura erakargarriago dute [47]. Beraz, landarediari esker, atxikimendu handiagoa sortzen da auzoarekiko eta komunitatearekiko [47]; 1. grafikoan atzeman daiteke gune berdeen eta giza kohesioaren arteko harremana.

3.4. **Estres mailaren gutxitzea eta atentzioaren berrezartzea**

Gune berdeek bi teoriaren arabera dute eragin positiboa osasun mentalean. Batetik, estres maila gutxitzen dute; Ulrich-en arabera [48, 49], «Stress Reduction Theory-SRT»-k gune berdeek estres maila gutxitzen dutela dio. Gune berde batean egoteak emozio positiboak sortzen ditu: negatiboak blokeatzen dira, eta estres maila gutxitzen da. Hori eboluzioaren oinarrian dauden erantzun biologikoen prozesu bezala azaltzen du Ulrich-ek. Bestetik, «Attention Restoration Theory-ART» dago; horren arabera, atentzioaren neketik suspertzeko balio dute gune berdeek. Teoriaren arabera, landarediak eta beste hainbat gune naturalek gure atentzioa esfortzurik gabe mantentzeko ahalmena dute: suspertzeko aukera dira [50, 51]; 1. grafikoaren bitartez, gune berdeen eta osasun mentalaren arteko erlazioak uler daitezke.

4. **OSASUN ONDORIOAK ETA EZTABAIDA**

1. taulan, gune berdeek osasunean dituzten eraginak aztertzen dira, osasun ondorio ezberdinetan sailkatuz eta horietan dauden emaitza esanguratsuenak aipatuz. Sei taldetan sailkatu dira: ugalketa osasuna, jarduera fisikoa, osasun mentala, asma eta alergia, ondorio kardiobaskularrak eta hilkortasuna. Guztira, 17 artikulu aztertu dira gune berdeak osasunean dituen emaitzak azaltzeko. 1. taulan gune berdearen eta osasunaren artean dauden emaitza esanguratsuenak aipatuak dira, nahiz eta taulan osasun fisiko eta mentalaren eta gune berdeen arteko asoziazioen emaitzak ikusi, kontuan hartu behar da ez dela asoziaziorik ikusi artikulu guztietan; artikulu hau dibulgaziozkoa izanik, emaitza esanguratsuenak hartu dira soilik kontuan.

https://doi.org/10.1387/ekaia.20910

1. taula. Gune berdeek osasunean duten eraginaren emaitza esanguratsuak, osasun arazo ezberdinetan sailkatuak

Autoreak	Urtea	N	Biztanle taldea	Neurketa objektiboa *vs.* subjektiboa	Bitartekariak	Emaitzak
UGALKETA OSASUNA						
Grazuleviciene R *et al.* [21]	2015	3292	Emakume haurdunak (Kaunas, Lituania)	Objektiboa	Ez du bitartekarien papera aztertzen	Etxebizitza inguruan berdetasun maila baxua izatea eta gune berde batera distantzia handitzea jaiotzean pisu baxua izatearekin (OR: 2,23 KT % 95: 1,20;4,15) eta goiztiartasunarekin (OR 1,77, 1,10-2,81) erlazionatu da.
Dadvand P *et al.* [17]	2012	2393	Emakume haurdunak (Espainia)	Objektiboa	Aire kutsaduraren bitartekaritza aipatzen du, nahiz eta oso arina izan	Gune berdeak jaiotze pisuarekin eta buruaren zirkunferentziaren neurriarekin erlazionatu dira. 500 m-ko bufferrean NDVIaren kuartilarteko hein bakoitzaren handitzeagatik, 44,2 g (KT % 95: 20,2;68,2) eta 1,7 mm-ko (KT % 95: 0,5;2,9) hazkundea izaten da. Asoziazioa indartsuagoa da hezkuntza maila baxuko emakumeengan.
Markevych *et al.* [52]	2014	3203	Emakume haurdunak (Munich, Alemania)	Objektiboa	Aire kutsadura eta zarata aztertu dira bitartekari bezala. Aire kutsaduran asoziazio negatiboa ikusi da; zaratan, aldiz, ez da asoziaziorik ikusi. Bitartekariak aztertzen jarraitzeko beharra azpimarratzen da	500 m-ko bufferrean NDVIaren kuartilarteko hein bakoitzaren handitzeagatik, 17,6 g-ko,(KT % 95:: 0,5;34,6) igoera gertatzen da haurraren jaiotze pisuan. Ez da auzoko gune berdeen artean eta jaiotza pisuaren artean erlaziorik ikusi.
Agay-Shay K, *et al.* [53]	2014	39132	Haur jaioberri ez-bikiak (Tel Aviv, Israel)	Objektiboa	Gune berdeek aire kutsaduran izan dezaketen eragina aztertu da, baina ez da asoziaziorik ikusi	Kuartilarteko hein bakoitzeko handitzea jaiotza pisuarekin erlazionatu da (19,2, KT % 95: 13,3;25,1), baita jaiotza pisu baxuaren arriskua gutxitzearekin ere (OR: 0,84, KT % 95: 0,78;0,90).

Autoreak	Urtea	N	Biztanle taldea	Neurketa objektiboa *vs*. subjektiboa	Bitartekariak	Emaitzak
			JARDUERA FISIKOA			
Sarkar C. [54]	2017	333183	38-73 urte (Erresuma Batua)	Objektiboa	Jarduera fisikoa jada bada mekanismo bitartekari bat	Bizitegiko berdetasuna positiboki erlazionatu da bidaia aktiboekin: lan bidaietatik kanpoko aktibitatean (OR:1,093 KT % 95:1,08;1,11) eta 30 minutu baino gehiago ibiltzean (OR:1,093 KT % 95: 1,03;1,05).
Almanza *et al*. [33]	2012	386	Haurrak 8-14 urte (Kalifornia)	Objektiboa	Jarduera fisikoa jada bada mekanismo bitartekari bat	Asoziazio indartsua ikusi da jarduera fisiko indartsuaren eta gune berdearen artean. 10. pertzentiletik 90. pertzentilerako berdetasunaren igoerak jarduera fisiko indartsua % 39an handitzen du (OR: 1,39 KT % 95: 1,36;1,44). Gainera, gune berdearekiko esposizio handiena zutenek, 90. pertzentilekoek, jarduera fisiko indartsuko eguneko tasa 5 aldiz handitzen zuten gune berdeekiko esposiziorik ez zutenen aldean.
Dunton *et al*. [32]	2014	135	Haurrak 8-14 urte (Hego Kalifornia)	Subjektiboa	Jarduera fisikoa jada bada mekanismo bitartekari bat	Parkearen erabilera luzea (>15 min) laukoiztu egiten da gune berderako distantzia 100 metro txikitzen denean. Landaredi dentsitatea 25. pertzentiletik 75 pertzentilera pasatzean, parkearen erabilera (>5min) bikoiztu egiten da
			OSASUN MENTALA			
Triguero-Mas *et al*. [55]	2015	8793	Helduak 48 urte bataz besteko (Katalunia)	Objektiboa	Jarduera fisikoa eta giza kohesio aztertu dira bitartekari bezala, baina ez da asoziaziorik ikusi	100 metroko bufferretan berdetasun mailaren igoera bakoitzeko osasun mental txarraren arrisku pertzepzioa (0,84 KT % 95: 0,76;0,93), depresio pertzepzioa (0,83 KT % 95: 0,77;0,90) edota osasun mentaleko espezialista bisitatzea jaitsi egiten da (0,77 KT % 95: 0,67;0,88). Gainontzeko buffer tamainetan ere ikusten dira asoziazioak osasun mentalaren hobekuntzaren eta berdetasun maila altuagoen artean.

https://doi.org/10.1387/ekaia.20910

Autoreak	Urtea	N	Biztanle taldea	Neurketa objektiboa *vs*. subjektiboa	Bitartekariak	Emaitzak
Brown *et al*. [56]	2018	249405	+65 urte (Florida, AEB)	Objektiboa	Ez du bitartekarien papera aztertzen	Diru sarrera gutxieneko taldeetan NDVIaren indizea handitzea osasun mentalaren hobetzearekin erlazionatu zen: depresioa jasateko probabilitatea jaitsi zen NDVIaren 0,1eko igoera bakoitzeko (OR: 0,790 $p < 0{,}0001$)
Banay *et al*. [57]	2019	38947	Emakume helduak 54-91 urte (AEB)	Objektiboa	Berdetasunaren eta depresioaren arteko bitartekaria jarduera fisikoa ote zen aztertu da, baina ez da asoziaziorik ikusi	Berdetasunaren kintil altuenean aurkitzen diren emakumeek % 13 arrisku txikiagoa dute depresioa izateko, kintil baxuenarekin alderatuta (KT % 95: 0,78; 0,98).
Liao *et al*. [58]	2019	1312	Emakume haurdunak (Wuhan, China)	Objektiboa	NDVIaren eta MDIaren artean aire kutsaduraren bitartekaritzak –% 11,10 (KT % 95: –38,73; –6,15) azaltzen du, PDIarekin aldiz, % 18,68 (KT % 95: 13,58; 28,05). Jarduera fisikoak NDVIaren eta PDIaren arteko % 4,14 (KT % 95: 2,30; 13,60) azaltzen du, eta MDIaren –% 1,14 (–1,74; –0,83)	Garapen neurologiko hobea ikusi da etxebizitzaren inguruan berdetasun maila altuak eduki dituzten haurretan: NDVIaren desbiderapen estandar bakoitzaren gehikuntzagatik PDIaren puntuazioa igotzen da (3,28 KT % 95: 2,15; 4,41)
Zijlema *et al*. [59]	2017	1602	Helduak 48 urte batez beste (PHENOTYPE kohortea)	Objektiboa eta subjektiboa	Jarduera fisikoa, bizilagunekiko interakzio soziala, bakardadea, bizilagunen arteko giza kohesioa, osasun mentalaren pertzepzioa, autoen zarataren molestia eta aire kutsaduraren kezka aldagaiak aztertu dira bitartekari bezala; ez da asoziaziorik ikusi.	Etxebizitzatik gune berde baterako distantzia 100 metro handitzeak funtzio kognitiboen testa amaitzeko denboraren % 1,5 luzatzea dakar (KT % 95: 0,13; 2,89)

Autoreak	Urtea	N	Biztanle taldea	Neurketa objektiboa *vs.* subjektiboa	Bitartekariak	Emaitzak
ASMA ETA ALERGIA						
Eldeirawi *et al.* [60]	2019	1915	Haurrak 4-18 urte (Illinois, Chicago)	Objektiboa	Ez du bitartekarien papera aztertzen	Ez da asoziaziorik ikusi bizitza osorako asmaren eta berdetasunaren artean, baina bai, 100 metroko bufferretako berdetasun maila eta sibilantziaren artean (OR: 0,82 KT % 95: 0,69; 0,96)
Andrusaityte *et al.* [61]	2016	1489	Haurrak 4-6 urte (Kaunas, Lituania)	Objektiboa	Ez du bitartekarien papera aztertzen	NDVIaren kuartilarteko hein bakoitzaren igoera, 100 metroko bufferrean, asmaren arriskuaren igoera estatistikoarekin asoziatu da (OR: 1,43 KT % 95: 1,10;1,85)
Fuertes *et al.* [62]	2016	13016	Haurrak 6-12 urte (Suedia, Australia, Herbehereak, Kanada eta Alemania)	Objektiboa	Aire kutsaduraren bitartekaritza aztertu da, baina ez da aldaketarik ikusi	NDVIa 500 metroko bufferraren eta errinitis alergikoaren arteko harreman positiboa ikusi da BAMSE[1] (OR: 1,42 KT % 95:1,13; 1,9) eta GINI/LISA[2] hegoaldeko (OR: 1,69 KT % 95: 1,19; 2,41 kohorteetan. Aldiz, kontrako asoziazioa ikusi da PIAMA[3] (OR: 0,67 KT %)%: 0,47; 0,95) kohortean
ONDORIO KARDIOBASKULARRAK						
Twohig-Benett eta Jones [63]	2018	Meta-analisia	Hainbat ikerketaren meta-analisia	Hainbat ikerketaren meta-analisia	Ez du bitartekarien papera aztertzen	Estatistikoki esanguratsuak diren asoziazioak ikusi dira gune berdea eta bihotz-maiztasunarekin –3,46 (% 95 KT: –4.05;-2.88) eta tentsio arterial diastolikoarekin –1.97 (% 95 KT: –3,45;-0,49)

[1] BAMSE: Jaiotza kohorte suediarraren luzerako aurrera begirako ikerketa.

[2] GINI eta LISA: Jaiotza kohorte alemaniarrak. GINI German infant study on the Influence of Nutrition Intervention plus environmental and genetic influences on allergy development). LISA Influence of lifestyle factors on the immune system and allergies in East and West Germany plus the influence of traffic emissions and genetics.

[3] PIAMA: Jaiotza kohorte herbeheretarra (Prevention and Incidence of Asthma and Mite Allergy).

https://doi.org/10.1387/ekaia.20910

Autoreak	Urtea	N	Biztanle taldea	Neurketa objektiboa *vs.* subjektiboa	Bitartekariak	Emaitzak
Tamosiunas *et al.* [64]	2014	5112	Biztanleria heldua (45-72) (Kaunas, Lituania)	Subjektiboa	Ez du bitartekarien papera aztertzen	Gune berdeetarako distantziaren eta gaixotasun kardiobaskularren arteko harremana ikusi da. 3. tertzileko distantziak 1,36ko (1,03-1,80 bitarteko) arrisku erlatiboa du 1. tertzilekoekin alderatuta. Aldiz, gizonezkoen kasuan, 3. tertzilak 1,51ko (1,04;2,19 bitarteko) arrisku erlatiboa dauka lehenengo tertzilarekin alderatuta; estatistikoki esanguratsua da
HILKORTASUNA						
James *et al.* [65]	2016	108630	Emakumeak 30-55 urte (AEB)	Objektiboa	4 bitartekari aztertu dira; laurek, elkarrekin batera, gune berdeen eta hilkortasunaren bitartekotasunaren % 27,1 (KT % 95: 14,7;44,6) azaltzen dute. Depresioak % 30,6 (KT % 95: 15,5;51,4) azaltzen du; giza kohesioak % 19,1 (KT % 95: 10;33,3); jarduera fisikoak % 2,1 (KT % 95: 0,2;19,3), eta aire kutsadurak % 4,4 (KT % 95: 2,4;7,7)	250 metroko bufferretan bizi diren emakumeek eta batez besteko berdetasun kintil altuenean daudenek, kintil baxuenarekin alderatuta, %12ko ratio txikiagoa (% 95 KT: 0,82-0,94) dute edozein hilkortasun kausa ez-istripuzko izateko
Ji *et al.* [66]	2019	23754	Edadetuak ≥65 urte (Txina)	Objektiboa	Ez du bitartekarien papera aztertzen	250 metroko bufferreko NDVI kuartil altuenean bizi diren pertsonek % 27 hilkortasun baxuagoa izan zuten kuartil baxuenarekin alderatuta (AE: 0,73 KT % 95: 0,70; 0,76 p < 0.0001)

Gune berdeek osasunari eragiteko duten ahalmenaren arrazoietako bat bitartekarien zeregina da. Bitartekarien bitartez, gune berdeek eragin positiboa izan dezakete osasunean; bai faktore negatiboren bat gutxitzen dutelako, bai faktore positiboren bat indartzen dutelako. Bitartekari garrantzitsuenetako bat berrezarpenaren gaitasuna da: gizakiak naturarekin eboluzioan zehar eduki duen harremanarengatik, gizakion mekanismo asko hobetu dira, eta, ondorioz, osasun mental eta fisiko hobe batera eramanez [48]. Lan honetan aztertu diren bitartekarien artean jarduera fisikoa eta aire kutsadura izan dira gehien aipatu direnak; 8. eta 7. artikuluetan aipatu dira, hurrenez hurren. Bigarren maila batean, zarata, giza kohesioa eta depresioa aztertu dira: 3 aldiz aipatu da giza kohesioa; 2 aldiz zarata, eta behin depresioa. Emaitza esanguratsuenak eduki dituzten bitartekari aztertuen artean, jarduera fisikoak eta aire kutsadurak jarraitzen dute izaten gune berde eta osasun mental nahiz fisikoaren artean bitartekaritza handiena dutenak. Jarduera fisikoaren kasuan, 5 artikulutan ikus daiteke eragina duela gune berde eta osasunaren hobetzearen arteko harremanean. Aldiz, aire kutsadura 4 artikulutan agertu da bitartekari esanguratsu bezala. Giza kohesioa eta depresioa izan dira beste bitartekari esanguratsuak, artikulu bakarrean baina. Hortaz, esan daiteke aire kutsadura eta jarduera fisikoa direla bitartekari indartsuenak; nolanahi ere, ikertzen jarraitzeko beharra ikusi da. Izan ere, aztertutako artikulu guztietatik 7 artikulutan ez da bitartekarien papera aztertu; gune berdeen eta osasun-hobekuntzaren arteko kausa zuzena ikertu dute soilik Bitartekariei buruzko emaitzak ez dira oso esanguratsuak, eta, beraz, ezin daiteke ziurtasunez esan hauek zer pisu izan dezaketen gune berdearen eta osasun mental nahiz fisikoaren artean. Gehiago ikertu beharko litzateke maila ezberdineko bitartekariak daudela aipatzekotan.

Gune berdeek osasunean duten eragina geroz eta esanguratsuagoa dela ikusten da, eta geroz eta ikerketa gehiagok baieztatzen dute hori. Hala ere, zehaztasun handiago batekin baieztatu ahal izateko, garrantzitsua da ikertzen jarraitzea eta esposizioen neurketa metodologiak hobetzen jarraitzea, analisi eta ikerketa hobeak lortzeko helburuarekin.

Metodologia hobe bat garatzeko, Robinsonek [29] erabilitakoa izango litzateke osoenetako bat: pertsona batek hiri batean jaso ditzakeen eta hipotesiarekin erlazionatuta dauden aldagai guztiak jasotzea eta batera aztertzea litzateke. Lehenago esan bezala, aldagai bakoitzaren eragina eta eragiteko modua ulertzeko metodologia zuzenena Robinsonek garatutakoa litzateke, eta honela, bide batez, bitartekarien papera eta pisua aztertu ahal izango lirateke. Gero eta ugariagoak dira, azkenaldian, hirietan jasan daitezkeen esposizioak banan-banan aztertu beharrean guztiak elkarrekin aztertzen dituzten ikerketak; esposizio guztiak elkarrekin aztertzeari «urban exposome» deritzote.

Azkenik, zenbat eta ebidentzia zientifiko gehiago dauden alor honetan, orduan eta argiago geratzen da hiri guneetan garrantzitsuak direla gune

https://doi.org/10.1387/ekaia.20910

berdeak (>5.000 m^2) eskuragarri edukitzea, biztanleriaren osasunerako eta hirien jasangarritasunerako.

5. LABURDURAK

AE = arrisku erlatiboa.
ART = Attention Restoration Theory.
CO_2 = karbono dioxidoa.
GIS = geografia informaziorako sistema.
GNSS = Global Navigation Satellite System.
KT = konfiantza tartea.
MOE = Munduko Osasun Erakundea.
NDVI = Normalized Difference Vegetation Index.
NIR = Near Infrared.
OR = Odd Ratio.
SRT = Stress Reduction Theory.

6. ESKER ONAK

AAk eskerrak eman nahi dizkie Eusko Jaurlaritzako Hezkuntza, Hizkuntza politika eta Kultura sailei, doktore tesia egiteko jaso duen diru-laguntzagatik. Biodonostiako Ingurumen epidemiologia eta haurren garapena ikerketa taldeak esker onak ematen dizkio Ekogune-Kutxa Fundazioari gai honi loturiko ikerketa finantziatu duelako.

