

# **Correlates of walking for travel in seven European cities: the PASTA project**

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**Competing interests**

The authors declare they have no actual or potential competing financial interests.

## **Abstract**

**Background:** while walking for travel can help reaching the daily recommended levels of physical activity we know relatively little about the correlates of walking for travel in the European context.

**Objective:** within the framework of the European “Physical Activity through Sustainable Transport Approaches” (PASTA) project, we aimed to explore the correlates of walking for travel in European cities.

**Methods:** the same protocol was applied in seven European cities. Using a web-based questionnaire, we collected information on the total minutes walking per week, and on individual characteristics, mobility behaviour and attitude (N=7875). Characteristics of the built environment (the home and the work/study addresses) were determined with GIS-based techniques. We conducted negative binomial regression analyses, including city as random effect. Factor and principal component analyses were also conducted to define profiles of the different variables of interest.

**Results:** living in high density residential areas, with richness of facilities, and density of public transport stations was associated with increased walking for travel, whereas the same characteristics at the work/study area were less strongly associated with the outcome when the residential and work/study environments were entered in the model jointly. A “walk-friendly social environment” was associated with walking for travel. All three factors describing different opinions about walking (ranging from good to bad) were associated with increasing minutes walking per week, while the importance given to certain criteria to choose a mode of transport provided different results according to the criteria.

65    **Discussion:** The present study supports findings from previous research regarding the  
66    role of the built environment in the promotion of walk for travel, and provides new  
67    findings to help achieving sustainable, healthy, liveable, and walkable cities.

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69    **Keywords:** walking, physical activity, built environment, urban, behaviour

## **Introduction**

Lack of physical activity is among the ten leading risk factors for mortality worldwide, and is a key risk factor for obesity and other non-communicable diseases (NCDs), such as cardiovascular diseases, cancer, and diabetes (WHO 2018). Indeed, it is estimated that people who are insufficiently active have between 20% and 30% increased risk of premature death compared to people who are sufficiently active (WHO 2018). According to a study conducted in 2015, physical inactivity costs 80.4 billion euros per year in Europe, which is equivalent to 6.2% of all European health spending. The authors also estimated that by 2030 these costs could be as high as 125 billion euros (International Sport and Culture Association and Centre for Economics and Business Research 2015). Moreover, a recent study including almost 2 million participants worldwide showed that physical inactivity levels have increased in high-income countries in the last 15 years (Guthold et al. 2018). The study noted that “if current trends continue, the 2025 global physical activity target (a 10% relative reduction in insufficient physical activity) will not be met”, and urged to implement policies to increase population levels of physical activity worldwide (Guthold et al. 2018).

It is recommended that in a typical week adults perform at least 150 min of moderate intensity aerobic physical activity (which includes walking), or alternatively at least 75 min of vigorous intensity aerobic physical activity or an equivalent combination of moderate- and vigorous-intensity activity (WHO 2018). Although walking for travel purposes is an easy and healthy way to reach the recommended levels of physical activity, in the last century the increasing use of motorized modes of transport (e.g. car or motorbike) has contributed to the drop in levels of physical activity among the general population, and has led to other traffic-related health problems such as air and noise

pollution (Giles-Corti et al. 2016; Nieuwenhuijsen 2016). In the past few years many studies have been conducted in order to evaluate the possible determinants contributing to the use of active modes of transport, particularly walking (Christian et al. 2013; Christiansen et al. 2016; D’Haese et al. 2015; Kerr et al. 2015; Knuiman et al. 2014; Marquet et al. 2017; Marquet and Miralles-Guasch 2015; Smith et al. 2017; Sugiyama et al. 2012; Wasfi et al. 2017; Yang 2016). However, these studies often contain small sample sizes, most of them focus on a particular domain of influence (e.g. policy context, built environment, social environment, personal or trip attributes), or are heterogeneous regarding the methods followed to assess both exposures and outcomes (Dons et al. 2015; Götschi et al. 2017). Moreover, the majority of these studies have been conducted in Australia and the United States, but fewer in other regions worldwide, including Europe (Sugiyama et al. 2012), where the built environment characteristics of the cities are significantly different (Dons et al. 2015; Kelly et al. 2017).

