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Green spaces and spectacles use in schoolchildren in Barcelona

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ABSTRACT

Myopia is one of the major causes of low visual acuity during childhood, and hence of the need for spectacles. It is generally more prevalent in urban areas where children are often less exposed to green spaces than in rural areas. This study evaluated the association between exposure to green space and use of spectacles (as a surrogate measure for myopia) in a cohort of 2727 schoolchildren (7–10 years old) recruited from 39 primary schools in Barcelona (2012–2015). We assessed exposure to green spaces by characterizing outdoor surrounding greenness at home and school and during commuting using satellite data on greenness (Normalized Difference Vegetation Index). We also obtained data on the annual average time children spent playing in green spaces through questionnaires. Cross-sectional analyses were conducted based on prevalent cases of spectacles use at baseline data collection campaign and longitudinal analyses based on incident cases of spectacles use during the three-year period between the baseline and last data collection campaigns. An interquartile range (IQR) increase in exposure to green space at home (500 m buffer) and school and during commuting was associated with respectively 14% (95% CI: 2%, 26%), 27% (95% CI: 6%, 44%), and 20% (95% CI: 5%, 33%) decrease in spectacles use in cross-sectional analyses. In longitudinal analyses, we observed a reduction of 23% (95% CI: 4%, 39%) and 34% (95% CI: 2%, 55%) associated with an IQR increase in greenness at home and school, respectively. Moreover, an IQR increase in time playing in green spaces was associated with a 28% (95% CI: 7%, 45%) reduction in the risk of spectacles use in the longitudinal analysis. Our observed reduced risk of spectacles use associated with higher contact with green space calls for more refined studies of the association between green spaces and refractive errors of visions.

1. Introduction

Myopia is the most common refractive error of vision, currently affecting about one-fifth of the world's population (~1.5 billion people) (Dolgin, 2015; Holden et al., 2014; Morgan et al., 2012; Pan et al., 2012). Myopia was once considered a purely genetic condition, but it is now increasingly recognized as having a multifactorial etiology, with both genetic and environmental factors involved (Goldschmidt and Jacobsen, 2014; Morgan and Rose, 2005; Morgan et al., 2012; Wojciechowski, 2011). During the past few decades, there has been a notable increase in the global prevalence of myopia, representing an alarming epidemic worldwide (Holden et al., 2014; Morgan et al., 2012; Pan et al., 2012). Although the reason(s) for this increasing trend are yet to be established, such a rapid increase suggests a more important contribution of non-genetic environmental and social factors in the development of myopia (Goldschmidt and Jacobsen, 2014; Lougheed, 2014; Morgan et al., 2012).

The increase in the global prevalence of myopia has coincided with the rapid and ongoing increase in the population residing in urban areas where the prevalence of myopia is consistently reported to be

Abbreviations: BREATHE, BRain dEvelopment and Air polluTion ultrafine particles in scHool children; CIs, Confidence intervals; OR, Odds ratio; OLI, Operational Land Imager; NDVI, Normalized Difference Vegetation Index; SES, Socioeconomic status; TIRS, Thermal Infrared Sensor

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higher than in rural areas (Ip et al., 2008; Katz et al., 1997; Morgan et al., 2012; Pan et al., 2012; Wolfram et al., 2014). The higher prevalence of myopia in urban areas could suggest that *urban lifestyle* such as more near-work (i.e. tasks such as reading book and working with computer that need sustained gaze on a close object) or less time spent outdoor and/or *urban-related environmental factors* contribute to its pathogenesis. Urban areas are characterized by the abundance of non-natural built-up infrastructures with limited green environments (Escobedo et al., 2011). Urban green space has been associated with more time children spent playing outdoors (Amoly et al., 2014), increased physical activity (Almanza et al., 2012), and less non-educational screen time (Dadvand et al., 2014a) (a surrogate of near-work) which in turn are associated with reduced risk of myopia (Dolgin, 2015; Morgan et al., 2012; Pan et al., 2012; Tong et al., 2002). Although through these pathways green space can potentially have a protective effect on myopia and despite calls for evaluation of this potential protective effect (Ip et al., 2008), there have been no reported studies to date on the impact of green spaces on refractive errors of visions including myopia. The aim of this analysis was to evaluate the association between exposure to green space and use of spectacles in primary schoolchildren.

