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Health impact assessment of increasing public transport and cycling use in Barcelona: A morbidity and burden of disease approach

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ABSTRACT

Objective. Quantify the health impacts on morbidity of reduced car trips and increased public transport and cycling trips.

Methods. A health impact assessment study of morbidity outcomes related to replacing car trips in Barcelona metropolitan (3,231,458 inhabitants). Through 8 different transport scenarios, the number of cases of disease or injuries related to physical activity, particulate matter air pollution <2.5 μm ($PM_{2.5}$) and traffic incidents in travelers was estimated. We also estimate $PM_{2.5}$ exposure and cases of disease in the general population.

Results. A 40% reduction in long-duration car trips substituted by public transport and cycling trips resulted in annual reductions of 127 cases of diabetes, 44 of cardiovascular diseases, 30 of dementia, 16 minor injuries, 0.14 major injuries, 11 of breast cancer and 3 of colon-cancer, amounting to a total reduction of 302 Disability Adjusted Life Years per year in travelers. The reduction in $PM_{2.5}$ exposure in the general population resulted in annual reductions of 7 cases of low birth weight, 6 of preterm birth, 1 of cardiovascular disease and 1 of lower respiratory tract infection.

Conclusions. Transport policies to reduce car trips could produce important health benefits in terms of reduced morbidity, particularly for those who take up active transportation.

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Introduction

Transportation is a key sector for the economy and social development. But transportation is also a major source of air pollutant emissions, representing for example 23% of greenhouse gas emissions globally (OECD, 2010b). Furthermore car use promotes physical inactivity and sedentary lifestyle which are associated with obesity, cardiovascular disease, diabetes, cancer, and other diseases. Both physical inactivity and air pollution have been classified as two of the 10 leading risk factors of burden of disease worldwide in 2010 (Douglas et al., 2011; Lim et al., 2013). Multiple international agencies have called for the implementation of public policies to increase the use of active transportation (walking and cycling) and public transport to reduce the car dependency in urban areas, to reduce greenhouse gas emissions, mitigate climate change and encourage physical activity (UNEP, 2010; WHO Europe, 2000).

Various studies estimating impacts of transport interventions or policies on health have been published recently. Some quantified the impact of implementing transport interventions on all cause mortality, such as public bicycle system in Barcelona (Rojas-Rueda et al., 2011). Others quantified the possible impacts on morbidity and mortality of future transport interventions, such as increasing the number of walking or cycling trips in different urban areas around the world (De Hartog et al., 2010; Grabow et al., 2011; Holm et al., 2012; Lindsay et al., 2011; Olabarria et al., 2012; Rabl and de Nazelle, 2012; Woodcock et al., 2009, 2013).

The present study aims to quantify the morbidity impacts of transport policies through a health impact assessment (HIA) approach, selecting the best available evidence based on a review of the literature. It takes into account different types of trips (short and long duration),

Abbreviations: BAU, Business as usual; DALYs, Disability Adjusted Life Years; HEI, Health Effects Institute; HIA, Health Impact Assessment; MeSH, Medical Subject Headings; METs, Metabolic Equivalent of Task; NO2, Nitrogen Dioxide; NOx, nitrogen oxides; OECD, Organization for Economic Co-operation and Development; OR, Odds ratio; PM_{10}, Particulate matter less than 10 μm; $PM_{2.5}$, Fine particles (less than 2.5 μm); RR, Relative Risk; UFP, Ultra-fine Particles; WHO, World Health Organization; YLD, Years Lived with Disability; YLL, Years of Life Lost.

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different modes of transport (bicycle, bus, tram, metro and train), different exposure populations (travelers and the general population) and different types of exposures (air pollution, physical activity and traffic incidents).

Methods

Scenarios

The HIA (Joffe and Mindell, 2002) was based on eight different scenarios of car trip replacement by public transport and bicycle trips used in a previous study conducted in the metropolitan area of Barcelona (Rojas-Rueda et al., 2012) (see Table 1).

Two populations were included in the analysis: 1) "Travelers", defined as those who performed a modal shift due to the intervention (new cyclist or new public transport user). In our assessment, the travelers were exposed to the three health determinants included in the model (air pollution, physical activity and traffic incidents). And 2) the "General population", defined as those who live in Barcelona city (all age groups). In our assessment the general population was exposed to changes in air pollution concentrations related to traffic reduction associated with the transport policy intervention (the 8 scenarios) in comparison with the concentrations of air pollution in the business as usual (BAU) scenario.

Transport data

The information needed on travel mode share and trip distances by mode of transport (car, bike, and public transport) was obtained from surveys and records conducted by the city and Metropolitan area of Barcelona (DSM, 2010). We estimated the average car trip length of "inside" (3.1 km) and "outside" (6.4 km) Barcelona and developed different scenarios of mode shifts to alternative modes (Table 1).