The EC funded “Physical Activity through Sustainable Transport Approaches” (PASTA) project is a multinational, interdisciplinary research project aiming to understand the correlates of active travel behaviour, as well as potential confounders and mediators (Dons et al. 2015; Gerike et al. 2016; Götschi et al. 2017). Although PASTA is a longitudinal study, with several waves of assessment, the current study uses data from the baseline questionnaire only. The main aim of the present cross-sectional study is to explore the correlates of walking for travel in seven European cities, using a common protocol in all cities, and including a range of correlates such as the built environment (both around the residence and the work or study locations), the social environment, personal characteristics and trip attributes. We also explored whether there are different

patterns of association between those participants working (full- or part-time) or studying and those not working (unemployed, retired, etc) or studying.

## **Materials and methods**

### ***Study design and population***

Details of the PASTA project are provided elsewhere (Dons et al. 2015; Gaupp-Berghausen et al. 2018; Gerike et al. 2016). Briefly, PASTA pursues a mixed-method and multilevel approach that is consistently applied in seven case study cities (Antwerp, Barcelona, London, Örebro, Rome, Vienna and Zurich) following a common protocol. The PASTA framework distinguishes hierarchical levels for various factors (i.e. city, individual, and trips), and three main domains or pathways that influence active mobility behaviour (and physical activity), namely socio-geographical factors, socio-psychological factors, and rationale or mode choice related factors (Dons et al. 2015).

A standardized recruitment strategy was developed for all cities using an opportunistic approach (e.g. a press releases, postcards and leaflets, direct targeting of local stakeholders and community groups, or extensive use of social media). To minimize attrition a user engagement strategy was developed, including incentivizing participation with a lottery. The lottery was done every three months, and each city decided how to give the incentives (cash or vouchers). Those participants with greater number of completed questionnaires the previous 3 months had greater chance of winning. Örebro (Sweden) was the only city that did not do a lottery (neither any other kind of incentive) because it was not allowed due to its recruitment particularities (workplace recruitment) (Dons et al. 2015; Gaupp-Berghausen et al. 2018). Participants had to be at least 18 years old (at least 16 years old in Zurich), and to live, work, study or regularly travel (i.e. at

least once a week) in the PASTA city of interest (Dons et al. 2015). Individual level information and correlates of active mobility were investigated through a large scale longitudinal web-based survey ([http://pastaproject.eu/fileadmin/editor-upload/sitecontent/City\\_survey/PASTA-questionnaires.pdf](http://pastaproject.eu/fileadmin/editor-upload/sitecontent/City_survey/PASTA-questionnaires.pdf)). The baseline questionnaire allowed to collect socio-demographic, individual, household, health, and attitudinal variables. Frequency of use of different modes of transport and the Global Physical Activity Questionnaire (GPAQ) questions gathered information on mobility and physical activity habits. In total 10691 participants answered the baseline questionnaire (Gaupp-Berghausen et al. 2018). However, for the current study 2701 participants were excluded because they did not have acceptable GPAQ indicators based on the validation criteria established by the GPAQ guideline (WHO). Of the remaining 7990, 115 participants were excluded because they did not provide home address at baseline and therefore indicators for the residential built environment characteristics were not available. In total 7875 participants were included in our main analyses. Out of those, 6957 participants also provided the work or study address and were included in our secondary analyses. The rest of the participants, N=918, reported not working or studying and were therefore not included in this secondary analysis. For each partner city the relevant permission to collect, store and process data was obtained from the local ethics committees. On enrolment, participants registered on the PASTA website and gave informed consent (see the “Participant information sheet” in [http://pastaproject.eu/fileadmin/editor-upload/sitecontent/City\\_survey/PASTA-questionnaires.pdf](http://pastaproject.eu/fileadmin/editor-upload/sitecontent/City_survey/PASTA-questionnaires.pdf)). Further details can be found in Dons et al. paper (Dons et al. 2015).

## ***Outcome assessment***



We followed the GPAQ standard procedures to validate the answers provided by the participants (WHO) and to calculate our outcome variable of interest “*Minutes walking per week for travel*”, which is the result of combining the GPAQ questions “*In a typical week, on how many days do you walk for at least 10 minutes continuously to get to and from places?*” and “*Typically, how much time do you spend walking on such a day?*”.

### ***Correlates of walking for travel***

According to the PASTA framework of active travel behaviour (Götschi et al. 2017), we considered many correlates that could be potentially associated with walking, including those related to the built environment, the social context, and individual level. Residential and work/study address built environment characteristics were systematically gathered in each city by collecting publicly available geographic information system (GIS) based data and information from other data sources (i.e. weather data, population statistics, etc.) and by means of stakeholder interviews (Dons et al. 2015). The rest of the information was collected through the web-based questionnaire previously mentioned.