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https://doi.org/10.1387/ekaia.20910

Testing the Multiple Pathways of Residential Greenness to Pregnancy Outcomes Model in a Sample of Pregnant Women in the Metropolitan Area of Donostia-San Sebastián artikuluaren material osagarria

Supplementary Table 1. Descriptive statistics, together with 10th and 90th percentiles, for the sample distributions of new-born weights (g) at gestational weeks 25-42 in Gipuzkoa

	Week	n	Min	Max	Median	IQR	Mean	SD	10%	90%			Week	n	Min	Max	Median	IQR	Mean	SD	10%	90%
	25	8	640	800	720	33	724	49	644	797			25	13	500	880	790	200	742	127	567	880
Females	26	9	700	1050	815	194	844	129	703	1036		Males	26	7	500	1060	735	125	758	171	512	1045
	27	8	690	1215	930	123	920	167	695	1199			27	6	905	1065	965	128	977	74	905	1065
	28	11	650	1400	940	185	987	228	679	1352			28	17	820	1430	1215	315	1190	192	890	1409
	29	10	800	1395	1050	220	1046	206	815	1378			29	20	630	1870	1280	266	1257	246	1024	1495
	30	25	900	3390	1432	400	1574	633	1126	2702			30	18	800	3650	1372	343	1528	671	946	2605
	31	17	910	1920	1514	419	1468	297	1055	1823			31	17	1330	2330	1800	470	1758	313	1354	2243
	32	25	1330	2500	1755	399	1824	323	1428	2339			32	35	1150	2365	1725	278	1770	291	1416	2205
	33	42	1240	2500	1875	360	1841	269	1500	2176			33	53	1100	2830	1950	415	1921	318	1550	2312
	34	79	1250	2910	2015	358	2046	303	1683	2482			34	112	710	3120	2175	440	2171	361	1746	2600
	35	160	1115	3940	2305	455	2312	426	1757	2747			35	169	1470	3720	2510	520	2486	412	1883	2907
	36	268	1155	4220	2575	565	2582	436	2051	3094			36	288	1450	3820	2670	576	2653	409	2102	3164
	37	636	1730	4060	2760	580	2755	429	2184	3310			37	704	1720	4160	2905	530	2894	402	2360	3400
	38	1389	1820	5100	3040	500	3069	400	2562	3580			38	1455	1860	4920	3160	530	3180	406	2660	3700
	39	2361	2095	4860	3240	520	3248	391	2750	3760			39	2331	1360	4740	3375	530	3384	396	2880	3900
	40	2660	2220	4900	3362	500	3376	377	2920	3860			40	2643	734	5120	3500	550	3524	397	3030	4040
	41	1622	1500	5160	3480	500	3498	390	3010	3983			41	1626	2450	4930	3640	545	3658	408	3150	4200
	42	155	2760	5010	3595	465	3615	374	3158	4102			42	168	2760	4790	3708	541	3708	413	3142	4218

Supplementary Table 2. Direct and indirect natural effect coefficients and SE by exposure, mediator and outcome.

Exposure: Availability of green space > 5000m^2 within 300 m

Mediator			Estimate	St. Error	z-value	p-value
	Response is prematurity					
NO_2	(Intercept)		-4.06	4,4762	-0.91	0.37
	Natural Direct Effect		-0.10	2.69	-0.04	0.97
	Natural Indirect Effect		-0.17	0,1524	-1.12	0.26
	Sex					
		Female	REF			
		Male	0.16	1.88	0.08	0.93
	Season					
		Autumn	REF			
		Spring	0.39	3.19	0.12	0.90
		Summer	-0.17	3.54	-0.05	0.96
		Winter	-0.53	8.08	-0.07	0.95
	Parity		0.34	0.70	0.49	0.63
	Privation index		0.19	0.31	0.63	0.53
	Response is SGA					
	(Intercept)		-2.59	0.79	-3.28	0.00
	Natural Direct Effect		0.68	0.55	1.23	0.22
	Natural Indirect Effect		-0.02	0.06	-0.24	0.81
	Sex					
		Female	REF			
		Male	0.49	0.37	1.33	0.18
	Season					
		Autumn	REF			
		Spring	-0.46	1.23	-0.37	0.71
		Summer	-0.02	0.46	-0.04	0.97
		Winter	-0.70	3.57	-0.20	0.84
	Parity		-0.59	0.33	-1.79	0.07
	Privation index		0.02	0.16	0.10	0.92
	Response is LGA					
	(Intercept)		-1.58	0.53	-2.97	0.00
	Natural Direct Effect		-0.52	0.32	-1.60	0.11
	Natural Indirect Effect (NIE)		0.03	0.04	0.70	0.49
	Sex					
		Female	REF			
		Male	-0.28	0.31	-0.91	0.37
	Season					
		Autumn	REF			
		Spring	0.20	0.43	0.46	0.64
		Summer	-0.14	0.37	-0.38	0.70
		Winter	0.00	0.50	0.01	0.99
	Parity		0.24	0.18	1.35	0.18
	Privation index		0.05	0.13	0.40	0.69
	Response is LBW					
	(Intercept)		-4.29	2.63	-1.63	0.10
	Natural Direct Effect (NDE)		0.39	2.35	0.16	0.87
	Natural Indirect Effect (NIE)		-0.12	0.11	-1.07	0.28
	Sex					
		Female	REF			
		Male	0.08	0.54	0.14	0.89
	Season					
		Autumn	REF			
		Spring	-0.15	1.98	-0.07	0.94
		Summer	-0.22	1.34	-0.16	0.87
		Winter	-0.35	5.54	-0.06	0.95
	Parity		0.13	0.25	0.50	0.62
	Privation index		0.41	0.21	1.93	0.05
	Response is birth weight					
	(Intercept)		3428.85	91.73	37.38	< 0.000
	Natural Direct Effect (NDE)		-138.65	60.35	-2.30	0.02
	Natural Indirect Effect (NIE)		6.62	5.26	1.26	0.21
	Sex					
		Female	REF			
		Male	24.64	48.91	0.50	0.61
	Season					
		Autumn	REF			
		Spring	66.32	70.93	0.94	0.35
		Summer	-3.93	60.20	-0.07	0.95
		Winter	83.16	77.62	1.07	0.28
	Parity		38.92	31.44	1.24	0.22
	Privation index		-19.27	20.59	-0.94	0.35

Exposure: Availability of green space > 5000m^2 within 500 m

Mediator			Estimate	St. Error	z-value	p-value
	Response is prematurity					
NO_2	(Intercept)		-4.68	10.15	-0.46	0.645
	Natural Direct Effect		0.99	8.27	0.12	0.905
	Natural Indirect Effect		-0.50	0.38	-1.31	0.191
	Sex					
		Female	REF			
		Male	0.14	1.36	0.11	0.915
	Season					
		Autumn	REF			
		Spring	0.39	4.14	0.10	0.924
		Summer	-0.13	5.21	-0.03	0.980
		Winter	-0.54	9.28	-0.06	0.953
	Parity		0.34	1.73	0.20	0.845
	Privation index		0.19	0.65	0.29	0.772
	Response is SGA					
	(Intercept)		-3.03	5.11	-0.59	0.553
	Natural Direct Effect		1.12	5.10	0.22	0.825
	Natural Indirect Effect		-0.05	0.14	-0.36	0.716
	Sex					
		Female	REF			
		Male	0.53	0.38	1.40	0.161
	Season					
		Autumn	REF			
		Spring	-0.47	0.95	-0.50	0.619
		Summer	-0.05	0.45	-0.11	0.916
		Winter	-0.71	3.38	-0.21	0.834
	Parity		-0.63	0.34	-1.86	0.063
	Privation index		0.01	0.16	0.08	0.937
	Response is LGA					
	(Intercept)		-1.90	0.67	-2.86	0.004
	Natural Direct Effect		-0.11	0.54	-0.20	0.842
	Natural Indirect Effect (NIE)		0.05	0.07	0.72	0.470
	Sex					
		Female	REF			
		Male	-0.28	0.30	-0.95	0.341
	Season					
		Autumn	REF			
		Spring	0.19	0.40	0.46	0.644
		Summer	-0.11	0.38	-0.29	0.770
		Winter	0.00	0.52	0.00	0.997
	Parity		0.24	0.19	1.30	0.192
	Privation index		0.06	0.12	0.46	0.647
	Response is LBW					
	(Intercept)		-4.22	5.73	-0.74	0.462
	Natural Direct Effect (NDE)		0.46	5.76	0.08	0.936
	Natural Indirect Effect (NIE)		-0.32	0.25	-1.25	0.212
	Sex					
		Female	REF			
		Male	0.08	0.55	0.15	0.884
	Season					
		Autumn	REF			
		Spring	-0.15	2.42	-0.06	0.949
		Summer	-0.23	1.04	-0.22	0.825
		Winter	-0.37	5.73	-0.07	0.948
	Parity		0.12	0.26	0.48	0.631
	Privation index		0.41	0.20	2.00	0.045
	Response is birth weight					
	(Intercept)		3434.07	102.17	33.61	< 0.000
	Natural Direct Effect (NDE)		-137.35	81.96	-1.68	0.094
	Natural Indirect Effect (NIE)		15.39	12.95	1.19	0.235
	Sex					
		Female	REF			
		Male	22.98	50.36	0.46	0.648
	Season					
		Autumn	REF			
		Spring	66.38	70.91	0.94	0.349
		Summer	4.21	60.32	0.07	0.944
		Winter	84.75	75.80	1.12	0.264
	Parity		41.82	31.60	1.32	0.186
	Privation index		-19.10	21.29	-0.90	0.370

Exposure: NDVI within 300 meters

Mediator			Estimate	St. Error	z-value	p-value
	Response is prematurity					
NO_2	(Intercept)		-4.28	3.24	-1.32	0.186
	Natural Direct Effect		-0.34	0.38	-0.88	0.378
	Natural Indirect Effect		0.19	0.14	1.34	0.180
	Sex					
		Female	REF			
		Male	0.16	1.57	0.10	0.918
	Season					
		Autumn	REF			
		Spring	0.39	3.76	0.10	0.917
		Summer	-0.17	4.04	-0.04	0.966
		Winter	-0.50	8.20	-0.06	0.951
	Parity		0.35	0.31	1.12	0.261
	Privation index		0.19	0.32	0.61	0.543
	Response is SGA					
	(Intercept)		-2.07	0.60	-3.43	0.001
	Natural Direct Effect		0.14	0.18	0.79	0.429
	Natural Indirect Effect		0.00	0.02	-0.07	0.942
	Sex					
		Female	REF			
		Male	0.50	0.37	1.32	0.185
	Season					
		Autumn	REF			
		Spring	-0.44	1.09	-0.41	0.685
		Summer	-0.08	0.44	-0.19	0.852
		Winter	-0.74	3.18	-0.23	0.817
	Parity		-0.60	0.34	-1.77	0.076
	Privation index		0.02	0.16	0.15	0.879
	Response is LGA					
	(Intercept)		-1.95	0.49	-3.99	< 0.001
	Natural Direct Effect (NDE)		-0.05	0.15	-0.30	0.761
	Natural Indirect Effect (NIE)		0.00	0.02	0.27	0.786
	Sex					
		Female	REF			
		Male	-0.28	0.32	-0.89	0.372
	Season					
		Autumn	REF			
		Spring	0.18	0.45	0.41	0.682
		Summer	-0.12	0.39	-0.30	0.767
		Winter	-0.01	0.50	-0.01	0.990
	Parity		0.24	0.19	1.30	0.195
	Privation index		0.06	0.12	0.48	0.631
	Response is LBW					
	(Intercept)		-4.09	1.08	-3.80	< 0.001
	Natural Direct Effect (NDE)		-0.07	0.19	-0.34	0.736
	Natural Indirect Effect (NIE)		0.08	0.09	0.90	0.368
	Sex					
		Female	REF			
		Male	0.08	0.54	0.15	0.879
	Season					
		Autumn	REF			
		Spring	-0.15	2.18	-0.07	0.944
		Summer	-0.24	0.89	-0.27	0.788
		Winter	-0.37	5.73	-0.06	0.949
	Parity		0.12	0.25	0.50	0.620
	Privation index		0.41	0.22	1.87	0.062
	Response is birth weight					
	(Intercept)		3323.52	70.32	47.26	< 0.001
	Natural Direct Effect		-6.15	22.28	-0.28	0.783
	Natural Indirect Effect		0.42	2.60	0.16	0.870
	Sex					
		Female	REF			
		Male	26.69	48.67	0.55	0.584
	Season					
		Autumn	REF			
		Spring	62.31	70.66	0.88	0.378
		Summer	6.22	59.61	0.10	0.917
		Winter	84.25	77.66	1.09	0.278
	Parity		40.84	31.48	1.30	0.195
	Privation index		-18.19	20.57	-0.88	0.377

			Estimate	St. Error	z-value	p-value
Mediator	**Response** is prematurity					
GHQ	(Intercept)		-3.70	8.91	-0.42	0.68
	Natural Direct Effect		-0.71	3.10	-0.23	0.82
	Natural Indirect Effect		0.06	0.23	0.25	0.80
	Sex					
		Female	REF			
		Male	0.09	2.39	0.04	0.97
	Season					
		Autumn	REF			
		Spring	0.10	5.13	0.02	0.98
		Summer	-0.12	3.72	-0.03	0.97
		Winter	-16.15	3.39	-4.76	0.00
	Parity		0.22	1.49	0.15	0.88
	Privation index		0.26	1.43	0.19	0.85
	Response is SGA					
	(Intercept)		-2.17	0.81	-2.68	0.01
	Natural Direct Effect (NDE)		0.46	0.56	0.82	0.41
	Natural Indirect Effect (NIE)		0.00	0.03	-0.05	0.96
	Sex					
		Female	REF			
		Male	0.57	0.43	1.32	0.19
	Season					
		Autumn	REF			
		Spring	-0.53	0.97	-0.54	0.59
		Summer	-0.22	0.46	-0.48	0.63
		Winter	-1.08	5.38	-0.20	0.84
	Parity		-0.80	0.36	-2.22	0.03
	Privation index		-0.01	0.18	-0.06	0.95
	Response is LGA					
	(Intercept)		-1.73	0.65	-2.68	0.01
	Natural Direct Effect (NDE)		-0.64	0.38	-1.69	0.09
	Natural Indirect Effect (NIE)		0.01	0.03	0.29	0.77
	Sex					
		Female	REF			
		Male	-0.06	0.34	-0.18	0.86
	Season					
		Autumn	REF			
		Spring	0.41	0.44	0.93	0.35
		Summer	-0.22	0.48	-0.46	0.65
		Winter	-0.32	2.40	-0.14	0.89
	Parity		0.32	0.22	1.46	0.15
	Privation index		0.02	0.14	0.16	0.87
	Response is LBW					
	(Intercept)		-4.00	2.82	-1.42	0.16
	Natural Direct Effect (NDE)		-0.20	2.48	-0.08	0.94
	Natural Indirect Effect (NIE)		0.04	0.08	0.58	0.56
	Sex					
		Female	REF			
		Male	0.14	0.86	0.17	0.87
	Season					
		Autumn	REF			
		Spring	-0.47	3.69	-0.13	0.90
		Summer	-0.40	1.72	-0.23	0.82
		Winter	-0.87	7.75	-0.11	0.91
	Parity		-0.02	0.26	-0.08	0.94
	Privation index		0.49	0.26	1.86	0.06
	Response is birth weight					
	(Intercept)		3425.96	91.19	37.57	< 0.000
	Natural Direct Effect (NDE)		-107.87	65.39	-1.65	0.10
	Natural Indirect Effect (NIE)		-1.24	4.54	-0.27	0.79
	Sex					
		Female	REF			
		Male	27.48	48.02	0.57	0.57
	Season					
		Autumn	REF			
		Spring	78.10	77.59	1.01	0.31
		Summer	-43.07	62.34	-0.69	0.49
		Winter	50.86	73.63	0.69	0.49
	Parity		56.08	31.49	1.78	0.07
	Privation index		-31.37	20.51	-1.53	0.13

			Estimate	St. Error	z-value	p-value
Mediator	**Response** is prematurity					
GHQ	(Intercept)		-4.23	9.35	-0.45	0.651
	Natural Direct Effect (NDE)		0.02	8.49	0.00	0.998
	Natural Indirect Effect (NIE)		0.11	0.19	0.61	0.542
	Sex					
		Female	REF			
		Male	0.10	2.18	0.04	0.965
	Season					
		Autumn	REF			
		Spring	0.10	4.66	0.02	0.984
		Summer	-0.06	3.89	-0.02	0.987
		Winter	-16.18	2.32	-6.98	0.000
	Parity		0.22	0.72	0.30	0.765
	Privation index		0.24	0.66	0.36	0.716
	Response is SGA					
	(Intercept)		-2.71	5.25	-0.52	0.605
	Natural Direct Effect (NDE)		1.01	5.18	0.19	0.846
	Natural Indirect Effect (NIE)		0.00	0.04	0.04	0.971
	Sex					
		Female	REF			
		Male	0.60	0.41	1.47	0.141
	Season					
		Autumn	REF			
		Spring	-0.54	0.58	-0.93	0.352
		Summer	-0.21	0.44	-0.48	0.632
		Winter	-1.05	5.28	-0.20	0.842
	Parity		-0.85	0.36	-2.35	0.019
	Privation index		-0.02	0.17	-0.10	0.925
	Response is LGA					
	(Intercept)		-2.02	1.65	-1.23	0.219
	Natural Direct Effect (NDE)		-0.20	1.59	-0.13	0.898
	Natural Indirect Effect (NIE)		0.03	0.05	0.55	0.583
	Sex					
		Female	REF			
		Male	-0.05	0.36	-0.14	0.887
	Season					
		Autumn	REF			
		Spring	0.38	0.45	0.84	0.401
		Summer	-0.18	0.45	-0.41	0.682
		Winter	-0.35	2.57	-0.14	0.890
	Parity		0.33	0.24	1.40	0.161
	Privation index		0.02	0.13	0.14	0.886
	Response is LBW					
	(Intercept)		-3.92	6.00	-0.65	0.514
	Natural Direct Effect (NDE)		-0.26	5.80	-0.05	0.964
	Natural Indirect Effect (NIE)		0.04	0.09	0.48	0.629
	Sex					
		Female	REF			
		Male	0.14	0.61	0.23	0.821
	Season					
		Autumn	REF			
		Spring	-0.47	4.02	-0.12	0.907
		Summer	-0.40	2.02	-0.20	0.845
		Winter	-0.88	7.89	-0.11	0.911
	Parity		-0.02	0.27	-0.06	0.950
	Privation index		0.49	0.27	1.82	0.069
	Response is birth weight					
	(Intercept)		3454.17	103.91	33.24	< 0.000
	Natural Direct Effect		-123.87	86.26	-1.44	0.151
	Natural Indirect Effect		-2.44	5.43	-0.45	0.652
	Sex					
		Female	REF			
		Male	27.30	50.86	0.54	0.591
	Season					
		Autumn	REF			
		Spring	78.54	73.26	1.07	0.284
		Summer	-40.56	60.51	-0.67	0.503
		Winter	44.71	75.59	0.59	0.554
	Parity		60.01	32.71	1.83	0.067
	Privation index		-32.08	22.08	-1.45	0.146

			Estimate	St. Error	z-value	p-value
Mediator	**Response** is prematurity					
GHQ	(Intercept)		-4.25	3.29	-1.29	0.197
	Natural Direct Effect (NDE)		-0.50	0.70	-0.71	0.476
	Natural Indirect Effect (NIE)		0.01	0.07	0.20	0.842
	Sex					
		Female	REF			
		Male	0.08	1.69	0.05	0.961
	Season					
		Autumn	REF			
		Spring	0.07	5.10	0.01	0.989
		Summer	-0.10	3.41	-0.03	0.976
		Winter	-16.21	2.38	-6.82	0.000
	Parity		0.23	0.68	0.34	0.738
	Privation index		0.27	0.69	0.39	0.695
	Response is SGA					
	(Intercept)		-1.82	0.60	-3.06	0.002
	Natural Direct Effect (NDE)		0.10	0.19	0.52	0.601
	Natural Indirect Effect (NIE)		0.00	0.01	0.18	0.860
	Sex					
		Female	REF			
		Male	0.56	0.40	1.41	0.159
	Season					
		Autumn	REF			
		Spring	-0.50	1.11	-0.45	0.651
		Summer	-0.26	0.47	-0.57	0.572
		Winter	-1.07	5.05	-0.21	0.831
	Parity		-0.81	0.38	-2.16	0.031
	Privation index		0.00	0.17	0.02	0.986
	Response is LGA					
	(Intercept)		-2.18	0.56	-3.92	< 0.001
	Natural Direct Effect (NDE)		0.02	0.18	0.14	0.891
	Natural Indirect Effect (NIE)		0.00	0.01	-0.22	0.828
	Sex					
		Female	REF			
		Male	-0.05	0.37	-0.13	0.899
	Season					
		Autumn	REF			
		Spring	0.37	0.44	0.86	0.391
		Summer	-0.17	0.46	-0.38	0.704
		Winter	-0.35	2.32	-0.15	0.880
	Parity		0.33	0.23	1.40	0.160
	Privation index		0.02	0.14	0.14	0.892
	Response is LBW					
	(Intercept)		-4.10	1.42	-2.88	0.004
	Natural Direct Effect (NDE)		-0.11	0.25	-0.42	0.672
	Natural Indirect Effect (NIE)		0.00	0.03	-0.14	0.886
	Sex					
		Female	REF			
		Male	0.14	0.83	0.17	0.866
	Season					
		Autumn	REF			
		Spring	-0.48	3.82	-0.13	0.899
		Summer	-0.39	1.42	-0.27	0.784
		Winter	-0.87	7.81	-0.11	0.911
	Parity		-0.01	0.26	-0.04	0.971
	Privation index		0.48	0.25	1.94	0.053
	Response is birth weight					
	(Intercept)		3340.20	71.37	46.80	< 0.001
	Natural Direct Effect		4.26	23.12	0.18	0.854
	Natural Indirect Effect		0.85	2.14	0.40	0.691
	Sex					
		Female	REF			
		Male	31.97	50.53	0.63	0.527
	Season					
		Autumn	REF			
		Spring	72.27	74.01	0.98	0.329
		Summer	-34.70	61.84	-0.56	0.575
		Winter	47.16	76.10	0.62	0.535
	Parity		57.66	33.55	1.72	0.086
	Privation index		-32.13	21.44	-1.50	0.134