Morbidity outcomes

To select the health outcomes we identified the dose–response functions published in the scientific literature that associate health determinants (air pollution and physical activity) with morbidity outcomes (Fig. 1). The selection of dose–response functions was based on proposals derived from a series of expert meetings held in Barcelona between 2010 and 2012, a systematic review of the scientific literature, and expert judgment. For traffic incidents, another approach was used, focusing on the data available for traffic incidents in Barcelona city. In this case we used the injury records for 2002–2009 for each mode of transport, which reported minor and major injuries within the city (ASPB, 2011).

Physical activity

To assess the physical activity in travelers it was assumed that for each public transport trip the traveler walked for 10 min and for cycling trips, trip duration depended on the distance traveled in each scenario (inside 3.1 km and outside 6.4 km). The relative risks (RR) obtained for physical activity and each morbidity outcome were used to estimate the number of cases of disease expected in each scenario (see Table 2).

Air pollution

Particulate matter less than 2.5 μm ($PM_{2.5}$) was selected as the main air pollutant in this model because it has shown strong associations with health outcomes (Lim et al., 2013; HEI, 2010). For travelers, we estimated and compared the exposure concentration and inhaled dose for travel by car, bicycle, walking, bus/tram and metro/train. Concentration levels for car, bike, walk and bus were obtained from a measurement study conducted in Barcelona (de Nazelle et al., 2011). For air pollution exposure in the general population we used the Barcelona Air-Dispersion Model (Lao and Teixido, 2011) to estimate the reduction in the concentrations in $PM_{2.5}$ in Barcelona city for each scenario.

Traffic incidents

Traffic injuries in Barcelona were estimated based on the injury records from 2002 to 2009 reported by the Barcelona Public Health Agency (ASPB, 2011). For each mode of transport, the risk of suffering a minor or major injury per billion of kilometers traveled was estimated using the average number of injuries (minor or major) per year and the kilometers traveled per year in each mode of transport. The kilometers traveled per year were calculated based on the number of trips per mode of transport and the average trip duration reported by the Barcelona Transport Department (DSM, 2010; RMB, 2006) (Tables 3 and 4).

Morbidity rates

We estimated population-attributable number of cases for each scenario based on dose–response function and morbidity rates for each disease (Perez and Kunzli, 2009; WHO, 2008). The relevant morbidity rates for the different diseases were obtained from different epidemiological studies and public records published for the local population (Bermejo-Pareja et al., 2008; Chacon et al., 2010; INE, 2006, 2010; Lopez-Abente et al., 2010; Martinez-Salio et al., 2010; Mata-Cases et al., 2006; Medrano et al., 2006; OECD, 2010a; Pollan et al., 2010). Each morbidity rate was obtained for age and sex specific groups (see Table 5).

Burden of disease

A Disability Adjusted Life Years (DALYs) approach was used to synthesize and compare the health impacts of different morbidity outcomes of the three main exposures (air pollution, physical activity and traffic injuries) and the two populations (travelers and general population) in each scenario, following the WHO approach (WHO, 2004).

Results

Physical activity impacts in travelers

In all scenarios there was a reduction in the number of cases with disease per year related to physical activity exposure in travelers (see Table 6). For cardiovascular disease the maximum change of cases per year was −44.33, for diabetes mellitus type 2 −127.90, for breast cancer in women −11.35, for colon cancer −3.66 and for dementia −30.54, all in scenario 8. The DALYs per year estimated change ranged from −103.33 (scenario 3) to −259.16 (scenarios 8) (see Table 7).

Table 1
Scenarios description, number of car trips replaced and percentages.

	Inside Barcelona scenarios[a]				Outside Barcelona scenarios[b]			
	Scenario 1	Scenario 2	Scenario 3	Scenario 4	Scenario 5	Scenario 6	Scenario 7	Scenario 8
Car trips reduction	20%	40%	20%[c]	40%[c]	20%[d]	40%[d]	20%[e]	40%[e]
Trips/day replaced by Bike (%)	94,460 (100)	188,920 (100)	47,230 (50)	94,460 (50)	0	0	34,065 (20)	68,130 (20)
Trips/day replaced by public transport (%)[f]	0	0	47,230 (50)	94,460 (50)	170,324 (100)	340,648 (100)	136,259 (80)	272,518 (80)

[a] Inside Barcelona scenarios refers to the trips that start and end in Barcelona city.
[b] Outside Barcelona scenarios refers to the trips that start or end in Barcelona city and start or end in Barcelona metropolitan area.
[c] Here we assumed that the 50% of the trips was replaced by bike, the 22% by bus/tram and 28% are by metro/train.
[d] Here we assumed that the 26% of the trips is replaced by bus/tram and 74% are by metro/train.
[e] Here we assumed that the 20% of the trips is replaced by bike, the 21% by bus/tram and 59% are by metro/train.
[f] Public transport includes: bus, tram, train and metro.

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