#### ***Individual characteristics***

A wide range of individual characteristics were collected. Based on previous literature (Christian et al. 2013; Christiansen et al. 2016; D’Haese et al. 2015; Kerr et al. 2015; Knuiman et al. 2014; Marquet et al. 2017; Marquet and Miralles-Guasch 2015; Smith et al. 2017; Sugiyama et al. 2012; Wasfi et al. 2017; Yang 2016) we included the following variables in the base model, as these are individual characteristics which have been shown to strongly influence travel model choices: age, gender, level of education [high education: education above secondary school (yes/no)], employment status (full-time, part-time, student, not working), access to car or a van (from now on “access to a car”;

never, sometimes, always), and access to a bike or an e-bike (from now on “access to bike”; yes, no).

#### *Built environment characteristics*

The same built environment characteristics were included in the present analysis for both the residential address and the work/study address, using a 300m radial buffer in both cases. Table 1 provides the complete details on how each indicator was calculated and/or defined. Briefly, using a diversity of sources depending on the variable of interest and the sources available in each city [Navteq (2012), Open Street Map (OSM) and local layers (2015-2017), or census/neighbourhood data (2011-2016)], we obtained information for street length density ( $\text{m}/\text{km}^2$ ), street connectivity (intersections/ $\text{km}^2$ ), building area density ( $\text{m}^2/\text{km}^2$ ), population density (inhabitants/ $\text{km}^2$ ), facilities density ( $\text{n}^\circ$  facilities/ $\text{km}^2$ ), facilities richness ( $\text{n}^\circ$  facilities type/total  $\text{n}^\circ$  facilities), density of public transport stations ( $\text{n}^\circ$  stations/ $\text{km}^2$ ), distance to the first public transport station (m). Levels of air pollutants  $\text{PM}_{2.5}$  ( $\mu\text{g}/\text{m}^3$ ) and  $\text{NO}_2$  ( $\mu\text{g}/\text{m}^3$ ) were estimated based on land use regression models (de Hoogh et al. 2016), while surrounding greenness was defined based on the normalized difference vegetation index [NDVI, images from years 2015-2016 (Nieuwenhuijsen et al. 2014), which goes from -1 (less green) to 1 (more green)]. We used land-cover map Corine (2006) to assess distance (m) and area ( $\text{km}^2$ ) of the closest major ( $\geq 0.5\text{ha}$ ) green space, access to a major green space (i.e. location is less than 300m from a major green space; yes, no), distance (m) and area ( $\text{km}^2$ ) of the closest major ( $\geq 0.5\text{ha}$ ) blue space, and access to a major blue space (i.e. location is less than 300m from a major blue space; yes, no). We chose the 300 m buffer for several reasons: first, it is commonly used in epidemiological studies on built environment and health (Nieuwenhuijsen and Khreis 2019); second, it is a distance that most of the population,

including the elderly, can walk; and third, some of the built environment indicators (e.g. facilities richness) were not available for other buffers (e.g. 100 m or 500 m). Finally, the 300m buffer allowed for more exposure variability among study participants in the context of European cities than the 500m buffer, particularly in dense cities such as Barcelona. We conducted, however, a sensitivity analyses with the available built environment indicators at 500m radial buffer. We also included information on the distance between the residential and the work/study address (m), the altitude difference (m) and the slope between both addresses. Finally, although city was included in the model as random effect (see the “Statistical Analysis” section), in order to explore the influence of each of the cities we conducted a sensitivity analysis excluding each city one by one from the model.

#### *Social norms and mobility culture in the neighbourhood*

Three different questions were used to determine the community context of each individual with regard to walking (Götschi et al. 2017): 1) “*Most people who are important to me think that I should walk for travel*”, 2) “*In my neighbourhood walking is well regarded*”, and 3) “*In my neighbourhood it is common for people to walk for travel*”. Response options were on a 5-point Likert-type scale from “very much disagree” to “very much agree”.

#### *Values and attitude towards walking for travel*

Two sets of questions were used to evaluate, on the one hand, the importance of certain criteria when choosing a mode of transport to travel and, on the other, the opinion about walking for travel in relation to different criteria. In particular, participants had to report the level of importance to them (5-point Likert-type scale from “not important” to “very

important”) of the following criteria: short travel time, lower travel cost, higher travel comfort, safer travel (with regard to traffic), safer travel (with regard to crime), lower exposure to air pollution, privacy, personal health benefits, low environmental impact, flexible departure time, more predictable time and journey reliability. Regarding opinion about walking for travel, the questionnaire asked “*Within your day-to-day travel needs in mind, would you say that walking for travel*” (5-point Likert-type scale from “very much disagree” to “very much agree” for each item): saves time, is comfortable, is safe (with regard to traffic), is safe (with regard to crime), is unpleasant due to high levels of air pollution, offers privacy, offers personal health benefits, offers flexibility (e.g. with regard to departure time), offers a predictable travel time.