Mediator		Estimate	St. Error	*z*-value	*p*-value
	Response is prematurity				
MVPA	(Intercept)	-4.18	4.71	-0.89	0.38
	Natural Direct Effect	-0.32	2.61	-0.12	0.90
	Natural Indirect Effect	0.01	0.17	0.08	0.94
	Sex				
	Female	REF			
	Male	-0.11	1.70	-0.07	0.95
	Season				
	Autumn	REF			
	Spring	0.13	4.59	0.03	0.98
	Summer	0.18	3.76	0.05	0.96
	Winter	-0.47	8.40	-0.06	0.96
	Parity	0.70	0.51	1.39	0.17
	Privation index	0.23	0.71	0.32	0.75
	Response is SGA				
	(Intercept)	-2.08	0.97	-2.15	0.03
	Natural Direct Effect	0.42	0.79	0.54	0.59
	Natural Indirect Effect	0.00	0.04	0.02	0.99
	Sex				
	Female	REF			
	Male	0.69	0.45	1.54	0.12
	Season				
	Autumn	REF			
	Spring	-0.77	2.30	-0.33	0.74
	Summer	-0.33	0.52	-0.64	0.52
	Winter	-0.70	3.40	-0.21	0.84
	Parity	-0.52	0.36	-1.44	0.15
	Privation index	-0.10	0.17	-0.58	0.56
	Response is LGA				
	(Intercept)	-1.84	0.65	-2.84	0.00
	Natural Direct Effect	-0.48	0.37	-1.30	0.19
	Natural Indirect Effect	-0.01	0.04	-0.30	0.76
	Sex				
	Female	REF			
	Male	-0.44	0.37	-1.18	0.24
	Season				
	Autumn	REF			
	Spring	0.19	0.47	0.41	0.68
	Summer	-0.18	0.45	-0.41	0.68
	Winter	-0.18	0.95	-0.18	0.85
	Parity	0.51	0.21	2.38	0.02
	Privation index	0.14	0.14	1.04	0.30
	Response is LBW				
	(Intercept)	-3.90	2.96	-1.32	0.19
	Natural Direct Effect	0.06	2.31	0.03	0.98
	Natural Indirect Effect	-0.02	0.12	-0.13	0.90
	Sex				
	Female	REF			
	Male	0.51	1.17	0.44	0.66
	Season				
	Autumn	REF			
	Spring	-0.40	3.54	-0.11	0.91
	Summer	-0.57	2.32	-0.24	0.81
	Winter	-0.34	5.95	-0.06	0.96
	Parity	0.30	0.40	0.75	0.45
	Privation index	0.29	0.25	1.15	0.25
	Response is birth weight				
	(Intercept)	3417.33	101.04	33.82	< 0.000
	Natural Direct Effect	-110.63	66.90	-1.65	0.10
	Natural Indirect Effect	-2.06	6.23	-0.33	0.74
	Sex				
	Female	REF			
	Male	-12.06	56.39	-0.21	0.83
	Season				
	Autumn	REF			
	Spring	46.86	79.00	0.59	0.55
	Summer	-35.11	67.37	-0.52	0.60
	Winter	50.64	85.45	0.59	0.55
	Parity	44.48	47.88	0.93	0.35
	Privation index	-8.49	23.28	-0.37	0.72

Mediator		Estimate	St. Error	*z*-value	*p*-value
	Response is prematurity				
MVPA	(Intercept)	-4.66	8.99	-0.52	0.604
	Natural Direct Effect	0.27	8.28	0.03	0.974
	Natural Indirect Effect	0.01	0.16	0.04	0.965
	Sex				
	Female	REF			
	Male	-0.10	1.41	-0.07	0.941
	Season				
	Autumn	REF			
	Spring	0.11	4.80	0.02	0.982
	Summer	0.21	3.44	0.06	0.951
	Winter	-0.51	8.18	-0.06	0.950
	Parity	0.70	0.47	1.50	0.133
	Privation index	0.23	0.38	0.62	0.536
	Response is SGA				
	(Intercept)	-2.60	4.92	-0.53	0.597
	Natural Direct Effect	0.95	4.89	0.19	0.846
	Natural Indirect Effect	0.00	0.07	0.01	0.993
	Sex				
	Female	REF			
	Male	0.73	0.46	1.60	0.111
	Season				
	Autumn	REF			
	Spring	-0.78	1.92	-0.41	0.684
	Summer	-0.32	0.50	-0.65	0.518
	Winter	-0.70	3.61	-0.19	0.846
	Parity	-0.57	0.37	-1.53	0.127
	Privation index	-0.11	0.17	-0.64	0.525
	Response is LGA				
	(Intercept)	-1.97	0.91	-2.16	0.031
	Natural Direct Effect	-0.25	0.77	-0.33	0.740
	Natural Indirect Effect	-0.02	0.07	-0.28	0.777
	Sex				
	Female	REF			
	Male	-0.44	0.36	-1.23	0.220
	Season				
	Autumn	REF			
	Spring	0.18	0.45	0.39	0.695
	Summer	-0.16	0.44	-0.36	0.721
	Winter	-0.22	0.80	-0.27	0.789
	Parity	0.53	0.22	2.41	0.016
	Privation index	0.14	0.14	1.03	0.301
	Response is LBW				
	(Intercept)	-3.77	6.14	-0.61	0.540
	Natural Direct Effect	-0.10	6.03	-0.02	0.987
	Natural Indirect Effect	-0.01	0.15	-0.06	0.954
	Sex				
	Female	REF			
	Male	0.51	0.85	0.60	0.551
	Season				
	Autumn	REF			
	Spring	-0.40	3.59	-0.11	0.912
	Summer	-0.58	2.46	-0.24	0.813
	Winter	-0.34	5.64	-0.06	0.952
	Parity	0.30	0.37	0.81	0.415
	Privation index	0.29	0.23	1.23	0.220
	Response is birth weight				
	(Intercept)	3452.80	110.76	31.17	< 0.000
	Natural Direct Effect	-133.90	86.98	-1.54	0.124
	Natural Indirect Effect	-3.97	9.20	-0.43	0.666
	Sex				
	Female	REF			
	Male	-13.88	56.79	-0.24	0.807
	Season				
	Autumn	REF			
	Spring	46.08	80.24	0.57	0.566
	Summer	-32.27	66.44	-0.49	0.627
	Winter	45.56	88.68	0.51	0.607
	Parity	51.05	44.98	1.14	0.256
	Privation index	-8.86	23.68	-0.37	0.708

Mediator		Estimate	St. Error	*z*-value	*p*-value
	Response is prematurity				
MVPA	(Intercept)	-4.43	3.68	-1.20	0.229
	Natural Direct Effect	-0.14	0.49	-0.29	0.775
	Natural Indirect Effect	0.02	0.08	0.28	0.783
	Sex				
	Female	REF			
	Male	-0.11	3.00	-0.04	0.971
	Season				
	Autumn	REF			
	Spring	0.10	4.82	0.02	0.983
	Summer	0.18	3.93	0.05	0.963
	Winter	-0.52	8.23	-0.06	0.950
	Parity	0.71	0.78	0.91	0.364
	Privation index	0.24	0.37	0.65	0.516
	Response is SGA				
	(Intercept)	-1.77	0.62	-2.84	0.004
	Natural Direct Effect	0.12	0.20	0.59	0.556
	Natural Indirect Effect	0.00	0.05	0.00	0.999
	Sex				
	Female	REF			
	Male	0.69	0.45	1.55	0.122
	Season				
	Autumn	REF			
	Spring	-0.75	2.51	-0.30	0.765
	Summer	-0.38	0.51	-0.74	0.459
	Winter	-0.71	3.52	-0.20	0.840
	Parity	-0.53	0.38	-1.40	0.162
	Privation index	-0.10	0.18	-0.53	0.595
	Response is LGA				
	(Intercept)	-2.22	0.57	-3.89	< 0.001
	Natural Direct Effect	-0.03	0.17	-0.21	0.836
	Natural Indirect Effect	-0.01	0.03	-0.39	0.698
	Sex				
	Female	REF			
	Male	-0.43	0.35	-1.22	0.224
	Season				
	Autumn	REF			
	Spring	0.16	0.45	0.35	0.728
	Summer	-0.16	0.43	-0.38	0.708
	Winter	-0.23	0.61	-0.38	0.708
	Parity	0.52	0.22	2.35	0.019
	Privation index	0.15	0.14	1.03	0.305
	Response is LBW				
	(Intercept)	-3.87	1.31	-2.95	0.003
	Natural Direct Effect	-0.12	0.25	-0.47	0.638
	Natural Indirect Effect	0.08	0.06	1.38	0.167
	Sex				
	Female	REF			
	Male	0.51	1.01	0.50	0.616
	Season				
	Autumn	REF			
	Spring	-0.40	3.19	-0.13	0.900
	Summer	-0.56	2.15	-0.26	0.793
	Winter	-0.35	5.87	-0.06	0.953
	Parity	0.30	0.36	0.82	0.415
	Privation index	0.29	0.22	1.31	0.191
	Response is birth weight				
	(Intercept)	3327.32	79.68	41.76	< 0.001
	Natural Direct Effect	-4.75	23.88	-0.20	0.842
	Natural Indirect Effect	-3.46	4.73	-0.73	0.465
	Sex				
	Female	REF			
	Male	-7.10	55.93	-0.13	0.899
	Season				
	Autumn	REF			
	Spring	40.08	79.01	0.51	0.612
	Summer	-25.97	67.83	-0.38	0.702
	Winter	43.78	88.39	0.50	0.620
	Parity	47.12	47.01	1.00	0.316
	Privation index	-7.80	23.74	-0.33	0.742

Supplementary Table 3. Natural effects models for Green/Blue availability in 300m by mediator and outcome for the study subsample (n = 256).

Mediator		Estimate	St. Error	z-value	p-value
Mediator	**Response** is prematurity				
NO_2	(Intercept)	-3.60	13.61	-0.26	0.792
	Natural Direct Effect	-0.28	5.10	-0.05	0.957
	Natural Indirect Effect	-0.07	2.70	-0.03	0.978
	Sex				
	Female	REF			
	Male	-0.28	10.15	-0.03	0.978
	Season				
	Autumn	REF			
	Spring	0.45	6.68	0.07	0.946
	Summer	-0.47	8.04	-0.06	0.953
	Winter	-16.01	5.25	-3.05	0.002
	Parity	0.66	4.31	0.15	0.878
	Privation index	0.08	2.99	0.03	0.980
	Response is SGA				
	(Intercept)	-1.06	2.67	-0.40	0.693
	Natural Direct Effect	0.12	1.48	0.08	0.936
	Natural Indirect Effect	-0.03	0.11	-0.31	0.761
	Sex				
	Female	REF			
	Male	0.62	1.14	0.54	0.587
	Season				
	Autumn	REF			
	Spring	-0.24	1.67	-0.14	0.887
	Summer	-0.54	1.62	-0.33	0.739
	Winter	-16.45	0.73	-22.41	< 0.001
	Parity	-1.03	1.50	-0.69	0.491
	Privation index	-0.57	1.72	-0.33	0.741
	Response is LGA				
	(Intercept)	-1.38	0.62	-2.22	0.027
	Natural Direct Effect	-0.20	0.45	-0.45	0.654
	Natural Indirect Effect	-0.02	0.07	-0.28	0.781
	Sex				
	Female	REF			
	Male	-0.47	0.38	-1.24	0.214
	Season				
	Autumn	REF			
	Spring	0.24	0.54	0.44	0.659
	Summer	-0.08	0.48	-0.17	0.866
	Winter	-0.04	2.21	-0.02	0.985
	Parity	0.35	0.26	1.34	0.179
	Privation index	-0.12	0.18	-0.65	0.514
	Response is LBW				
	(Intercept)	-2.29	7.49	-0.31	0.759
	Natural Direct Effect	-1.34	6.81	-0.20	0.844
	Natural Indirect Effect	-0.14	0.45	-0.32	0.752
	Sex				
	Female	REF			
	Male	0.14	6.56	0.02	0.982
	Season				
	Autumn	REF			
	Spring	-0.10	8.58	-0.01	0.991
	Summer	-0.53	8.20	-0.07	0.948
	Winter	-16.04	4.41	-3.64	< 0.001
	Parity	0.11	3.51	0.03	0.975
	Privation index	-0.20	4.80	-0.04	0.967
	Response is birth weight				
	(Intercept)	3201.57	102.56	31.22	< 0.001
	Natural Direct Effect	51.47	68.73	0.75	0.454
	Natural Indirect Effect	21.81	14.60	1.49	0.135
	Sex				
	Female	REF			
	Male	52.89	62.24	0.85	0.396
	Season				
	Autumn	REF			
	Spring	61.32	88.77	0.69	0.490
	Summer	54.39	77.48	0.70	0.483
	Winter	153.83	91.43	1.68	0.093
	Parity	29.54	48.29	0.61	0.541
	Privation index	16.84	28.06	0.60	0.549

Mediator		Estimate	St. Error	z-value	p-value
Mediator	**Response** is prematurity				
GHQ	(Intercept)	-3.58	31.86	-0.11	0.911
	Natural Direct Effect	-0.49	9.06	-0.05	0.957
	Natural Indirect Effect	0.04	1.77	0.02	0.981
	Sex				
	Female	REF			
	Male	-0.17	11.56	-0.02	0.988
	Season				
	Autumn	REF			
	Spring	0.39	17.07	0.02	0.982
	Summer	-0.51	9.78	-0.05	0.959
	Winter	-16.15	11.36	-1.42	0.155
	Parity	0.73	6.47	0.11	0.910
	Privation index	0.14	5.18	0.03	0.978
	Response is SGA				
	(Intercept)	-1.07	2.25	-0.48	0.634
	Natural Direct Effect	0.12	0.89	0.13	0.894
	Natural Indirect Effect	0.00	0.07	0.02	0.983
	Sex				
	Female	REF			
	Male	0.63	0.99	0.64	0.523
	Season				
	Autumn	REF			
	Spring	-0.34	1.79	-0.19	0.848
	Summer	-0.62	1.47	-0.42	0.674
	Winter	-16.78	0.85	-19.71	< 0.001
	Parity	-0.93	1.61	-0.58	0.561
	Privation index	-0.48	1.37	-0.35	0.725
	Response is LGA				
	(Intercept)	-1.97	0.77	-2.55	0.011
	Natural Direct Effect	-0.01	0.54	-0.02	0.987
	Natural Indirect Effect	0.00	0.06	-0.07	0.943
	Sex				
	Female	REF			
	Male	-0.25	0.47	-0.52	0.605
	Season				
	Autumn	REF			
	Spring	0.46	0.63	0.73	0.468
	Summer	0.04	0.62	0.06	0.954
	Winter	-0.22	5.61	-0.04	0.969
	Parity	0.41	0.34	1.23	0.220
	Privation index	-0.08	0.24	-0.33	0.742
	Response is LBW				
	(Intercept)	-2.31	5.78	-0.40	0.689
	Natural Direct Effect	-1.58	7.06	-0.22	0.823
	Natural Indirect Effect	0.01	1.22	0.01	0.991
	Sex				
	Female	REF			
	Male	0.24	6.26	0.04	0.970
	Season				
	Autumn	REF			
	Spring	-0.16	7.95	-0.02	0.984
	Summer	-0.70	7.86	-0.09	0.929
	Winter	-16.41	4.33	-3.79	0.000
	Parity	0.24	3.24	0.08	0.940
	Privation index	-0.11	4.09	-0.03	0.978
	Response is birth weight				
	(Intercept)	3186.04	109.88	29.00	< 0.001
	Natural Direct Effect	107.19	72.73	1.47	0.141
	Natural Indirect Effect	-3.02	12.05	-0.25	0.802
	Sex				
	Female	REF			
	Male	64.03	65.13	0.98	0.326
	Season				
	Autumn	REF			
	Spring	51.27	101.09	0.51	0.612
	Summer	15.83	79.23	0.20	0.842
	Winter	99.11	102.21	0.97	0.332
	Parity	20.25	52.08	0.39	0.697
	Privation index	12.55	30.57	0.41	0.681

Mediator		Estimate	St. Error	z-value	p-value
Mediator	**Response** is prematurity				
MVPA	(Intercept)	-3.29	16.49	-0.20	0.842
	Natural Direct Effect	-0.72	6.42	-0.11	0.910
	Natural Indirect Effect	-0.01	1.93	-0.01	0.995
	Sex				
	Female	REF			
	Male	-0.30	11.36	-0.03	0.979
	Season				
	Autumn	REF			
	Spring	-0.03	9.32	0.00	0.998
	Summer	-0.44	7.99	-0.05	0.957
	Winter	-16.26	6.51	-2.50	0.013
	Parity	0.84	5.14	0.16	0.871
	Privation index	0.09	4.98	0.02	0.986
	Response is SGA				
	(Intercept)	-1.48	2.80	-0.53	0.597
	Natural Direct Effect	0.39	1.71	0.23	0.817
	Natural Indirect Effect	-0.05	0.13	-0.42	0.672
	Sex				
	Female	REF			
	Male	0.75	1.43	0.52	0.602
	Season				
	Autumn	REF			
	Spring	-0.18	2.49	-0.07	0.941
	Summer	-0.45	1.30	-0.35	0.726
	Winter	-16.78	0.73	-22.94	< 0.001
	Parity	-0.92	1.82	-0.51	0.614
	Privation index	-0.39	1.27	-0.31	0.757
	Response is LGA				
	(Intercept)	-1.21	0.73	-1.66	0.097
	Natural Direct Effect	-0.35	0.50	-0.70	0.482
	Natural Indirect Effect	0.06	0.10	0.62	0.537
	Sex				
	Female	REF			
	Male	-0.68	0.50	-1.37	0.169
	Season				
	Autumn	REF			
	Spring	0.03	0.60	0.05	0.963
	Summer	-0.25	0.57	-0.45	0.656
	Winter	-0.66	5.43	-0.12	0.904
	Parity	0.38	0.35	1.07	0.287
	Privation index	-0.03	0.21	-0.12	0.902
	Response is LBW				
	(Intercept)	-2.11	6.62	-0.32	0.749
	Natural Direct Effect	-1.45	6.52	-0.22	0.824
	Natural Indirect Effect	-0.10	0.83	-0.12	0.907
	Sex				
	Female	REF			
	Male	0.23	5.28	0.04	0.965
	Season				
	Autumn	REF			
	Spring	0.03	7.80	0.00	0.996
	Summer	-0.58	7.22	-0.08	0.936
	Winter	-16.15	4.43	-3.65	0.000
	Parity	0.27	2.79	0.10	0.922
	Privation index	-0.23	3.69	-0.06	0.949
	Response is birth weight				
	(Intercept)	3255.77	122.70	26.53	< 0.001
	Natural Direct Effect	80.41	81.38	0.99	0.323
	Natural Indirect Effect	9.62	13.91	0.69	0.489
	Sex				
	Female	REF			
	Male	-3.45	74.94	-0.05	0.963
	Season				
	Autumn	REF			
	Spring	9.24	109.37	0.08	0.933
	Summer	4.91	87.10	0.06	0.955
	Winter	82.61	100.86	0.82	0.413
	Parity	13.61	61.93	0.22	0.826
	Privation index	13.24	34.21	0.39	0.699

Supplementary Table 4. Direct and indirect natural effect coefficients and SE by exposure, mediator and outcome for the study subsample (n = 256).