2. Methods

2.1. Study setting and participants

We undertook this study in Barcelona, Spain, a port city situated on the Northeastern part of the Iberian Peninsula. It has a Mediterranean climate characterized by hot and dry summers, mild winters, and maximum precipitation and vegetation during autumn and spring. This study was conducted based on data collected by the BRain dEvelopment and Air polluTion ultrafine particles in scHool childrEn (BREATHE) project which aimed that evaluating the impact of air pollution (main aim) and green spaces (secondary aim) on brain development (Dadvand et al., 2015a). Of the 416 schools in Barcelona, 40 urban schools were initially selected to obtain maximum contrast in air pollution levels (i.e., nitrogen dioxide — NO_2), of which 39 (19 public and 20 private schools) accepted to participate and were included in the study (Supplementary Fig. S1). Participating schools were similar to the remaining schools in Barcelona in terms of the neighborhood socioeconomic vulnerability index (0.46 versus 0.50, *t*-test p=0.57) and NO_2 levels (51.5 versus 50.9 μg/m^3, *t*-test p=0.72). Further details regarding the selection of schools have been previously reported (Dadvand et al., 2015a).

All schoolchildren (n=5,019) without special needs in the 2nd to 4th grades (7–10 years) of these schools were invited to participate by letters and/or presentations in schools for parents, of which 2,897 (58%) agreed to take part in BREATHE. All children had been in the school for more than six months (and 98% more than one year) before the beginning of the study. The choice of primary schoolchildren to test our hypothesized association was in line with most studies (e.g. (Guggenheim et al., 2012; Guo et al., 2013; He et al., 2015; Saw et al., 2006; Tong et al., 2002; Williams et al., 2008)) on the environmental determinants of myopia that have focused on early years of primary school as a suitable window of exposure, because it is a period when environmental factors have greatest opportunity to affect rapidly changing eyes.

All parents or guardians signed the informed consent and the study was approved (No. 2010/41221/I) by the Clinical Research Ethical Committee of the Parc de Salut MAR, Barcelona, Spain.

2.2. Outcome and covariate data

We considered the use of spectacles as a surrogate for myopia because when low visual acuity increases during childhood, this is particularly likely to be associated with the onset of myopia (Leone et al., 2010; Xiang et al., 2013). Data on the use of spectacles were collected twice: once in the baseline data collection campaign during 2012 and once in a follow-up campaign during 2015 using questionnaires. Sociodemographic data including child's sex and age and parental ethnicity and indicators of socioeconomic status such as educational achievement and employment status together with data on pregnancy period and childhood were obtained from parents through questionnaires.

2.3. Exposure to green space

Our exposure assessment encompassed two aspects of contact with green space: 1) outdoor surrounding greenness, a measure of general greenness in the main microenvironments (home, school and the commuting route between these two) for schoolchildren, and 2) the time spent playing in green spaces, a measure of use of green spaces by study participants.

2.3.1. Outdoor surrounding greenness

We characterized outdoor surrounding greenness (i.e. photosynthetically active vegetation) for the main microenvironments for schoolchildren encompassing greenness surrounding home, within and around school boundaries, and surrounding commuting route between home and school (hereafter referred to as *commuting greenness*) (Dadvand et al., 2015a).

To assess outdoor surrounding greenness, we applied the Normalized Difference Vegetation Index (NDVI) derived from the Landsat 8 Operational Land Imager (OLI) and Thermal Infrared Sensor (TIRS) images at 30 m×30 m resolution (US Geology Survey, 2015). NDVI is an indicator of greenness based on land surface reflectance of visible (red) and near-infrared parts of spectrum (Weier and Herring, 2011). It ranges between −1 and 1 with higher numbers indicating more greenness. To achieve maximum exposure contrast, we looked for available cloud-free Landsat 8 images during springs/autumns (i.e. the maximum vegetation period of the year for our study region) of the relevant years to our study period (2012–2015) from the NASA's Earth Observing System Data and Information System (EOSDIS) website. Based on this search we generated our NDVI map using the image obtained on 16th April 2013 (Supplementary Fig. S1).

Residential greenness was abstracted as the average of NDVI in buffers of 100 m, 250 m, and 500 m (Dadvand et al., 2012a, 2012b, 2015a, 2015b) around the home address of each study participant. For 174 children (5.9%) who shared two homes, we used the address where the child spent most of her/his time.

To assess greenness within school premises, we first digitized the school boundaries and then averaged NDVI values within those boundaries (Dadvand et al., 2015a, 2015b). To assess greenness surrounding schools we averaged NDVI values across a 50 m buffer around the school boundaries (Dadvand et al., 2015a, 2015b). We then averaged greenness within and surrounding school boundaries to obtain *school greenness*.

Data on the main mode of travel to and from school was obtained from parents via questionnaires. Around 60% of participants reported walking as the main mode of commuting while the 38% reported commuting by motor vehicles (private car, bus, motorcycle, or tram). The remaining 2% reported the underground metro train as the main mode of transport, for whom we assumed no exposure to greenness during commuting. For participants reporting walking as the main mode of commuting, we identified the shortest walking route to school and for participants reporting motor vehicles as the main mode of commuting, we identified the shortest driving route to school, based on street networks (network distance) using network analyst extension from ArcGIS software v10. We defined commuting greenness as the average of NDVI in a 50 m buffer around the commuting route (Dadvand et al., 2015a).