#### *Transport habits*

The question “*How often do you currently use each of the following methods of travel to get to and from places? (walk, bike or e-bike, motorcycle or moped, public transport, car or van)*” was used to evaluate the influence of transport habits on the minutes walking per week, and also to understand behavioural patterns of mobility. There were six possible answers: never, less than once a month, on 1-3 days/month, on 1-3 days/week, daily or almost daily, don’t know (this last answer was treated as missing).

#### ***Statistical Analysis***

##### *Multiple imputation of the data*

Because there were some participants with missing information for some of the variables of interest (mostly between 0% and 6.6%, except income which had a 21.9% of missing values; see Tables S1, S2 and S3 for further details on the proportions of observations with missing data for questionnaire and built environment variables, respectively), and

assuming that data was missing at random (MAR), we followed multiple imputation procedures prior to analysing the data in order to avoid loss of participants (Royston 2005). The procedure of the imputation process and the variables considered are detailed in Table S4 of the Supplemental material. Briefly, we conducted multiple imputations by chained equations carrying out 20 imputations with 10 cycles for each imputation that generated 20 complete datasets. For the imputation process we used many more variables than the ones finally included in the analyses in order to have the richest information possible (Table S4). As the demographic composition and the built environment characteristics varied among cities (Table S1-S3), the imputations were carried out separately for each city and afterwards the seven databases were merged into one single database. We analysed the datasets following the standard combination rules for multiple imputations, which consist of three phases: 1) imputation - creating multiply imputed data, 2) completed data analysis of multiply imputed data, and 3) pooling of individual analyses from phase 2 using Rubin's combination rules (Marshall et al. 2009; Rubin 1987).

#### *Negative binomial regression analysis*

Negative binomial regression analyses including city as random effect were conducted [Incidence Rate Ratio (IRR) obtained] in order to explore the correlates of “minutes walking per week for travel”, the outcome of interest. As explained in the “Individual characteristics” section, we created a base model including age, gender, level of education, employment status, access to car, and access to a bike (Table 2). Then, all potential correlates of walking were included one by one to the base model to evaluate the association with minutes walking per week. All built environment characteristic variables were scaled to the mean (thus, IRRs were derived using the standard deviation

(SD) as the exposure contrast), except surrounding greenness, for which we used the interquartile range (IQR), and access to green spaces and access to blue spaces, which were binary variables. Streets length, connectivity, building area, population, facilities, and public transport stations are expressed per km<sup>2</sup> (density). However, in terms of interpretation, the reader might desire to use the indicators per area of the buffer (area of a 300m buffer=0.2809 km<sup>2</sup>). In this case the SD of each of these variables has to be multiplied by 0.2809 [e.g. if SD of street length density is 7031 m/km<sup>2</sup>, then the new value for area of the buffer is 1975 m]. Also, some of the 5-point Likert-type variables had very low prevalence in some of the categories of reference and were therefore re-categorized into four or three categories instead of five for the purpose of this analysis. The criteria to collapse categories was whether the category or the sum of two or more categories reached a prevalence of at least 5% within each city (the original categories are described in Table S1, whereas the new categories are provided in the tables of the supplemental material including the associations with the outcomes). These variables were modelled using categorical indicator terms with a single reference category. These same analyses were conducted for the total study population (N=7875) and the working/studying population (N=6957), which additionally had information on the built environment characteristics at work or place of study.

#### *Factor and principal component analyses*

In addition, we created factors and principal components for the different sets of variables in order to reduce the number of variables and capture patterns of built environment characteristics, social norms and mobility culture in the neighbourhood, values and attitude towards walking, and transport habits. We combined the use of the Eigenvalue as a value of reference with the application of subjective criteria (such as whether the factors

obtained made sense or were providing new information with respect to other factors) to decide the final number of factors and principal components. The aim was to detect profiles that were of interest for the purpose and aim of the present study. For the built environment characteristics, we chose to conduct a factor analysis, as the aim was to create latent variables describing walkable and/or non-walkable areas (within 300m buffer). All the built environment variables were included in the factor analysis except access to green and blue spaces, as these two variables were created based on distance to the closest major green or blue space, respectively, which were variables already included in the factor analysis. This procedure was conducted for the residential built environment characteristics (N=7875), the work/study built environment characteristics (N=6957) and for the residential and the work/study built environment characteristics altogether (N=6957). For social norms and mobility culture in the neighbourhood, values and attitude towards walking, and transport habits we conducted principal component analysis (PCA), as the aim was to reduce all the information from the single variables into a reduced number of components. The different groups of factors and principal components thus derived were then also included one by one to the base model and, in a second step, altogether at the same time.