Exposure											
Availability of walkable blue space within 300 m						Availability of green space > 5000m^2 within 300 m					
		Estimate	St. Error	*z*-value	*p*-value			Estimate	St. Error	*z*-value	*p*-value
Mediator	**Response** is prematurity					**Mediator**	**Response** is prematurity				
NO_2	(Intercept)	-4.15	10.28	-0.40	0.687	NO_2	(Intercept)	-3.02	6.52	-0.46	0.644
	Natural Direct Effect	0.51	4.38	0.12	0.908		Natural Direct Effect	-1.32	8.44	-0.16	0.876
	Natural Indirect Effect	0.06	1.08	0.06	0.954		Natural Indirect Effect	-0.42	0.86	-0.49	0.622
	Sex						Sex				
	Female	REF					Female	REF			
	Male	-0.27	8.25	-0.03	0.974		Male	-0.34	5.15	-0.07	0.947
	Season						Season				
	Autumn	REF					Autumn	REF			
	Spring	0.58	6.10	0.09	0.925		Spring	0.51	6.45	0.08	0.937
	Summer	-0.45	7.62	-0.06	0.953		Summer	-0.59	6.73	-0.09	0.930
	Winter	-16.00	4.27	-3.74	< 0.001		Winter	-15.85	4.19	-3.78	0.000
	Parity	0.62	4.01	0.16	0.876		Parity	0.61	2.13	0.29	0.776
	Privation index	0.16	2.48	0.06	0.949		Privation index	-0.04	2.62	-0.02	0.987
	Response is SGA						**Response** is SGA				
	(Intercept)	-1.05	1.84	-0.57	0.568		(Intercept)	-0.91	2.00	-0.45	0.650
	Natural Direct Effect	0.30	1.21	0.25	0.804		Natural Direct Effect	-0.08	0.98	-0.08	0.935
	Natural Indirect Effect	-0.01	0.08	-0.17	0.862		Natural Indirect Effect	-0.05	0.15	-0.31	0.760
	Sex						Sex				
	Female	REF					Female	REF			
	Male	0.60	1.13	0.53	0.596		Male	0.63	1.00	0.63	0.530
	Season						Season				
	Autumn	REF					Autumn	REF			
	Spring	-0.19	1.59	-0.12	0.907		Spring	-0.21	1.68	-0.13	0.899
	Summer	-0.55	1.55	-0.36	0.722		Summer	-0.57	1.13	-0.50	0.615
	Winter	-16.43	0.73	-22.65	< 0.001		Winter	-16.43	0.68	-24.14	< 0.001
	Parity	-1.03	1.38	-0.74	0.457		Parity	-1.02	1.49	-0.68	0.496
	Privation index	-0.59	1.27	-0.47	0.640		Privation index	-0.60	1.46	-0.41	0.681
	Response is LGA						**Response** is LGA				
	(Intercept)	-1.59	0.56	-2.82	0.005		(Intercept)	-1.32	0.56	-2.36	0.018
	Natural Direct Effect	0.03	0.47	0.07	0.945		Natural Direct Effect	-0.37	0.47	-0.79	0.429
	Natural Indirect Effect	-0.02	0.05	-0.30	0.764		Natural Indirect Effect	-0.02	0.10	-0.17	0.869
	Sex						Sex				
	Female	REF					Female	REF			
	Male	-0.47	0.39	-1.19	0.234		Male	-0.48	0.40	-1.20	0.231
	Season						Season				
	Autumn	REF					Autumn	REF			
	Spring	0.26	0.57	0.46	0.649		Spring	0.28	0.55	0.50	0.615
	Summer	-0.06	0.49	-0.12	0.905		Summer	-0.09	0.48	-0.19	0.851
	Winter	-0.05	2.22	-0.02	0.983		Winter	-0.03	2.14	-0.01	0.989
	Parity	0.35	0.27	1.29	0.196		Parity	0.35	0.26	1.35	0.178
	Privation index	-0.08	0.18	-0.44	0.660		Privation index	-0.14	0.19	-0.72	0.470
	Response is LBW						**Response** is LBW				
	(Intercept)	-3.07	8.72	-0.35	0.724		(Intercept)	-2.51	7.49	-0.34	0.738
	Natural Direct Effect	-0.88	9.72	-0.09	0.928		Natural Direct Effect	-1.32	8.82	-0.15	0.881
	Natural Indirect Effect	0.00	1.44	0.00	0.998		Natural Indirect Effect	-0.30	0.79	-0.38	0.707
	Sex						Sex				
	Female	REF					Female	REF			
	Male	0.17	6.37	0.03	0.978		Male	0.11	5.50	0.02	0.984
	Season						Season				
	Autumn	REF					Autumn	REF			
	Spring	-0.09	8.59	-0.01	0.992		Spring	0.14	8.00	0.02	0.986
	Summer	-0.42	8.10	-0.05	0.958		Summer	-0.56	7.96	-0.07	0.944
	Winter	-16.13	5.07	-3.19	0.001		Winter	-15.95	4.39	-3.63	< 0.001
	Parity	0.04	3.89	0.01	0.992		Parity	0.05	2.91	0.02	0.987
	Privation index	-0.04	3.61	-0.01	0.992		Privation index	-0.21	4.20	-0.05	0.961
	Response is birth weight						**Response** is birth weight				
	(Intercept)	3253.60	84.01	38.73	< 0.001		(Intercept)	3239.56	97.72	33.15	< 0.001
	Natural Direct Effect	26.36	70.48	0.37	0.709		Natural Direct Effect	6.70	78.43	0.09	0.932
	Natural Indirect Effect	15.35	14.36	1.07	0.285		Natural Indirect Effect (NIE	36.91	20.05	1.84	0.066
	Sex						Sex				
	Female	REF					Female	REF			
	Male	51.62	64.66	0.80	0.425		Male	52.13	61.42	0.85	0.396
	Season						Season				
	Autumn	REF					Autumn	REF			
	Spring	63.30	92.81	0.68	0.495		Spring	54.96	96.39	0.57	0.569
	Summer	47.51	75.50	0.63	0.529		Summer	51.69	79.34	0.65	0.515
	Winter	152.43	84.50	1.80	0.071		Winter	153.35	91.26	1.68	0.093
	Parity	32.22	48.18	0.67	0.504		Parity	31.90	47.34	0.67	0.500
	Privation index	6.06	24.23	0.25	0.803		Privation index	10.81	28.30	0.38	0.703

		Estimate	St. Error	z-value	p-value
Mediator	**Response** is prematurity				
GHQ	(Intercept)	-4.14	16.16	-0.26	0.798
	Natural Direct Effect	0.52	8.41	0.06	0.951
	Natural Indirect Effect	0.07	1.11	0.07	0.948
	Sex				
	Female	REF			
	Male	-0.24	10.49	-0.02	0.982
	Season				
	Autumn	REF			
	Spring	0.53	7.01	0.08	0.939
	Summer	-0.44	9.07	-0.05	0.961
	Winter	-16.17	4.62	-3.50	< 0.001
	Parity	0.67	6.19	0.11	0.914
	Privation index	0.22	3.05	0.07	0.943
	Response is SGA				
	(Intercept)	-1.03	1.91	-0.54	0.591
	Natural Direct Effect (NDE)	0.31	1.25	0.25	0.804
	Natural Indirect Effect (NIE	0.01	0.09	0.06	0.953
	Sex				
	Female	REF			
	Male	0.59	1.12	0.53	0.596
	Season				
	Autumn	REF			
	Spring	-0.28	1.23	-0.23	0.818
	Summer	-0.64	1.44	-0.44	0.660
	Winter	-16.79	0.65	-25.82	< 0.001
	Parity	-0.93	1.63	-0.57	0.567
	Privation index	-0.52	1.40	-0.37	0.711
	Response is LGA				
	(Intercept)	-2.05	0.92	-2.24	0.025
	Natural Direct Effect (NDE)	0.22	0.56	0.40	0.688
	Natural Indirect Effect (NIE	-0.01	0.05	-0.12	0.904
	Sex				
	Female	REF			
	Male	-0.24	0.48	-0.51	0.611
	Season				
	Autumn	REF			
	Spring	0.49	1.16	0.42	0.675
	Summer	0.03	0.82	0.04	0.969
	Winter	-0.26	5.69	-0.05	0.964
	Parity	0.41	0.33	1.22	0.222
	Privation index	-0.07	0.23	-0.32	0.752
	Response is LBW				
	(Intercept)	-3.09	12.00	-0.26	0.797
	Natural Direct Effect (NDE)	-0.97	10.15	-0.10	0.924
	Natural Indirect Effect (NIE	0.06	0.98	0.07	0.947
	Sex				
	Female	REF			
	Male	0.26	6.29	0.04	0.967
	Season				
	Autumn	REF			
	Spring	-0.21	7.73	-0.03	0.978
	Summer	-0.53	8.29	-0.06	0.949
	Winter	-16.39	4.76	-3.44	< 0.001
	Parity	0.13	4.74	0.03	0.978
	Privation index	0.04	4.32	0.01	0.993
	Response is birth weight				
	(Intercept)	3254.76	91.13	35.72	< 0.001
	Natural Direct Effect (NDE)	76.02	77.67	0.98	0.328
	Natural Indirect Effect (NIE	-4.84	11.26	-0.43	0.667
	Sex				
	Female	REF			
	Male	60.47	64.05	0.94	0.345
	Season				
	Autumn	REF			
	Spring	55.75	98.45	0.57	0.571
	Summer	3.96	80.70	0.05	0.961
	Winter	92.49	99.72	0.93	0.354
	Parity	25.68	51.88	0.50	0.621
	Privation index	-0.93	28.82	-0.03	0.974

		Estimate	St. Error	z-value	p-value
Mediator	**Response** is prematurity				
GHQ	(Intercept)	-3.19	14.73	-0.22	0.828
	Natural Direct Effect (NDE)	-1.80	12.61	-0.14	0.887
	Natural Indirect Effect (NIE	0.06	1.18	0.05	0.961
	Sex				
	Female	REF			
	Male	-0.26	13.28	-0.02	0.985
	Season				
	Autumn	REF			
	Spring	0.46	17.48	0.03	0.979
	Summer	-0.52	12.13	-0.04	0.966
	Winter	-16.12	8.76	-1.84	0.066
	Parity	0.70	10.45	0.07	0.947
	Privation index	0.09	5.14	0.02	0.987
	Response is SGA				
	(Intercept)	-0.88	1.91	-0.46	0.646
	Natural Direct Effect (NDE)	-0.15	0.74	-0.20	0.844
	Natural Indirect Effect (NIE	0.00	0.09	-0.03	0.973
	Sex				
	Female	REF			
	Male	0.63	1.60	0.39	0.695
	Season				
	Autumn	REF			
	Spring	-0.31	1.95	-0.16	0.873
	Summer	-0.66	1.25	-0.53	0.598
	Winter	-16.76	0.84	-20.05	< 0.001
	Parity	-0.91	1.62	-0.56	0.574
	Privation index	-0.52	0.39	-1.34	0.181
	Response is LGA				
	(Intercept)	-1.82	0.68	-2.66	0.008
	Natural Direct Effect (NDE)	-0.22	0.49	-0.44	0.660
	Natural Indirect Effect (NIE	0.00	0.05	-0.06	0.954
	Sex				
	Female	REF			
	Male	-0.25	0.46	-0.54	0.590
	Season				
	Autumn	REF			
	Spring	0.45	0.64	0.71	0.479
	Summer	0.01	0.63	0.01	0.991
	Winter	-0.22	5.82	-0.04	0.970
	Parity	0.41	0.34	1.23	0.219
	Privation index	-0.11	0.24	-0.46	0.648
	Response is LBW				
	(Intercept)	-2.56	8.62	-0.30	0.767
	Natural Direct Effect (NDE)	-1.66	8.97	-0.19	0.853
	Natural Indirect Effect (NIE	0.00	0.73	0.01	0.996
	Sex				
	Female	REF			
	Male	0.13	7.25	0.02	0.986
	Season				
	Autumn	REF			
	Spring	0.06	12.30	0.01	0.996
	Summer	-0.59	7.44	-0.08	0.937
	Winter	-16.33	4.28	-3.82	< 0.001
	Parity	0.14	4.16	0.03	0.973
	Privation index	-0.10	4.47	-0.02	0.983
	Response is birth weight				
	(Intercept)	3228.58	105.57	30.58	< 0.001
	Natural Direct Effect	74.20	76.14	0.98	0.330
	Natural Indirect Effect	-2.74	12.18	-0.23	0.822
	Sex				
	Female	REF			
	Male	61.49	66.29	0.93	0.354
	Season				
	Autumn	REF			
	Spring	43.71	101.30	0.43	0.666
	Summer	14.00	83.45	0.17	0.867
	Winter	100.42	101.28	0.99	0.321
	Parity	23.39	55.85	0.42	0.675
	Privation index	8.27	31.08	0.27	0.790

		Estimate	St. Error	z-value	p-value
Mediator	**Response** is prematurity				
MVPA	(Intercept)	-	-	-	-
	Natural Direct Effect	-	-	-	-
	Natural Indirect Effect	-	-	-	-
	Sex				
	Female	REF			
	Male	-	-	-	-
	Season				
	Autumn	REF			
	Spring	-	-	-	-
	Summer	-	-	-	-
	Winter	-	-	-	-
	Parity	-	-	-	-
	Privation index	-	-	-	-
	Response is SGA				
	(Intercept)	-1.29	2.44	-0.53	0.597
	Natural Direct Effect	0.57	1.45	0.40	0.693
	Natural Indirect Effect	-0.10	0.16	-0.59	0.554
	Sex				
	Female	REF			
	Male	0.67	1.65	0.41	0.684
	Season				
	Autumn	REF			
	Spring	-0.12	2.51	-0.05	0.963
	Summer	-0.50	2.05	-0.24	0.807
	Winter	-16.79	1.07	-15.77	< 0.001
	Parity	-0.90	1.74	-0.52	0.604
	Privation index	-0.45	1.51	-0.29	0.769
	Response is LGA				
	(Intercept)	-1.47	0.63	-2.33	0.020
	Natural Direct Effect	-0.15	0.54	-0.28	0.781
	Natural Indirect Effect	0.13	0.17	0.74	0.460
	Sex				
	Female	REF			
	Male	-0.67	0.49	-1.36	0.174
	Season				
	Autumn	REF			
	Spring	0.05	0.61	0.09	0.929
	Summer	-0.24	0.58	-0.42	0.678
	Winter	-0.68	5.59	-0.12	0.904
	Parity	0.37	0.35	1.05	0.293
	Privation index	0.02	0.21	0.08	0.935
	Response is LBW				
	(Intercept)	-3.04	6.38	-0.48	0.634
	Natural Direct Effect	-0.70	8.92	-0.08	0.937
	Natural Indirect Effect	-0.19	0.52	-0.36	0.718
	Sex				
	Female	REF			
	Male	0.35	4.77	0.07	0.941
	Season				
	Autumn	REF			
	Spring	-0.02	7.73	0.00	0.998
	Summer	-0.42	7.57	-0.06	0.955
	Winter	-16.28	3.62	-4.50	< 0.001
	Parity	0.19	3.16	0.06	0.951
	Privation index	-0.02	3.64	-0.01	0.996
	Response is birth weight				
	(Intercept)	3325.73	100.56	33.07	< 0.001
	Natural Direct Effect	17.81	72.68	0.25	0.806
	Natural Indirect Effect	19.37	21.28	0.91	0.363
	Sex				
	Female	REF			
	Male	-10.51	74.20	-0.14	0.887
	Season				
	Autumn	REF			
	Spring	8.34	109.25	0.08	0.939
	Summer	-0.08	88.22	0.00	0.999
	Winter	85.45	103.12	0.83	0.407
	Parity	17.25	62.31	0.28	0.782
	Privation index	0.04	31.00	0.00	0.999

		Estimate	St. Error	z-value	p-value
Mediator	**Response** is prematurity				
MVPA	(Intercept)	-3.01	19.21	-0.16	0.876
	Natural Direct Effect	-1.60	11.64	-0.14	0.890
	Natural Indirect Effect	0.03	3.83	0.01	0.993
	Sex				
	Female	REF			
	Male	-0.41	15.92	-0.03	0.979
	Season				
	Autumn	REF			
	Spring	0.05	15.64	0.00	0.997
	Summer	-0.43	9.69	-0.05	0.964
	Winter	-16.22	9.96	-1.63	0.103
	Parity	0.76	8.83	0.09	0.931
	Privation index	0.03	5.26	0.01	0.996
	Response is SGA				
	(Intercept)	-1.11	2.62	-0.42	0.672
	Natural Direct Effect	-0.09	0.99	-0.10	0.924
	Natural Indirect Effect	0.00	0.10	-0.04	0.967
	Sex				
	Female	REF			
	Male	0.74	1.85	0.40	0.690
	Season				
	Autumn	REF			
	Spring	-0.18	2.57	-0.07	0.945
	Summer	-0.50	2.03	-0.25	0.805
	Winter	-16.75	0.90	-18.55	< 0.001
	Parity	-0.87	1.34	-0.65	0.514
	Privation index	-0.46	1.59	-0.29	0.772
	Response is LGA				
	(Intercept)	-1.24	0.67	-1.84	0.066
	Natural Direct Effect	-0.28	0.50	-0.57	0.568
	Natural Indirect Effect	-0.05	0.09	-0.57	0.572
	Sex				
	Female	REF			
	Male	-0.69	0.49	-1.42	0.157
	Season				
	Autumn	REF			
	Spring	0.06	0.63	0.10	0.925
	Summer	-0.26	0.56	-0.47	0.640
	Winter	-0.67	5.58	-0.12	0.905
	Parity	0.37	0.35	1.05	0.293
	Privation index	-0.03	0.21	-0.14	0.890
	Response is LBW				
	(Intercept)	-2.29	6.91	-0.33	0.740
	Natural Direct Effect	-1.74	8.54	-0.20	0.839
	Natural Indirect Effect	0.03	0.72	0.04	0.967
	Sex				
	Female	REF			
	Male	0.09	5.23	0.02	0.987
	Season				
	Autumn	REF			
	Spring	0.26	7.63	0.03	0.973
	Summer	-0.54	7.31	-0.07	0.941
	Winter	-16.02	3.81	-4.20	0.000
	Parity	0.15	3.33	0.04	0.965
	Privation index	-0.20	3.80	-0.05	0.959
	Response is birth weight				
	(Intercept)	3274.87	110.23	29.71	< 0.001
	Natural Direct Effect	94.77	81.81	1.16	0.247
	Natural Indirect Effect	-8.59	12.92	-0.67	0.506
	Sex				
	Female	REF			
	Male	-3.20	72.21	-0.04	0.965
	Season				
	Autumn	REF			
	Spring	0.31	111.55	0.00	0.998
	Summer	7.64	89.90	0.09	0.932
	Winter	84.73	101.39	0.84	0.403
	Parity	14.60	62.45	0.23	0.815
	Privation index	12.18	34.19	0.36	0.722

Supplementary Table 5. Population-average effects for the natural effects models reported in Table 2, applicable to a typical individual in the population.

		Log(OR) Estimate	Log(OR) St. Error	*z*-value	*p*-value (>|z|)	Log(OR) LB	Log(OR) UB	OR Estimate	OR 95% LB	OR 95% UB
Exposure: availability of green space (within 300 m)	**Response** is prematurity									
Mediator: average nitrogen dioxide during the whole pregnancy	Natural Direct Effect (NDE)	-0.0982	2.3592	-0.042	0.967	-4.8747	4.0704	0.906	0.008	58.578
	Natural Indirect Effect (NIE)	-0.1491	0.1903	-0.784	0.433	-0.4957	0.1940	0.861	0.609	1.214
	Total Effect	-0.2474	2.2418	-0.110	0.912					
	Response is SGA									
	Natural Direct Effect (NDE)	0.6620	0.9120	0.726	0.468	-1.2514	2.3235	1.939	0.286	10.211
	Natural Indirect Effect (NIE)	0.0085	0.0785	0.109	0.913	-0.1295	0.1783	1.009	0.879	1.195
	Total Effect	0.6706	0.9049	0.741	0.459					
	Response is LGA									
	Natural Direct Effect (NDE)	-0.5114	0.3157	-1.620	0.105	-1.1551	0.0826	0.600	0.315	1.086
	Natural Indirect Effect (NIE)	0.0105	0.0444	0.237	0.812	-0.0721	0.1019	1.011	0.930	1.107
	Total Effect	-0.5009	0.3118	-1.606	0.108					
	Response is LBW									
	Natural Direct Effect (NDE)	0.3796	2.3089	0.164	0.869	-4.5094	4.5414	1.462	0.011	93.826
	Natural Indirect Effect (NIE)	-0.0756	0.1396	-0.541	0.588	-0.3578	0.1892	0.927	0.699	1.208
	Total Effect	0.3040	2.2870	0.133	0.894					
Exposure: availability of green space (within 300 m)	**Response** is prematurity									
Mediator: average nitrogen dioxide during the third trimester of pregagncy	Natural Direct Effect (NDE)	-0.2230	2.4968	-0.089	0.929	-5.5348	4.2525	0.8001	0.0039	70.2835
	Natural Indirect Effect (NIE)	-0.0244	0.1302	-0.188	0.851	-0.2843	0.2261	0.9759	0.7525	1.2537
	Total Effect	-0.2474	2.4956	-0.099	0.921					
	Response is SGA									
	Natural Direct Effect (NDE)	0.6562	0.7507	0.874	0.382	-0.8930	2.0496	1.928	0.409	7.765
	Natural Indirect Effect (NIE)	0.0131	0.0640	0.205	0.837	-0.1084	0.1426	1.013	0.897	1.153
	Total Effect	0.6694	0.7444	0.899	0.369					
	Response is LGA									
	Natural Direct Effect (NDE)	-0.517	0.324	-1.595	0.111	-1.1685	0.1031	0.596	0.311	1.109
	Natural Indirect Effect (NIE)	0.018	0.044	0.404	0.686	-0.0656	0.1061	1.018	0.936	1.112
	Total Effect	-0.500	0.321	-1.558	0.119					
	Response is LBW									
	Natural Direct Effect (NDE)	0.2779	2.6732	0.104	0.917	-5.4249	5.0538	1.320	0.004	156.609
	Natural Indirect Effect (NIE)	0.0252	0.0997	0.253	0.800	-0.1893	0.2013	1.026	0.827	1.223
	Total Effect	0.3031	2.6684	0.114	0.910					
Exposure: availability of green space (within 300 m)	**Response** is prematurity									
Mediator: GHQ	Natural Direct Effect (NDE)	-0.6989	2.3922	-0.292	0.770	-5.7016	3.6755	0.497	0.003	39.469
	Natural Indirect Effect (NIE)	0.0939	0.1976	0.475	0.635	-0.3249	0.4498	1.098	0.723	1.568
	Total Effect	-0.6051	2.4018	-0.252	0.801					
	Response is SGA									
	Natural Direct Effect (NDE)	0.4468	0.9305	0.480	0.631	-1.4788	2.1687	1.563	0.228	8.747
	Natural Indirect Effect (NIE)	-0.0289	0.0895	-0.323	0.747	-0.2022	0.1485	0.972	0.817	1.160
	Total Effect	0.4179	0.9252	0.452	0.651					
	Response is LGA									
	Natural Direct Effect (NDE)	-0.6205	0.3669	-1.691	0.091	-1.3691	0.0689	0.538	0.254	1.071
	Natural Indirect Effect (NIE)	0.0086	0.0654	0.132	0.895	-0.1222	0.1343	1.009	0.885	1.144
	Total Effect	-0.6119	0.3637	-1.682	0.093					
	Response is LBW									
	Natural Direct Effect (NDE)	-0.1964	2.4296	-0.081	0.936	-5.3244	4.1995	0.822	0.005	66.653
	Natural Indirect Effect (NIE)	0.1479	0.1634	0.905	0.365	-0.2028	0.4377	1.159	0.816	1.549
	Total Effect	-0.0485	2.4409	-0.020	0.984					
Exposure: availability of green space (within 300 m)	**Response** is prematurity									
Mediator: objective physical activity	Natural Direct Effect (NDE)	-0.3084	2.8968	-0.106	0.915	-6.4606	4.8948	0.735	0.002	133.589
	Natural Indirect Effect (NIE)	-0.0468	0.2245	-0.208	0.835	-0.5087	0.3714	0.954	0.601	1.450
	Total Effect	-0.3551	2.8766	-0.123	0.902					
	Response is SGA									
	Natural Direct Effect (NDE)	0.4107	1.0758	0.382	0.703	-1.8158	2.4012	1.508	0.163	11.037
	Natural Indirect Effect (NIE)	-0.0514	0.0936	-0.549	0.583	-0.2387	0.1282	0.950	0.788	1.137
	Total Effect	0.3593	1.0660	0.337	0.736					
	Response is LGA									
	Natural Direct Effect (NDE)	-0.4574	0.3554	-1.287	0.198	-1.1490	0.2441	0.633	0.317	1.277
	Natural Indirect Effect (NIE)	-0.0466	0.0876	-0.532	0.595	-0.2267	0.1166	0.954	0.797	1.124
	Total Effect	-0.5040	0.3479	-1.449	0.147					
	Response is LBW									
	Natural Direct Effect (NDE)	0.0555	3.0461	0.018	0.985	-6.4671	5.4733	1.057	0.002	238.256
	Natural Indirect Effect (NIE)	0.0070	0.1648	0.042	0.966	-0.3500	0.2959	1.007	0.705	1.344
	Total Effect	0.0625	3.0318	0.021	0.984					

		Log(OR) Estimate	Log(OR) St. Error	*z*-value	*p*-value (>|*z*|)	Log(OR) LB	Log(OR) UB	OR Estimate	OR 95% LB	OR 95% UB
Exposure: availability of green space (within 500 m)	**Response** is prematurity									
Mediator: average nitrogen dioxide during the whole pregnancy	Natural Direct Effect (NDE)	0.952	8.1109	0.117	0.9070	-20.4262	11.3679	2.590	0.000	86497.193
	Natural Indirect Effect (NIE)	-0.562	0.4366	-1.286	0.1980	-1.4016	0.3098	0.570	0.246	1.363
	Total Effect	0.390	7.8804	0.049	0.9610					
	Response is SGA									
	Natural Direct Effect (NDE)	1.102	5.2304	0.211	0.8330	-11.1742	9.3287	3.010	0.000	11256.086
	Natural Indirect Effect (NIE)	-0.045	0.1568	-0.284	0.7760	-0.3094	0.3054	0.956	0.734	1.357
	Total Effect	1.057	5.2227	0.202	0.8400					
	Response is LGA									
	Natural Direct Effect (NDE)	-0.105	0.8945	-0.118	0.9063	-1.9555	1.5508	0.900	0.141	4.715
	Natural Indirect Effect (NIE)	0.014	0.0969	0.146	0.8843	-0.1700	0.2097	1.014	0.844	1.233
	Total Effect	-0.091	0.8891	-0.103	0.9180					
	Response is LBW									
	Natural Direct Effect (NDE)	0.455	5.5047	0.083	0.9340	-12.3775	9.2004	1.577	0.000	9900.720
	Natural Indirect Effect (NIE)	-0.329	0.2502	-1.314	0.1890	-0.8029	0.1777	0.720	0.448	1.194
	Total Effect	0.127	5.4248	0.023	0.9810					
Exposure: availability of green space (within 500 m)	**Response** is prematurity									
Mediator: average nitrogen dioxide during the third trimester of pregagncy	Natural Direct Effect (NDE)	0.594	7.9311	0.075	0.9400	-20.3352	10.7542	1.810	0.000	46826.136
	Natural Indirect Effect (NIE)	-0.173	0.3044	-0.567	0.5710	-0.7153	0.4780	0.842	0.489	1.613
	Total Effect	0.421	7.8599	0.054	0.9570					
	Response is SGA									
	Natural Direct Effect (NDE)	1.091	5.3253	0.205	0.8380	-11.4376	9.4373	2.977	0.000	12548.015
	Natural Indirect Effect (NIE)	-0.038	0.1159	-0.328	0.7430	-0.2559	0.1986	0.963	0.774	1.220
	Total Effect	1.053	5.3233	0.198	0.8430					
	Response is LGA									
	Natural Direct Effect (NDE)	-0.117	0.8905	-0.131	0.8960	-1.9327	1.5578	0.890	0.145	4.748
	Natural Indirect Effect (NIE)	0.029	0.0960	0.301	0.7640	-0.1591	0.2170	1.029	0.853	1.242
	Total Effect	-0.088	0.8886	-0.099	0.9210					
	Response is LBW									
	Natural Direct Effect (NDE)	0.186	5.7128	0.033	0.9740	-13.2605	9.1333	1.205	0.000	9258.098
	Natural Indirect Effect (NIE)	-0.048	0.1204	-0.398	0.6910	-0.2852	0.1867	0.953	0.752	1.205
	Total Effect	0.138	5.6982	0.024	0.9810					
Exposure: availability of green space (within 500 m)	**Response** is prematurity									
Mediator: GHQ	Natural Direct Effect (NDE)	0.021	8.4238	0.002	0.9980	-22.5573	10.4635	1.021	0.000	35013.088
	Natural Indirect Effect (NIE)	0.222	0.2691	0.825	0.4090	-0.3721	0.6826	1.249	0.689	1.979
	Total Effect	0.243	8.4117	0.029	0.9770					
	Response is SGA									
	Natural Direct Effect (NDE)	0.975	5.4150	0.180	0.8570	-11.7568	9.4695	2.650	0.000	12958.116
	Natural Indirect Effect (NIE)	-0.098	0.1281	-0.769	0.4420	-0.3709	0.1311	0.906	0.690	1.140
	Total Effect	0.876	5.4184	0.162	0.8720					
	Response is LGA									
	Natural Direct Effect (NDE)	-0.199	1.5555	-0.128	0.8980	-3.4559	2.6416	0.820	0.032	14.036
	Natural Indirect Effect (NIE)	0.122	0.1151	1.061	0.2890	-0.1177	0.3333	1.130	0.889	1.396
	Total Effect	-0.077	1.5682	-0.049	0.9610					
	Response is LBW									
	Natural Direct Effect (NDE)	-0.256	6.0053	-0.043	0.9660	-14.3930	9.1473	0.774	0.000	9388.952
	Natural Indirect Effect (NIE)	0.144	0.1889	0.760	0.4470	-0.2516	0.4887	1.154	0.778	1.630
	Total Effect	-0.113	5.9678	-0.019	0.9850					
Exposure: availability of green space (within 500 m)	**Response** is prematurity									
Mediator: objective physical activity	Natural Direct Effect (NDE)	0.265	8.0237	0.033	0.9740	-20.7212	10.7311	1.304	0.000	45758.490
	Natural Indirect Effect (NIE)	0.109	0.3034	0.359	0.7200	-0.4975	0.6917	1.115	0.608	1.997
	Total Effect	0.374	7.9754	0.047	0.9630					
	Response is SGA									
	Natural Direct Effect (NDE)	0.923	5.2992	0.174	0.8620	-11.4407	9.3317	2.517	0.000	11290.223
	Natural Indirect Effect (NIE)	-0.130	0.1434	-0.904	0.3660	-0.4284	0.1336	0.878	0.652	1.143
	Total Effect	0.794	5.3059	0.150	0.8810					
	Response is LGA									
	Natural Direct Effect (NDE)	-0.244	1.3021	-0.187	0.8520	-2.9320	2.1723	0.784	0.053	8.778
	Natural Indirect Effect (NIE)	0.053	0.1241	0.423	0.6720	-0.2012	0.2852	1.054	0.818	1.330
	Total Effect	-0.191	1.2964	-0.147	0.8830					
	Response is LBW									
	Natural Direct Effect (NDE)	-0.096	5.6778	-0.017	0.9870	-13.2898	8.9669	0.909	0.000	7839.358
	Natural Indirect Effect (NIE)	0.048	0.2147	0.225	0.8220	-0.3965	0.4453	1.050	0.673	1.561
	Total Effect	-0.047	5.6664	-0.008	0.9930					

		Log(OR) Estimate	Log(OR) St. Error	z-value	p-value (>|z|)	Log(OR) LB	Log(OR) UB	OR Estimate	OR 95% LB	OR 95% UB
Exposure: Neighboorhood greenness (NDVI) within 300 meters	**Response** is prematurity									
Mediator: average nitrogen dioxide during the whole pregnancy	Natural Direct Effect (NDE)	-0.3251	0.3274	-0.993	0.321	-0.9358	0.3476	0.7225	0.3854	1.4706
	Natural Indirect Effect (NIE)	0.2803	0.1905	1.471	0.141	-0.0838	0.6630	1.3235	0.8892	1.9432
	Total Effect	-0.0448	0.3454	-0.130	0.897					
	Response is SGA									
	Natural Direct Effect (NDE)	0.1347	0.1570	0.858	0.391	-0.1681	0.4472	1.0122	0.8452	1.5640
	Natural Indirect Effect (NIE)	0.0122	0.1079	0.113	0.910	-0.2070	0.2158	1.1581	0.8130	1.2408
	Total Effect	0.1468	0.1835	0.800	0.424					
	Response is LGA									
	Natural Direct Effect (NDE)	-0.0423	0.1434	-0.295	0.768	-0.3091	0.2528	0.9586	0.7341	1.2877
	Natural Indirect Effect (NIE)	-0.0129	0.0607	-0.212	0.832	-0.1341	0.1039	0.9872	0.8745	1.1094
	Total Effect	-0.0552	0.1521	-0.363	0.717					
	Response is LBW									
	Natural Direct Effect (NDE)	-0.0645	0.1946	-0.331	0.740	-0.4263	0.3365	0.9376	0.6529	1.4000
	Natural Indirect Effect (NIE)	0.1447	0.1476	0.980	0.327	-0.1515	0.4270	1.1557	0.8594	1.5327
	Total Effect	0.0803	0.1933	0.415	0.678					
Exposure: Neighboorhood greenness (NDVI) within 300 meters	**Response** is prematurity									
Mediator: average nitrogen dioxide during the third trimester of pregagncy	Natural Direct Effect (NDE)	-0.2454	0.4295	-0.571	0.568	-1.0458	0.6377	0.7824	0.3514	1.8922
	Natural Indirect Effect (NIE)	0.0737	0.1638	0.450	0.653	-0.2572	0.3850	1.0765	0.7732	1.4696
	Total Effect	-0.1717	0.4222	-0.407	0.684					
	Response is SGA									
	Natural Direct Effect (NDE)	0.1330	0.1682	0.791	0.429	-0.1850	0.4743	1.1422	0.8311	1.6069
	Natural Indirect Effect (NIE)	0.0104	0.1066	0.098	0.922	-0.1936	0.2244	1.0105	0.8240	1.2515
	Total Effect	0.1434	0.1875	0.765	0.444					
	Response is LGA									
	Natural Direct Effect (NDE)	-0.0375	0.1529	-0.245	0.806	-0.3336	0.2658	0.9632	0.7163	1.3044
	Natural Indirect Effect (NIE)	-0.0193	0.0596	-0.323	0.747	-0.1349	0.0987	0.9809	0.8738	1.1038
	Total Effect	-0.0568	0.1611	-0.352	0.724					
	Response is LBW									
	Natural Direct Effect (NDE)	0.0006	0.1966	0.003	0.998	-0.3745	0.3964	1.0006	0.6877	1.4864
	Natural Indirect Effect (NIE)	-0.0156	0.0896	-0.174	0.862	-0.1871	0.1640	0.9845	0.8294	1.1782
	Total Effect	-0.0150	0.1960	-0.076	0.939					
Exposure: Neighboorhood greenness (NDVI) within 300 meters	**Response** is prematurity									
Mediator: GHQ	Natural Direct Effect (NDE)	-0.5014	0.6060	-0.827	0.408	-1.5803	0.7952	0.6057	0.2059	2.2149
	Natural Indirect Effect (NIE)	-0.0908	0.1430	-0.635	0.526	-0.3555	0.2050	0.9132	0.7008	1.2275
	Total Effect	-0.5922	0.6079	-0.974	0.330					
	Response is SGA									
	Natural Direct Effect (NDE)	0.0960	0.1780	0.540	0.589	-0.2549	0.4426	1.1008	0.7750	1.5568
	Natural Indirect Effect (NIE)	0.0217	0.1107	0.196	0.845	-0.1688	0.2651	1.0219	0.8447	1.3035
	Total Effect	0.1177	0.2077	0.567	0.571					
	Response is LGA									
	Natural Direct Effect (NDE)	0.0229	0.1645	0.139	0.889	-0.2951	0.3497	1.0231	0.7445	1.4187
	Natural Indirect Effect (NIE)	-0.0011	0.0711	-0.015	0.988	-0.1365	0.1422	0.9989	0.8724	1.1529
	Total Effect	0.0218	0.1645	0.132	0.895					
	Response is LBW									
	Natural Direct Effect (NDE)	-0.1041	0.2548	-0.408	0.683	-0.5962	0.4026	0.9012	0.5509	1.4956
	Natural Indirect Effect (NIE)	-0.0887	0.1100	-0.806	0.420	-0.3015	0.1295	0.9151	0.7397	1.1383
	Total Effect	-0.1928	0.2575	-0.748	0.454					
Exposure: Neighboorhood greenness (NDVI) within 300 meters	**Response** is prematurity									
Mediator: objective physical activity	Natural Direct Effect (NDE)	-0.1411	0.4443	-0.318	0.751	-0.9622	0.7796	0.8684	0.3821	2.1806
	Natural Indirect Effect (NIE)	-0.0378	0.1483	-0.255	0.799	-0.3143	0.2671	0.9629	0.7303	1.3062
	Total Effect	-0.1789	0.4459	-0.401	0.688					
	Response is SGA									
	Natural Direct Effect (NDE)	0.1171	0.1862	0.629	0.529	-0.2500	0.4798	1.1242	0.7788	1.6157
	Natural Indirect Effect (NIE)	0.0360	0.1403	0.256	0.798	-0.2106	0.3395	1.0366	0.8101	1.4042
	Total Effect	0.1531	0.2238	0.684	0.494					
	Response is LGA									
	Natural Direct Effect (NDE)	-0.0337	0.1552	-0.217	0.828	-0.3252	0.2833	0.9669	0.7224	1.3275
	Natural Indirect Effect (NIE)	0.0085	0.0875	0.097	0.922	-0.1528	0.1901	1.0086	0.8583	1.2094
	Total Effect	-0.0252	0.1663	-0.151	0.880					
	Response is LBW									
	Natural Direct Effect (NDE)	-0.1173	0.2504	-0.469	0.639	-0.5926	0.3888	0.8893	0.5529	1.4752
	Natural Indirect Effect (NIE)	0.0211	0.1100	0.191	0.848	-0.1727	0.2586	1.0213	0.8414	1.2951
	Total Effect	-0.0963	0.2639	-0.365	0.715					

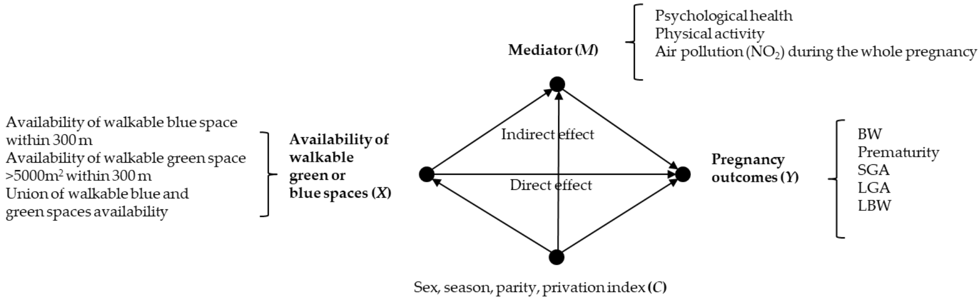
Supplementary Table 6. Population-average effects for the natural effects models reported in Table 3, applicable to a typical individual in the population.

		Log(OR) Estimate	Log(OR) St. Error	*z*-value	*p*-value (>|z|)	Log(OR) LB	Log(OR) UB	OR Estimate	OR 95% LB	OR 95% UB
Exposure: availability of blue space (within 300 m)	**Response** is prematurity									
Mediator: average nitrogen dioxide during the whole pregnancy	Natural Direct Effect (NDE)	0.4862	4.0275	0.121	0.904	-6.7845	9.0029	1.6261	0.0011	8126.6104
	Natural Indirect Effect (NIE)	0.0675	0.5763	0.117	0.907	-1.0018	1.2573	1.0698	0.3672	3.5159
	Total Effect	0.5537	4.0249	0.138	0.891					
	Response is SGA									
	Natural Direct Effect (NDE)	0.2760	1.2694	0.217	0.828	-2.1175	2.8583	1.3178	0.1203	17.4318
	Natural Indirect Effect (NIE)	-0.0514	0.1549	-0.332	0.740	-0.3273	0.2800	0.9499	0.7208	1.3232
	Total Effect	0.2245	1.2788	0.176	0.861					
	Response is LGA									
	Natural Direct Effect (NDE)	0.0315	0.4464	0.071	0.944	-0.8001	0.9500	1.0320	0.4493	2.5856
	Natural Indirect Effect (NIE)	-0.0092	0.0595	-0.155	0.877	-0.1372	0.0961	0.9908	0.8718	1.1008
	Total Effect	0.0223	0.4414	0.051	0.960					
	Response is LBW									
	Natural Direct Effect (NDE)	-0.8731	8.3990	-0.104	0.917	-11.6967	21.2266	0.4177	0.0000	1654260000.0000
	Natural Indirect Effect (NIE)	0.0074	0.6048	0.012	0.990	-1.2355	1.1353	1.0075	0.2907	3.1121
	Total Effect	-0.8657	8.3067	-0.104	0.917					
Exposure: availability of blue space (within 300 m)	**Response** is prematurity									
Mediator: average nitrogen dioxide during the third trimester of pregagncy	Natural Direct Effect (NDE)	0.4671	4.0367	0.116	0.908	-6.8495	8.9742	1.5954	0.0011	7896.5029
	Natural Indirect Effect (NIE)	0.1057	1.1112	0.095	0.924	-1.9792	2.3765	1.1115	0.1382	10.7673
	Total Effect	0.5728	4.1322	0.139	0.890					
	Response is SGA									
	Natural Direct Effect (NDE)	0.2810	1.0013	0.281	0.779	-1.6202	2.3046	1.3245	0.1979	10.0204
	Natural Indirect Effect (NIE)	-0.0542	0.1575	-0.344	0.731	-0.3187	0.2985	0.9473	0.7271	1.3478
	Total Effect	0.2268	1.0063	0.225	0.822					
	Response is LGA									
	Natural Direct Effect (NDE)	0.0193	0.4567	0.042	0.966	-0.8659	0.9241	1.0195	0.4207	2.5197
	Natural Indirect Effect (NIE)	0.0010	0.0685	0.015	0.988	-0.1424	0.1260	1.0010	0.8672	1.1343
	Total Effect	0.0204	0.4422	0.046	0.963					
	Response is LBW									
	Natural Direct Effect (NDE)	-0.8297	8.3630	-0.099	0.921	-11.3385	21.4437	0.4362	0.0000	2055311000.0000
	Natural Indirect Effect (NIE)	-0.0194	0.6572	-0.030	0.976	-1.3205	1.2554	0.9807	0.2670	3.5094
	Total Effect	-0.8491	8.3504	-0.102	0.919					
Exposure: availability of blue space (within 300 m)	**Response** is prematurity									
Mediator: GHQ	Natural Direct Effect (NDE)	0.4977	4.4813	0.111	0.912	-7.5614	10.0050	1.6450	0.0005	22135.8984
	Natural Indirect Effect (NIE)	0.0176	0.6940	0.025	0.980	-1.2575	1.4630	1.0177	0.2844	4.3189
	Total Effect	0.5153	4.4631	0.115	0.908					
	Response is SGA									
	Natural Direct Effect (NDE)	0.2868	0.8335	0.344	0.731	-1.3238	1.9435	1.3322	0.2661	6.9828
	Natural Indirect Effect (NIE)	-0.1057	0.1854	-0.570	0.568	-0.4259	0.3007	0.8997	0.6532	1.3508
	Total Effect	0.1811	0.8318	0.218	0.828					
	Response is LGA									
	Natural Direct Effect (NDE)	0.2188	0.5034	0.435	0.664	-0.7525	1.2209	1.2445	0.4712	3.3902
	Natural Indirect Effect (NIE)	-0.0327	0.0913	-0.358	0.720	-0.2081	0.1498	0.9678	0.8121	1.1616
	Total Effect	0.1861	0.4984	0.373	0.709					
	Response is LBW									
	Natural Direct Effect (NDE)	-0.9608	8.3762	-0.115	0.909	-11.6390	21.1951	0.3826	0.0000	1602941000.0000
	Natural Indirect Effect (NIE)	0.0472	0.3497	0.135	0.893	-0.6340	0.7368	1.0483	0.5305	2.0892
	Total Effect	-0.9136	8.3107	-0.110	0.912					
Exposure: availability of blue space (within 300 m)	**Response** is prematurity									
Mediator: objective physical activity	Natural Direct Effect (NDE)	-	-	-	-	-	-	-	-	-
	Natural Indirect Effect (NIE)	-	-	-	-	-	-	-	-	-
	Total Effect	-	-	-	-					
	Response is SGA									
	Natural Direct Effect (NDE)	0.5250	1.1988	0.438	0.661	-1.7248	2.9744	1.6905	0.1782	19.5782
	Natural Indirect Effect (NIE)	-0.1390	0.2256	-0.616	0.538	-0.5931	0.2912	0.8702	0.5526	1.3381
	Total Effect	0.3860	1.1467	0.337	0.736					
	Response is LGA									
	Natural Direct Effect (NDE)	-0.1437	0.4827	-0.298	0.766	-1.0395	0.8525	0.8661	0.3536	2.3455
	Natural Indirect Effect (NIE)	0.0719	0.1698	0.424	0.672	-0.2742	0.3914	1.0746	0.7602	1.4790
	Total Effect	-0.0718	0.4891	-0.147	0.883					
	Response is LBW									
	Natural Direct Effect (NDE)	-0.6928	8.4397	-0.082	0.935	-11.1574	21.9257	0.5002	0.0000	3328218000.0000
	Natural Indirect Effect (NIE)	-0.1941	0.8198	-0.237	0.813	-1.8016	1.4119	0.8236	0.1650	4.1038
	Total Effect	-0.8869	8.4277	-0.105	0.916					

		Log(OR) Estimate	Log(OR) St. Error	z-value	p-value ($>\lvert z \rvert$)	Log(OR) LB	Log(OR) UB	OR Estimate	OR 95% LB	OR 95% UB
Exposure: availability of green space (within 300 m)	**Response** is prematurity									
Mediator: average nitrogen dioxide during the whole pregnancy	Natural Direct Effect (NDE)	-1.3035	8.1882	-0.159	0.874	-11.8084	20.2888	0.2716	0.0000	647640600.0000
	Natural Indirect Effect (NIE)	-0.4827	1.1592	-0.416	0.677	-2.5546	1.9894	0.6171	0.0777	7.3109
	Total Effect	-1.7863	8.2088	-0.218	0.828					
	Response is SGA									
	Natural Direct Effect (NDE)	-0.0728	0.6511	-0.112	0.911	-1.3037	1.2484	0.9298	0.2715	3.4849
	Natural Indirect Effect (NIE)	-0.0614	0.1825	-0.337	0.736	-0.4264	0.2891	0.9404	0.6529	1.3352
	Total Effect	-0.1342	0.6061	-0.221	0.825					
	Response is LGA									
	Natural Direct Effect (NDE)	-0.3617	0.4239	-0.853	0.393	-1.1445	0.5170	0.6965	0.3184	1.6769
	Natural Indirect Effect (NIE)	-0.0239	0.1200	-0.199	0.842	-0.2548	0.2156	0.9764	0.7751	1.2406
	Total Effect	-0.3856	0.4041	-0.954	0.340					
	Response is LBW									
	Natural Direct Effect (NDE)	-1.3163	8.4118	-0.156	0.876	-11.7188	21.2549	0.2681	0.0000	1701708000.0000
	Natural Indirect Effect (NIE)	-0.3121	0.6792	-0.460	0.646	-1.5846	1.0778	0.7319	0.2050	2.9382
	Total Effect	-1.6284	8.3234	-0.196	0.845					
Exposure: availability of green space (within 300 m)	**Response** is prematurity									
Mediator: average nitrogen dioxide during the third trimester of pregagncy	Natural Direct Effect (NDE)	-1.4934	8.0139	-0.186	0.852	-11.7955	19.6182	0.2246	0.0000	331200600.0000
	Natural Indirect Effect (NIE)	-0.2687	0.9169	-0.293	0.769	-2.0245	1.5698	0.7644	0.1321	4.8055
	Total Effect	-1.7621	8.0357	-0.219	0.826					
	Response is SGA									
	Natural Direct Effect (NDE)	-0.1093	0.8570	-0.127	0.899	-1.7620	1.5973	0.8965	0.1717	4.9398
	Natural Indirect Effect (NIE)	-0.0239	0.1499	-0.159	0.873	-0.3083	0.2794	0.9764	0.7347	1.3223
	Total Effect	-0.1332	0.8097	-0.164	0.869					
	Response is LGA									
	Natural Direct Effect (NDE)	-0.3779	0.4094	-0.923	0.356	-1.1694	0.4353	0.6853	0.3106	1.5454
	Natural Indirect Effect (NIE)	-0.0059	0.0659	-0.089	0.929	-0.1367	0.1217	0.9942	0.8722	1.1295
	Total Effect	-0.3837	0.4110	-0.934	0.351					
	Response is LBW									
	Natural Direct Effect (NDE)	-1.5537	8.2981	-0.187	0.851	-12.2990	20.2289	0.2115	0.0000	609982000.0000
	Natural Indirect Effect (NIE)	-0.0461	1.1862	-0.039	0.969	-2.3047	2.3453	0.9550	0.0998	10.4360
	Total Effect	-1.5997	8.2991	-0.193	0.847					
Exposure: availability of green space (within 300 m)	**Response** is prematurity									
Mediator: GHQ	Natural Direct Effect (NDE)	-1.7452	8.2601	-0.211	0.833	-12.0626	20.3164	0.1746	0.0000	665725500.0000
	Natural Indirect Effect (NIE)	0.0875	1.0295	0.085	0.932	-1.9114	2.1243	1.0914	0.1479	8.3667
	Total Effect	-1.6577	8.1998	-0.202	0.840					
	Response is SGA									
	Natural Direct Effect (NDE)	-0.1352	1.0503	-0.129	0.898	-2.1978	1.9193	0.8736	0.1110	6.8165
	Natural Indirect Effect (NIE)	-0.0839	0.1496	-0.561	0.575	-0.3581	0.2282	0.9196	0.6990	1.2563
	Total Effect	-0.2190	1.0257	-0.214	0.831					
	Response is LGA									
	Natural Direct Effect (NDE)	-0.2126	0.4740	-0.449	0.654	-1.1678	0.6901	0.8085	0.3111	1.9938
	Natural Indirect Effect (NIE)	-0.0150	0.1009	-0.149	0.882	-0.1991	0.1964	0.9851	0.8195	1.2171
	Total Effect	-0.2276	0.4834	-0.471	0.638					
	Response is LBW									
	Natural Direct Effect (NDE)	-1.6530	8.1906	-0.202	0.840	-12.0111	20.0954	0.1915	0.0000	533731700.0000
	Natural Indirect Effect (NIE)	0.0340	0.6597	0.052	0.959	-1.3205	1.2657	1.0346	0.2670	3.5457
	Total Effect	-1.6190	8.1753	-0.198	0.843					
Exposure: availability of green space (within 300 m)	**Response** is prematurity									
Mediator: objective physical activity	Natural Direct Effect (NDE)	-1.5555	8.2012	-0.190	0.850	-11.7983	20.3499	0.2111	0.0000	688419100.0000
	Natural Indirect Effect (NIE)	-0.0598	1.5888	-0.038	0.970	-3.1284	3.0997	0.9420	0.0438	22.1908
	Total Effect	-1.6153	8.2961	-0.195	0.846					
	Response is SGA									
	Natural Direct Effect (NDE)	-0.0873	0.6609	-0.132	0.895	-1.3522	1.2384	0.9164	0.2587	3.4502
	Natural Indirect Effect (NIE)	-0.1099	0.1614	-0.681	0.496	-0.4116	0.2211	0.8960	0.6626	1.2474
	Total Effect	-0.1971	0.6469	-0.305	0.761					
	Response is LGA									
	Natural Direct Effect (NDE)	-0.2739	0.4771	-0.574	0.566	-1.1946	0.6755	0.7604	0.3028	1.9650
	Natural Indirect Effect (NIE)	-0.0085	0.1210	-0.070	0.944	-0.2297	0.2447	0.9915	0.7947	1.2772
	Total Effect	-0.2825	0.4645	-0.608	0.543					
	Response is LBW									
	Natural Direct Effect (NDE)	-1.7201	8.2184	-0.209	0.834	-11.7798	20.4359	0.1791	0.0000	750262100.0000
	Natural Indirect Effect (NIE)	-0.0526	0.8413	-0.063	0.950	-1.7584	1.5392	0.9487	0.1723	4.6611
	Total Effect	-1.7727	8.2979	-0.214	0.831					

		Log(OR) Estimate	Log(OR) St. Error	z-value	p-value (>|z|)	Log(OR) LB	Log(OR) UB	OR Estimate	OR 95% LB	OR 95% UB
Exposure: availability of green/blue space (within 300 m)	**Response** is prematurity									
Mediator: average nitrogen dioxide during the whole pregnancy	Natural Direct Effect (NDE)	-0.2704	3.2734	-0.083	0.934	-7.0312	5.8003	0.7631	0.0009	330.4110
	Natural Indirect Effect (NIE)	-0.1395	0.5764	-0.242	0.809	-1.1187	1.1408	0.8698	0.3267	3.1292
	Total Effect	-0.4099	3.2010	-0.128	0.898					
	Response is SGA									
	Natural Direct Effect (NDE)	0.1097	1.4128	0.078	0.938	-2.8278	2.7101	1.1160	0.0591	15.0307
	Natural Indirect Effect (NIE)	-0.0538	0.1679	-0.321	0.749	-0.3729	0.2852	0.9476	0.6887	1.3301
	Total Effect	0.0559	1.4156	0.039	0.969					
	Response is LGA									
	Natural Direct Effect (NDE)	-0.1971	0.4261	-0.463	0.644	-1.0289	0.6414	0.8211	0.3574	1.8991
	Natural Indirect Effect (NIE)	-0.0405	0.0878	-0.461	0.645	-0.2229	0.1214	0.9603	0.8002	1.1291
	Total Effect	-0.2376	0.4025	-0.590	0.555					
	Response is LBW									
	Natural Direct Effect (NDE)	-1.3316	5.9677	-0.223	0.823	-11.0653	12.3275	0.2641	0.0000	225829.5000
	Natural Indirect Effect (NIE)	-0.1573	0.5154	-0.305	0.760	-1.2492	0.7713	0.8544	0.2867	2.1625
	Total Effect	-1.4889	5.8784	-0.253	0.800					
Exposure: availability of green/blue space (within 300 m)	**Response** is prematurity									
Mediator: average nitrogen dioxide during the third trimester of pregagncy	Natural Direct Effect (NDE)	-0.3574	3.5696	-0.100	0.920	-7.4441	6.5486	0.6995	0.0006	698.2915
	Natural Indirect Effect (NIE)	-0.0359	0.5457	-0.066	0.948	-1.1016	1.0376	0.9647	0.3323	2.8225
	Total Effect	-0.3933	3.5596	-0.110	0.912					
	Response is SGA									
	Natural Direct Effect (NDE)	0.0841	1.0327	0.081	0.935	-2.0178	2.0303	1.0877	0.1330	7.6162
	Natural Indirect Effect (NIE)	-0.0248	0.1562	-0.159	0.874	-0.3015	0.3106	0.9756	0.7397	1.3642
	Total Effect	0.0594	1.0180	0.058	0.954					
	Response is LGA									
	Natural Direct Effect (NDE)	-0.2149	0.4094	-0.525	0.600	-1.0220	0.5827	0.8067	0.3599	1.7909
	Natural Indirect Effect (NIE)	-0.0230	0.0566	-0.406	0.685	-0.1387	0.0832	0.9773	0.8705	1.0868
	Total Effect	-0.2378	0.4040	-0.589	0.556					
	Response is LBW									
	Natural Direct Effect (NDE)	-1.4721	6.1012	-0.241	0.809	-11.1493	12.7668	0.2294	0.0000	350399.4000
	Natural Indirect Effect (NIE)	-0.0174	0.2724	-0.064	0.949	-0.6140	0.4536	0.9827	0.5412	1.5740
	Total Effect	-1.4896	6.0361	-0.247	0.805					
Exposure: availability of green/blue space (within 300 m)	**Response** is prematurity									
Mediator: GHQ	Natural Direct Effect (NDE)	-0.4717	3.9649	-0.119	0.905	-8.3552	7.1870	0.6239	0.0002	1322.1430
	Natural Indirect Effect (NIE)	0.0567	0.4183	0.135	0.892	-0.6732	0.9666	1.0583	0.5101	2.6289
	Total Effect	-0.4150	3.8585	-0.108	0.914					
	Response is SGA									
	Natural Direct Effect (NDE)	0.1104	1.4158	0.078	0.938	-2.8010	2.7487	1.1167	0.0607	15.6224
	Natural Indirect Effect (NIE)	-0.1153	0.1803	-0.640	0.522	-0.4219	0.2849	0.8911	0.6558	1.3296
	Total Effect	-0.0050	1.4242	-0.003	0.997					
	Response is LGA									
	Natural Direct Effect (NDE)	-0.0089	0.4749	-0.019	0.985	-0.9938	0.8679	0.9912	0.3702	2.3818
	Natural Indirect Effect (NIE)	-0.0312	0.0974	-0.320	0.749	-0.2142	0.1674	0.9693	0.8072	1.1823
	Total Effect	-0.0400	0.4764	-0.084	0.933					
	Response is LBW									
	Natural Direct Effect (NDE)	-1.5681	5.9237	-0.265	0.791	-11.1781	12.0424	0.2085	0.0000	169801.6000
	Natural Indirect Effect (NIE)	0.0260	1.1732	0.022	0.982	-2.3568	2.2421	1.0264	0.0947	9.4127
	Total Effect	-1.5421	6.0396	-0.255	0.798					
Exposure: availability of green/blue space (within 300 m)	**Response** is prematurity									
Mediator: objective physical activity	Natural Direct Effect (NDE)	-0.6974	4.9365	-0.141	0.888	-9.7260	9.6246	0.4979	0.0001	15133.0292
	Natural Indirect Effect (NIE)	-0.0736	1.1432	-0.064	0.949	-2.2151	2.2661	0.9290	0.1091	9.6417
	Total Effect	-0.7710	4.8618	-0.159	0.874					
	Response is SGA									
	Natural Direct Effect (NDE)	0.3670	1.3279	0.276	0.782	-2.3362	2.8691	1.4434	0.0967	17.6212
	Natural Indirect Effect (NIE)	-0.1547	0.1790	-0.864	0.387	-0.4923	0.2095	0.8567	0.6112	1.2331
	Total Effect	0.2123	1.3232	0.160	0.873					
	Response is LGA									
	Natural Direct Effect (NDE)	-0.3380	0.4621	-0.731	0.465	-1.2219	0.5897	0.7132	0.2947	1.8034
	Natural Indirect Effect (NIE)	0.0016	0.1311	0.012	0.990	-0.2789	0.2349	1.0016	0.7566	1.2647
	Total Effect	-0.3365	0.4514	-0.745	0.456					
	Response is LBW									
	Natural Direct Effect (NDE)	-1.4336	6.3412	-0.226	0.821	-11.6546	13.2023	0.2384	0.0000	541630.4000
	Natural Indirect Effect (NIE)	-0.1297	0.9023	-0.144	0.886	-2.0640	1.4729	0.8784	0.1269	4.3620
	Total Effect	-1.5633	6.3840	-0.245	0.807					

Supplementary Figure S1.Directed Acyclic Graph representing the hypotheses tested in this research work for only a fraction (San Sebastián/Donostia) of the whole study population. The model is similar to that used for the whole population, except that the exposures (X) now studied are blue space availability within 300 meters, green space availability within 300 meters, and the union (but not the intersection) of the two former exposures (i.e. whether either a blue area, or a green area, or both, is available for the mother within 300 m around her home)



Is Brief Exposure to Green Space in School the Best Option to Improve Attention in Children? artikuluaren material osagarria

Supplementary Material 1

2. Material and methods

2. 6. Description of the experiments

A basic experiment was carried out in each of four Gipuzkoan schools to test for the effect of the exposure to activities in green vs. grey spaces on the school students' performance in multiple-choice computer-based tests (128 questions). Students (random factor <Subject>) were randomly assigned to each of two levels of the fixed factor <Exposure>, that is <grey> and <green> spaces. Five univariate responses (Table 2) were recorded in two occasions on each subject, one before applying the exposure (level <before> of the fixed factor <Time>) and another after applying the exposure (level <after> of the fixed factor <Time>). Student's sex and age were also recorded.

2. 7. Repeated measures: statistical design and model

Each basic experiment is to be understood as a split-unit (or split-plot) statistical design (Casella 2008), where subjects represent the whole units, exposures represent the whole-unit treatments, and time represents the split-unit treatment. The two measures of each response taken on each subject are correlated although, there being just two repeated measures, then we may assume equicorrelation (Casella 2008) and, therefore, Cochran's theorem (Cochran 1934) is satisfied, with the final consequence that *F*-tests are valid. This specific type of split-unit design is known as a repeated-measures design and the corresponding statistical model may be written as follows (Pinheiro & Bates 2000; Casella 2008):

(equation 1) $$Y_{ijk} = \mu + \tau_i + \varepsilon_{ij} + \gamma_k + (\tau\gamma)_{ik} + \delta_{ijk},$$

where Y_{ijk} is a given response to Exposure i (= 1, …, t) of subject (whole unit) j (= 1, …, r) at Time k (= 1, …, g); μ is the overall mean effect; τ_i is the effect of Exposure i (i.e. the whole unit treatment: Subjects in Exposure); ε_{ij} is the effect of Subject j in Exposure i (i.e. the whole unit error), where ε_{ij} is independently and identically distributed as $N(0, \sigma^2_\varepsilon)$; γ_k is the effect of Time k (i.e. the split unit treatment); $(\tau\gamma)_{ik}$ is the interaction between Exposure i and Time k; and δ_{ijk} is the experimental error (i.e. the split unit error: Time x Subjects in Exposure), where δ_{ijk}, which is independent of ε_{ij}, is assumed to be independently and identically distributed as $N(0, \sigma^2_\delta)$. Since Exposure has two levels (green/blue and grey spaces) and since Time has two levels (before and after), $t = 2$ and $g = 2$; since different numbers of subjects were used in each school, r varies in each basic experiment as specified in Table 1.

In a repeated-measures design, treatment (fixed factor <Exposure>, in this case) and time (treated as a fixed factor <Time>) are crossed (Casella 2008), which is a feature that repeated-measures designs share with two-way completely randomised designs. These two designs, however, differ in that randomization in completely randomised designs is not restricted, whereas in split-unit designs randomization is restricted to the whole units (i.e. the subjects). As a consequence, in a repeated-measures design there is a correlation structure that arises from the multiple observations taken on whole units (Pinheiro & Bates 2000), and this is the reason why we need equation 1 to describe the experimental structure. Repeated-measures designs also differ from simple (with just two levels of a given treatment) crossover designs, because in crossover designs each group of subjects receives both treatment levels, albeit in opposite orders (Casella 2008), whereas in repeated-measures designs each group of subjects receives just one treatment level. Thus, the effect of the exposure under a repeated-measures design is measured by the term $(\tau\gamma)_{ik}$ in equation 1, i.e. by the interaction between Exposure i and Time k. Since the goal of each of our basic experiments was to test for the effect of the exposure to activities in green/blue vs. grey spaces on the school students' performance in multiple-choice tests, we focused our analysis on the said term.

2. 8. Linear mixed effects modelling: the analysis of the basic experiments

Univariate responses from experimental settings may be analysed using the ANOVA approach (Casella 2008), but we preferred the Restricted Maximum Likelihood (ReML) approach within the framework of linear mixed effects modelling (Pinheiro & Bates 2000; Bolker & Brooks 2009). This was so because the flexible ReML approach yields unbiased estimates for random terms in mixed models (such as the terms ε_{ij} and δ_{ijk} in equation 1), is resistant to unequal numbers of experimental subjects (as it occurs in most of our experiments: Table 1) and, if needed, allows modelling observed heterogeneity, thereby obtaining correct tests without transformation of the response variables (Pinheiro & Bates 2000; Madsen & Thyregod 2010). We used function lme() of R package nlme (Pinheiro, Bates et al. 2018) in R software v. 4.0.0 (R Core Team 2020).

2.9. Meta-analysis: combining the results of the basic experiments

Once we quantified the effect of the exposure levels in each basic experiment (as measured by the term $(\tau\gamma)_{ik}$ in equation 1), we combined the available evidence from each school using the meta-analysis methodology (Higgins, Thomas, et al., 2019). For this purpose, we used the function metagen() of the R package meta (Balduzzi, Rücker et al., 2019), applying the generic inverse variance method (Borenstein et al., 2010) for pooling the available data of each of the five response variables.

Because we were unready to assume that the effects from the basic experiments came from a homogeneous population (an assumption under the fixed effect model), we fitted both fixed (equation 2) and random (equation 3) effects models (Borenstein et al., 2010):

(equation 2) $$\hat{\theta}_k = \theta + \sigma_k \varepsilon_k,\ \epsilon_k \overset{i.i.d.}{\sim} N(0,1);$$

(equation 3) $$\hat{\theta}_k = \theta + \mu_k + \sigma_k \varepsilon_k,\ \epsilon_k \overset{i.i.d.}{\sim} N(0,1);\ \mu_k \overset{i.i.d.}{\sim} N(0,\tau^2);$$

where ϑ_k and σ_k denote the intervention effect of experiment k and Var(ϑ_k), respectively, and the μ_k parameter allows for modelling a fraction of the observed between-experiment variability as an extra random effect.

In the latter case, between-experiment variance, τ^2, was estimated, as advised by Veroniki et al. (2016), via the restricted maximum-likelihood estimator (Viechtbauer, 2005). Notice that the fixed effects model is the particular case of the random effects model when $\tau^2 = 0$. Prediction intervals for each response variable were calculated according to Higgins et al. (2009) and presented according to Guddat et al. (2012). Finally, we used funnel plots (Sterne & Egger, 2001) and Egger et al.'s test (Egger, Smith, et al. 1997) to examine potential bias in the above meta-analyses.

5. References

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Supplementary Table S1. Summary of the experimental layout, together with the number of subjects employed in each experiment (school). Students (subjects)

School	Level of exposure	Location of exposures	Number of subjects	Age (SD) in days	Proportion of females	Proportion of males
School 1	Grey space	Within school premises	22	2483.5 (126.4)	0.50	0.50
	Green space	Within school premises	20	2481.5 (115.4)	0.50	0.50
School 2	Grey space	Within school premises	15	2492.6 (117.6)	0.53	0.47
	Green space	Within school premises	15	2525.2 (119.7)	0.47	0.53
School 3	Grey space	Outside school premises	28	2491.2 (94.8)	0.61	0.39
	Green space	Outside school premises	32	2503.9 (100.2)	0.44	0.56
School 4	Grey space	Outside school premises	15	2451.9 (94.9)	0.40	0.60
	Green space	Outside school premises	13	2469.2 (112.2)	0.46	0.54

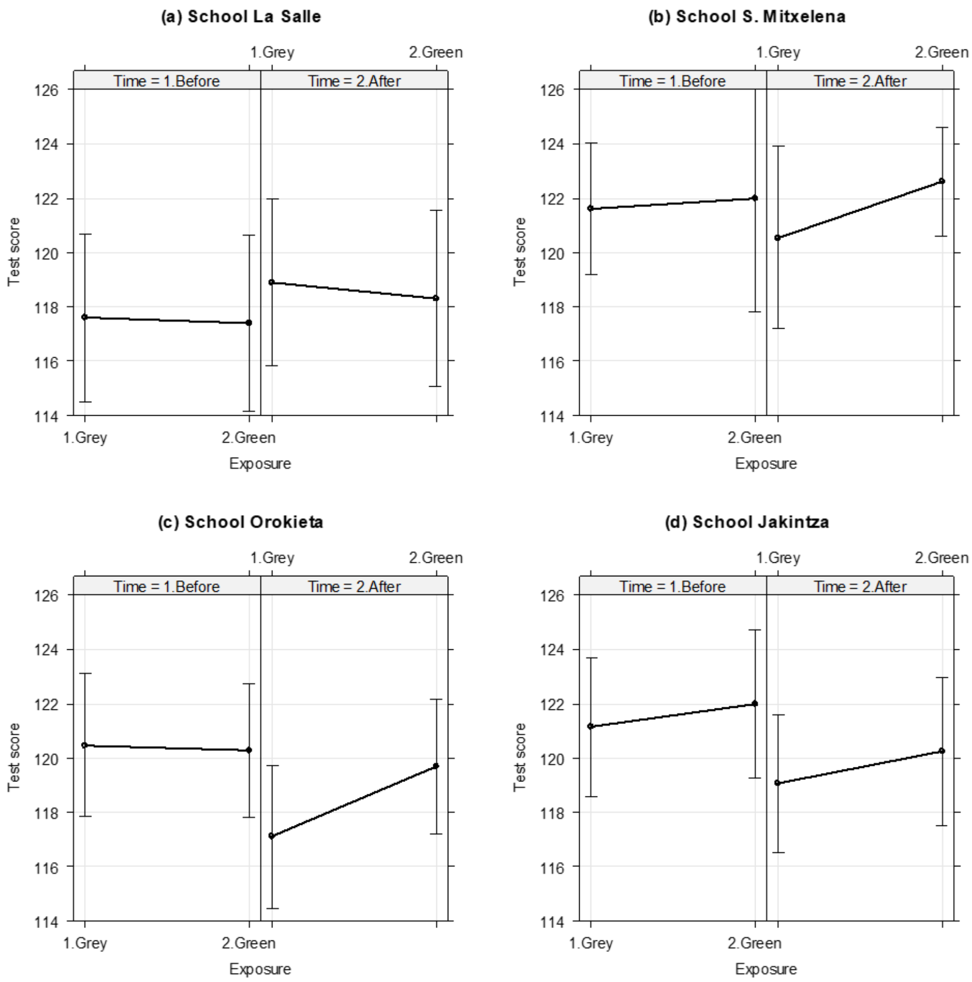
Supplementary Table S2. Kendall's rank correlation tau across schools, together with tests of the null hypothesis that (true) tau is equal to 0.

Variable 1	Variable 2	τ	*p*-value
Test score	Accuracy	0.6031	< 0.001
Test score	Reaction Time	-0.2442	< 0.001
Test score	Impulsivity	0.1063	< 0.001
Test score	Standard error for the reaction time	-0.4042	< 0.001
Accuracy	Reaction Time	0.0683	0.0499
Accuracy	Impulsivity	0.1802	< 0.001
Accuracy	Standard error for the reaction time	-0.1639	< 0.001
Reaction Time	Impulsivity	0.0400	0.2455
Reaction Time	Standard error for the reaction time	0.3795	< 0.001
Impulsivity	Standard error for the reaction time	0.0015	0.9660

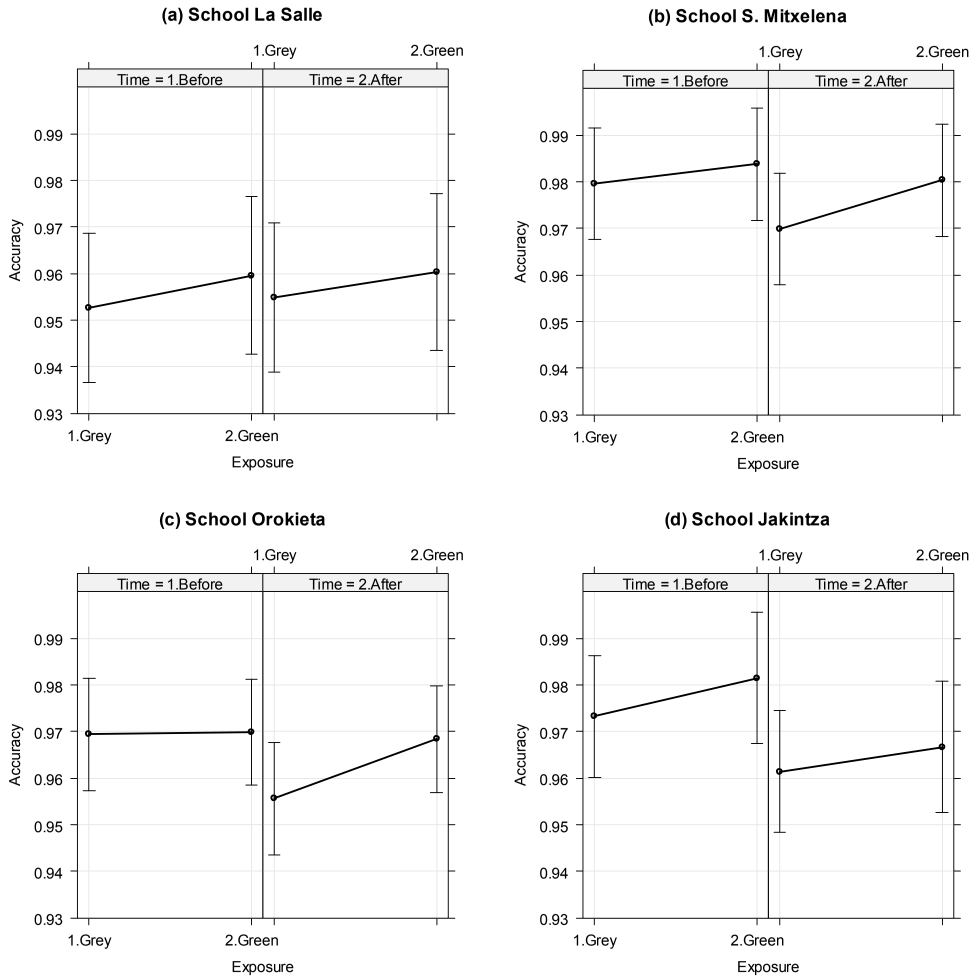
Supplementary Table S3. Egger's test

Meta-analysis	*t*-value	df	*p*-value	Bias	St. Err. bias	Intercept
Test score	-1.03	2	0.412	-2.43	2.37	6.17
Accuracy	0.38	2	0.739	0.81	2.13	-0.01
Reaction time	-1.41	2	0.294	-3.63	2.57	150.08
Impulsivity	-1.71	2	0.229	-3.37	1.97	555.68
Variability in reaction time	1.58	2	0.255	2.56	1.62	-45.65

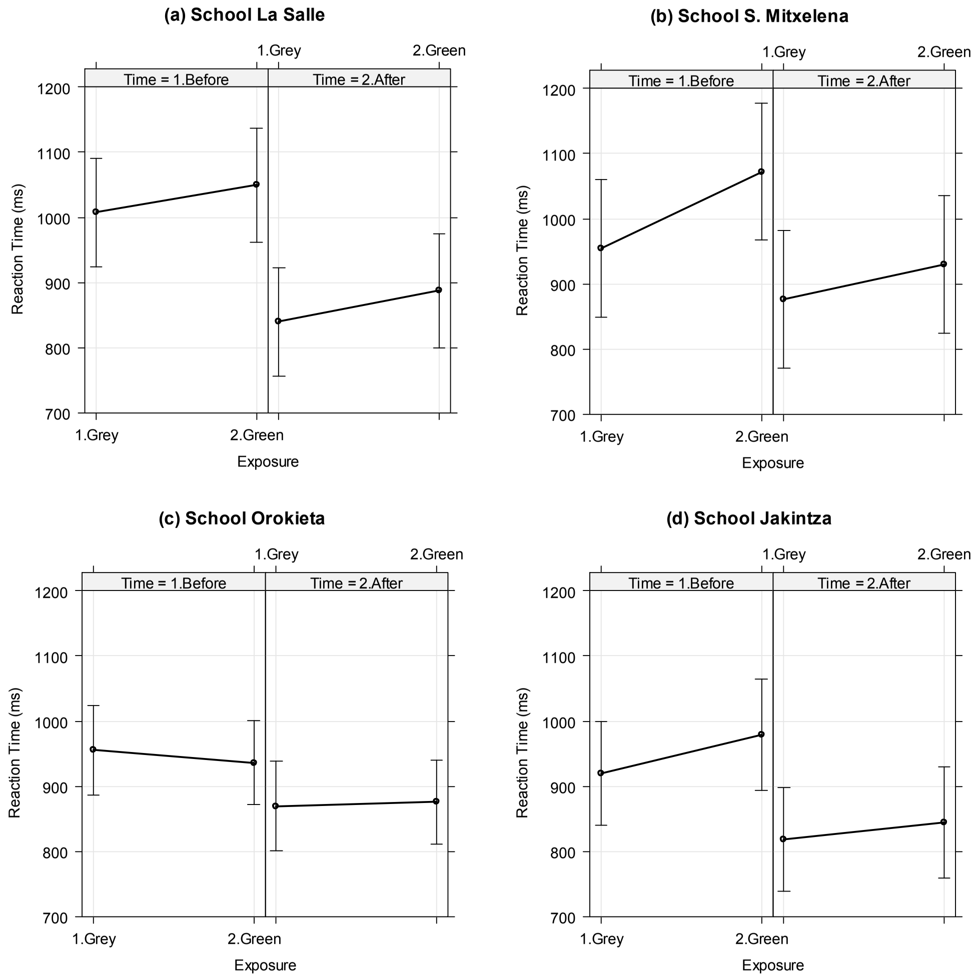
Supplementary Figure S1. Test score before and after experimental exposure to activities in grey and green spaces (fitted relationship).



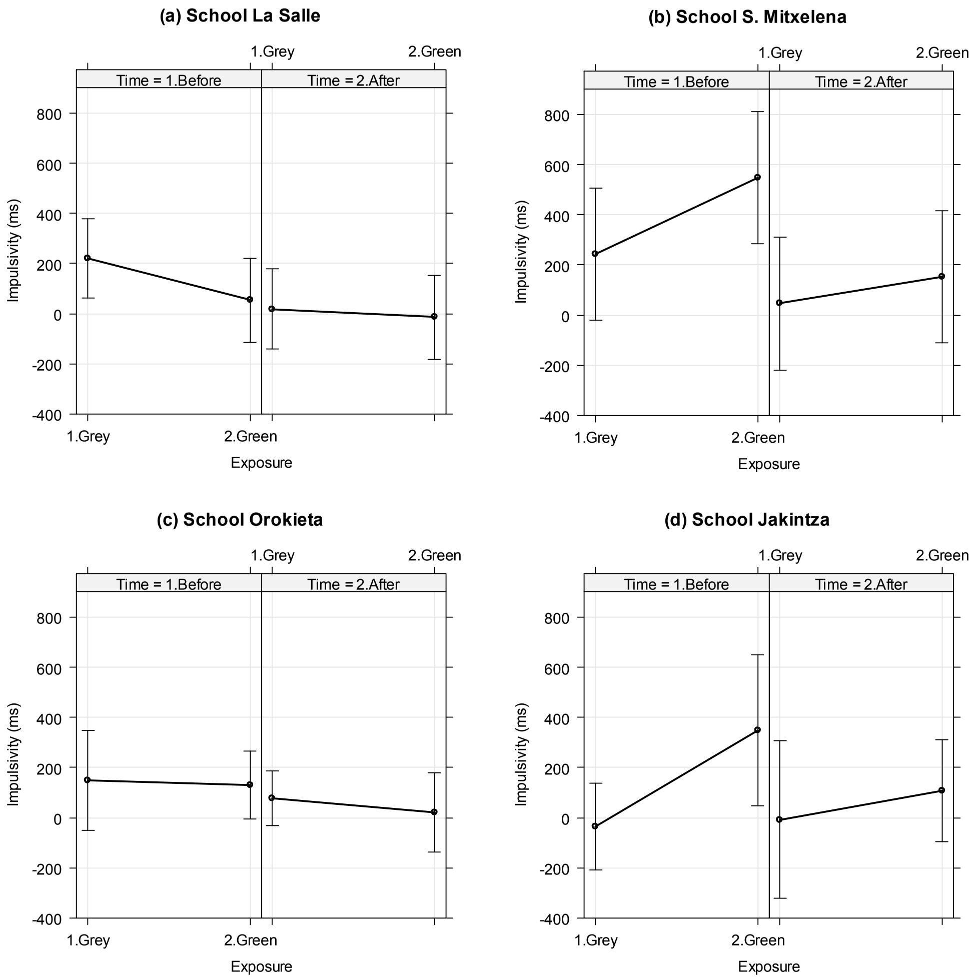
Supplementary Figure S2. Test accuracy before and after experimental exposure to activities in grey and green spaces (fitted relationship).



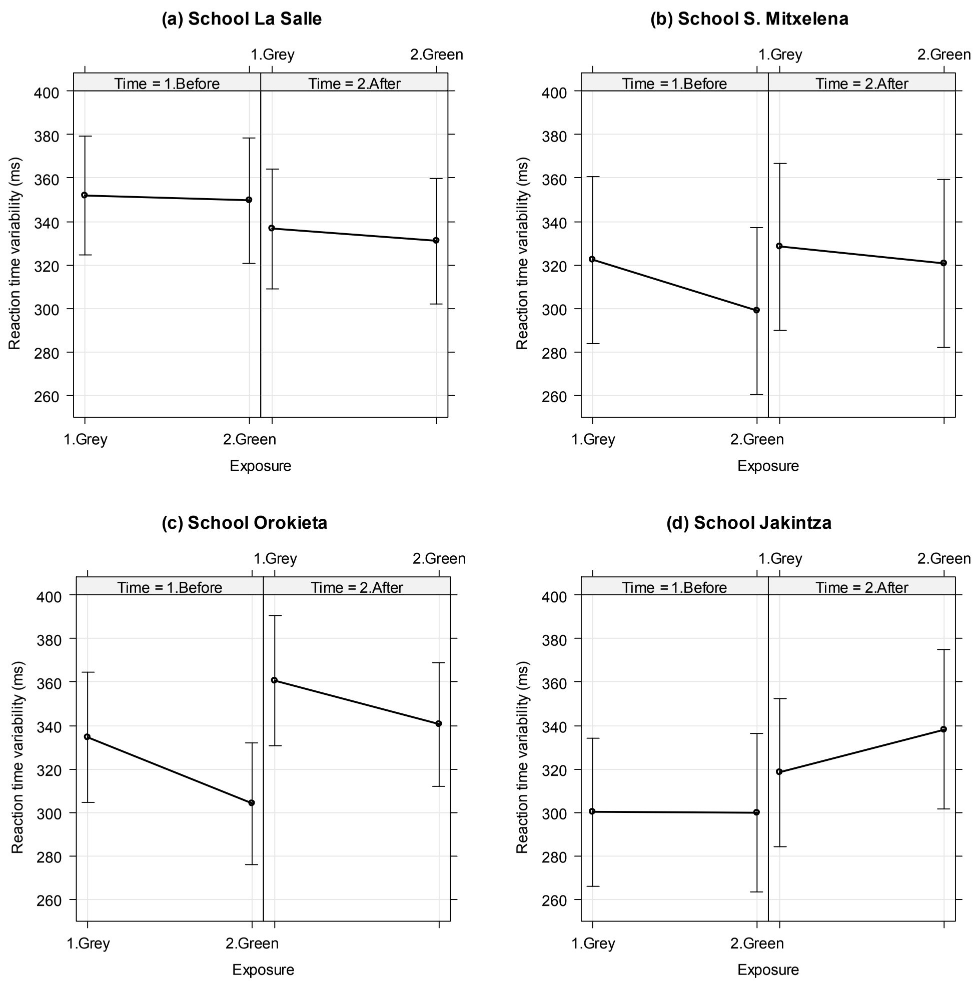
Supplementary Figure S3. Reaction time (ms) before and after experimental exposure to activities in grey and green spaces (fitted relationship).



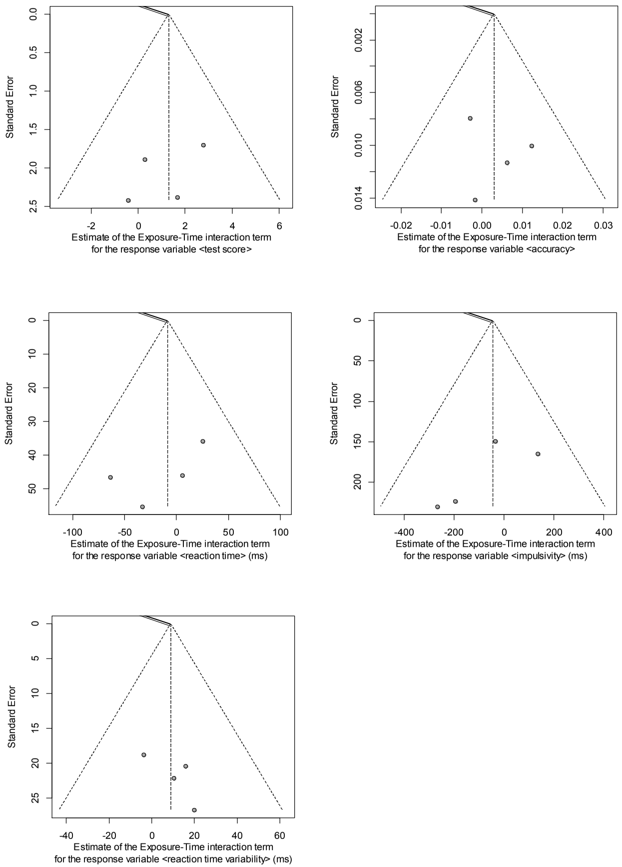
Supplementary Figure S4. Impulsivity (ms) before and after experimental exposure to activities in grey and green spaces (fitted relationship).



Supplementary Figure S5. Reaction time variability (ms) before and after experimental exposure to activities in grey and green spaces (fitted relationship).



Supplementary Figure S6. Funnel plots for the meta-analysis reported in Figs. 1-5



Effects of residential greenness on attention in a longitudinal study at 8 and 11-13 years artikuluaren material osagarria

Table S1. Characteristics of NDVI and VCF maps

Greenness	Cohort	Follow-up	Satellite	Sensor	Date
NDVI					
	Asturias	7-8	Landsat 5	TM[a]	24/06/2011
	Gipuzkoa		Landsat 5	TM[a]	26/06/2010
	Asturias	11-12	Landsat 8	OLI[b]	21/04/2017
	Gipuzkoa		Landsat 8	OLI[b]	07/04/2017
VCF					
	Asturias	7-8	Landsat 7	EMT+[c]	01/01/2015
	Gipuzkoa		Landsat 7	EMT+[c]	01/01/2015
	Asturias	11-12	Landsat 7	ETM+[c]	01/01/2015
	Gipuzkoa		Landsat 7	EMT+[c]	01/01/2015

[a] *Thematic Mapper* [b] *Operation Land Imager* [c] *Enhanced Thematic Mapper Plus*

Figure S1. DAG Model

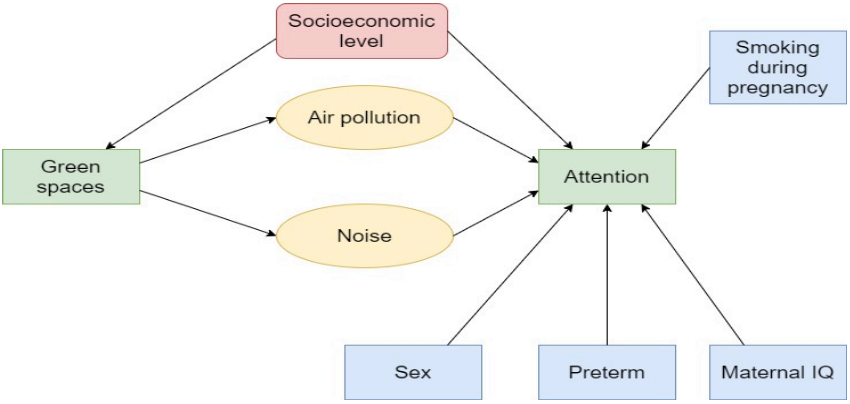


Table S2. Description of characteristics between included and excluded participants.

Characteristics	8-y follow-up Include (n = 751)	Exclude (n = 381)	p-value[a]	10-13-y follow-up Include (n = 598)	Exclude (n = 534)	p-value[a]
Sex (female)	0.489	0.465	0.547	0.507	0.466	0.000
Preterm birth(yes)	0.049	0.038	0.000	0.046	0.045	0.000
Age (mean (min-max))	8.10 (7.7-9.7)	-	-	11.4 (10.3-13.1)	-	-
Maternal IQ	9.76(3.67)	9.03(3.67)	0.000	9.76(3.67)	9.03(3.67)	0.008
Maternal smoking during pregnancy (yes)	0.132	0.162	0.000	0.121	0.167	0.000
Neighbourhood socioeconomic status			0.092			0.000
1 Better	0.309	0.378		0.370	0.280	

2	0.326	0.328		0.362	0.287	
3	0.186	0.147		0.137	0.231	
4	0.137	0.123		0.102	0.161	
5 Lower	0.041	0.024		0.029	0.040	
Parity			0.144			0.134
0	0.590	0.532		0.599	0.539	
1	0.364	0.387		0.350	0.396	
2	0.040	0.070		0.044	0.057	
3	0.005	0.008		0.007	0.006	
4	0.001	0.003		0.002	0.190	
Birth weight (gr.)	3290(545)	3285(580)	0.664	3290(558.75)	3285(553.75)	0.707
Time watching TV 8y(min.)	60(60)	84(30)	0.734	60(75)	60(60)	0.921
Time watching TV 10-13y(min.)	60(30)	60(30)	0.424	60(30)	60(7.5)	0.982
Time sleeping (hrs.)	10.29(0.93)	10.79(0.61)	0.000	10.36(0.68)	10(1.5)	0.000
Time spent in sedentary (hrs.)	90.5(13)	90.5(12.8)	0.975	90.5(12.28)	91(13.48)	0.794
Maternal education			0.000			0.000
Primary or without education	0.118	0.226		0.114	0.202	
Secondary	0.401	0.389		0.395	0.405	
University	0.482	0.362		0.490	0.393	
Social class			0.000			0.000
I- More rich	0.420	0.318		0.443	0.326	
II	0.227	0.192		0.226	0.206	
III-Less rich	0.353	0.467		0.319	0.469	
Type of breastfeeding			0.000			0.000
Maternal breastfeeding	0.273	0.214		0.283	0.220	
Mixed	0.547	0.511		0.563	0.501	
Artificial feeding	0.181	0.275		0.153	0.279	
Nursery(yes)	0.722	0.767	0.203	0.741	0.722	0.388

a p-value for the difference between children included and excluded in each follow-up

Table S3 Description of measures of covariates at age of 8 and 11-13 years.

	8-y follow-up				11-13-y follow-up				
Variables	Total	Asturias	Gipuzkoa	p-value[a]	Total	Asturias	Gipuzkoa	p-value[a]	p-value[b]
Neighbourhood socioeconomic status				0.000				0.000	0.005
1 Better	30.89	3.34	56.12		37.02	2.74	56.88		
2	32.62	25.91	38.78		36.18	30.14	39.68		
3	18.64	34.26	4.34		13.74	31.96	3.17		
4	13.72	27.86	0.77		10.22	27.40	0.26		
5 Lower	4.13	8.64	0.00		2.85	7.76	0.00		
Age at the test moment	8.011 (0.418)	8.266 (0.312)	7.854 (0.192)	0.000	11.031 (1.606)	12.507 (0.372)	10.812 (0.334)	0.000	0.000
Sex				0.386				0.034	0.547
Female	48.87	47.08	50.51		50.67	44.75	54.09		
Male	51.13	52.92	49.49		49.33	55.25	45.91		
Preterm				0.245				0.261	0.910
No	95.15	94.05	96.15		95.44	93.93	96.30		
Yes	4.85	5.95	3.85		4.56	6.07	3.70		
Maternal IQ	9.763 (3.672)	9.763 (2.938)	9.763 (3.672)	0.129	9.763 (3.672)	9.763 (2.938)	9.763 (3.672)	0.129	0.704
Maternal smoking during pregnancy				0.092				0.107	0.607
No	86.84	84.46	88.98		87.95	84.83	89.73		
Yes	13.16	15.54	11.02		12.05	15.17	10.27		

Note: p-values are reported for chi-squared test for categorical variables and Mann-Whitney U test for continuous variables. For continuous variables, median (IQR) and for categorical variables count (percentage) of each category has been reported. p-value[a] for the difference between children in each cohort. p-value[b] for the difference between children with attention availability data at the 8-year follow-up and at 11-13-y follow-up.

Table S4. Coefficients (together with 95%CI) of the regression models estimating the association between several versions of exposure measurements (NDVI, VCF, green disponibility, green distance) and two measurements of attention score (Hit Rt median/Hit Rt se), once that the effect of the covariates have been accounted for among participants who have not changed residence.

	8 years		10-13 years n=598	
	ANT			
	Hit rt median	Hit rt se	Hit rt median	Hit rt se
NDVI - 100m buffers	7.961(-8.808;24.730)	-0.069(-7.169;7.031)	-9.166 (-21.044; 2.712)	-4.408(-11.316;2.500)
300m buffers	-0.840(-17.866;16.187)	-1.309 (-8.510;5.893)	**-11.371(-23.140;0.398)***	**-7.445(-14.277;-0.613)****
500m buffers	-3.237(-20.586;14.111)	-3.253(-10.587;4.082)	-8.811(-20.617;2.996)	-6.747 (-13.596;0.101)*
VCF - 100m buffers	5.301(-11.905;22.508)	0.981(-6.300;8.262)	1.934(-10.623;14.491)	3.807(-3.483;11.096)
300m buffers	-8.066 (-24.646;8.515)	-4.389(-11.399;2.621)	-7.203 (-19.118;4.713)	-4.061(-10.986;2.864)
500m buffers	-11.923(-28.336;4.489)	**-6.612(-13.544;0.320)***	-4.546(-16.227;7.134)	-3.751(-10.534;3.033)
Green disponibility100	2.392(-31.831;36.615)	4.227(-10.452;18.907)	-3.175(-27.666;21.316)	-4.418(-18.580;9.744)
Green disponibility200	-1.210 (-54.786;52.366)	-7.292(-30.270;15.686)	-8.992(-47.889;29.906)	-16.519(-38.969;5.931)
Green disponibility300	-14.872(-123.711;93.967)	7.03(-39.668;53.729)	-18.274(-86.727;50.178)	-22.180(-61.733;17.372)
Green distance	1.112(-15.678;17.902)	0.543(-6.661;7.747)	4.891(-7.197;16.979)	4.754(-2.229;11.736)

**p<0.1; **p<0.05; ***p<0.01. Adjusted for socioeconomic status, age at the time of attention test, sex, preterm, maternal IQ and maternal smoking during pregnancy.*

Table S5. Coefficients (together with 95%CI) of the regression mixed effect models estimating the association between several versions of exposure measurements (NDVI, VCF, green disponibility, green distance) and two measurements of attention score (Hit Rt median/Hit Rt se), once that the effect of the covariates have been accounted for among participants who have not changed residence.

	Hit rt median			Hit rt se		
	Value	Std.Error	p-value	Value	Std.Error	p-value
NDVI - 100m buffers	64.685	132.649	0.626	3.822	57.967	0.947
300m buffers	-27.632	133.254	0.836	1.293	58.637	0.982
500m buffers	-60.977	143.382	0.671	-20.136	63.408	0.751
VCF - 100m buffers	1.988	3.009	0.509	-0.148	1.302	0.909
300m buffers	-1.194	2.231	0.593	-0.326	0.966	0.736
500m buffers	-2.710	2.091	0.195	-0.657	0.910	0.471
Green disponibility100	-28.042	37.719	0.458	1.390	16.304	0.932
Green disponibility200	-56.338	58.756	0.338	4.141	25.541	0.871
Green disponibility300	-30.924	106.957	0.773	70.152	45.973	0.128
Green distance	0.211	0.226	0.352	-0.009	0.099	0.930

**p<0.1; **p<0.05; ***p<0.01 Mixed effects models with random factor (cohort) adjusted for age, socioeconomic level, cohort:age and exposition:age.*

9.2. Argitaratutako beste lanak

Anabitarte, A., Ibarluzea, J., Azkona, K., & Lertxundi, A. (2020). Hiriko gune berdeak eta osasuna. Ekaia Aldizkaria. https://doi.org/https://doi.org/10.1387/ekaia.20910

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Soraluce Olañeta, A., Imaz Goienetxea, L., **Anabitarte, A**., Álvarez Guerrico, L., Sancho Martínez, R., Bikuña Ugarte, E., & Basterrechea Irurzun, M. (2019). Tuberkulosiaren intzidentzia eta desparekotasun soziala Gipuzkoan, 2010-2017 denboraldian. Osagaiz: Osasun-Zientzien Aldizkaria, 3(2). https://doi.org/10.26876/osagaiz.2.2019.265

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Torres Toda, M., **Anabitarte, A.**, Cirach, M., Estarlich, M., Fernández-Somoano, A., González-Safont, L., Guxens, M., Julvez, J., Riaño-Galán, I., Sunyer, J., & Dadvand, P. (2020). Residential Surrounding Greenspace and Mental Health in Three Spanish Areas. International Journal of Environmental Research and Public Health, 17(16), 5670. https://doi.org/10.3390/ijerph17165670

10. Kongresuetan aurkeztutako lanak

Congreso geoEuskadi: Cartografía e Información Geográfica. Donostia – San Sebastián (Espainia) 26/09/2018

-¿Está relacionada la exposición ambiental con el nivel socio-económico en Donostialdea?

15th INMA Scientific Conferences 2018. Donostia – San Sebastián (Espainia) 14/11/2018-15/11/2018

-Is the socio-economic level associated to the environmental exposition in Donostialdea?

Urban Transitions 2018. Integrating Urban and Transport Planning, Environmental and Health for Healthier Urban Living. Sitges (Espainia) 25/11/2018-27/11/2018

-Is the socio-economic level associated to the environmental exposition in Donostialdea?

II Jornadas Doctorales de la UPV/EHU. Bilbo (Espainia) 03/07/2019

-Hiriko gune berdeak osasunean duten eragina

31st annual conference of the International Society for Environmental Epidemiology (ISEE 2019). Utrecht (Herbehereak) 25/08/2019-28/08/2019

-Children exposure to green and blue spaces and attention span

-Smoking during pregnancy and cognitive and psychomotor development at 1 year and in preschool age

32nd Annual Conference of the International Society for Environmental Epidemiology (ISEE 2020). Online 24/08/2020-27/08/2020

-Testing direct and indirect effects of green space availability on reproductive outcomes

I Congreso Virtual de la Sociedad Española de Epidemiología (SEE) y da Associação Portuguesa de Epidemiologia (APE). Online 21/10/2020-30/10/2020

-Testando los efectos directos e indirectos de espacios verdes y azules en la salud reproductiva

IkerGazte: Nazioarteko ikerkuntza euskaraz (2021). Gasteiz (Espainia) 09/06/2021-11/06/2021

-Hiriko gune berdeak eta osasunean duten eragina

Curso de verano "Dime dónde vives y te diré a qué te expones. Los efectos en salud de los factores ambientales". Donostia – San Sebastián (Espainia) 21/07/2021-22/07/2021

-Características de nuestras ciudades, espacios verdes, caminabilidad y efectos en la salud

XXXIX Reunión Anual de la Sociedad Española de Epidemiología (SEE), XVI Congresso da Associação Portuguesa de Epidemiologia (APE) y XIX Congreso de la Sociedad Española de Salud Pública y Administración Sanitaria (SESPAS). León (Espainia) 07/09/2021-10/09/2021

- Influencia del verdor residencial en la atención en niños de dos cohortes atlánticas de INMA

11. Egonaldiak

ISGlobal (Instituto de Salud Global de Barcelona). Bartzelona (Espainia) 01/03/2017-30/06/2017

Gainbegirale: Mònica Guxens eta Antònia Valentín

ISGlobal (Instituto de Salud Global de Barcelona). Bartzelona (Espainia) 03/09/2018-31/01/2019

Gainbegirale: Mònica Guxens eta Antònia Valentín eman ta zabal zazu

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