### *Collinearity*

After evaluating each single correlate of walking for travel, we introduced all the different factors and principal components into one single model (Model A). Given that transport habits, attitudes and values towards modes of transport influence one each other (Kroesen et al. 2017), we applied another model excluding transport habits principal components from the main model (Model B). We calculated the variance inflation factors (VIFs) to assess collinearity among the variables of the base model, city and the principal

components and factors obtained for built environment characteristics, the importance of certain criteria when choosing a mode of transport, opinion about walking, social norms and mobility culture in the neighbourhood, and transport habits. Data analysis was conducted with STATA 14.0 (imputation, and factor and principal component analysis), and with R version 3.5.0 (negative binomial regression analysis). We considered that there was an association and statistical significance when the p-value was <0.05.

## **Results**

### ***Characteristics of the study population***

There were differences among participants of the different PASTA cities (Table S1). Overall, the mean age of the study population was 39.6 years (min=16.1, max=91.4 years), Barcelona participants were the youngest (36.3 years) and Örebro's the eldest (44.4 years) (Table S1). A 52.9% of the participants were females, ranging between 37.2% in Rome to 62.5% in Örebro. Our study population was highly educated, with more than 70% of the participants reporting to have a high level of education (university education), ranging from 62.3% in Zurich to 84.6% in London. Only 7.8% reported not working (home duties, unemployed, retired, sickness leave or parental leave), and full-time workers were more prevalent in Antwerp (70.7%) than in other cities (e.g. Vienna 47.6%). On average, 50.7% reported to always have access to a car and 80.8% to have access to a bike, with certain differences among cities.

On average, participants from Barcelona walked the most minutes per week (258.8 minutes per week), whereas participants from Antwerp walked the least (49.6 minutes per week). Results of the base model showed that age and gender were not statistically significantly associated with minutes walking per week (Table 2). However, having a



high level of education [IRR (95%CI)=0.82 (0.72, 0.93)], access to a car [either sometimes or always, IRR (95%CI)=0.80 (0.68, 0.94) and 0.73 (0.62, 0.84), respectively], and access to a bike [IRR (95%CI)=0.66 (0.57, 0.77)] were statistically significantly associated with fewer minutes walking per week. On the contrary, participants who did not work or study walked 65% (95%CI=32%, 106%) more minutes per week compared to those working full-time (full-time workers walked, on average, 111 minutes per week less than those not working) (Table 2).

### ***Correlates of walking for travel***

#### *Residential built environment characteristics*

There were clear differences among cities regarding residential built environment characteristics; for instance, comparing the two cities in the “extremes”, Barcelona participants lived in much denser areas, in terms of street (26410 m/km<sup>2</sup>), building area (441064 m<sup>2</sup>/km<sup>2</sup>) and population density (33502 inhabitants/km<sup>2</sup>), and with more street connectivity (279 intersections/km<sup>2</sup>) and more facilities (300/km<sup>2</sup>) within a 300 m buffer than participants from Örebro (12312 m/km<sup>2</sup>, 128912 m<sup>2</sup>/km<sup>2</sup>, 3702 inhabitants/km<sup>2</sup>, 78 intersections/km<sup>2</sup> and 18 facilities/km<sup>2</sup>, respectively). However, Örebro participants had greener residential surroundings than participants from other cities (Table S2).

A number of residential built environment characteristics were statistically significantly associated with more minutes walking per week (Table 3), such as street length density [for each standard deviation (SD)=7031 m/km<sup>2</sup> the increase was 11% (95%CI=3%, 19%)], street connectivity [for each SD=108 intersections/km<sup>2</sup> the increase was 8% (95%CI=1%, 16%)], building area density [for each SD=157735 m<sup>2</sup>/km<sup>2</sup> the increase was 8% (95%CI=0%, 16%)], population density [for each SD=12822 inhabitants/km<sup>2</sup> the

increase was of 9% (95%CI=1%, 19%)], richness of facilities [for each SD=0.09 facilities types/total n° facilities the increase was 9% (95%CI=3%, 17%)], density of public transport stations [for each SD=20.2 stations/km<sup>2</sup> the increase was 7% (95%CI=1%, 14%)], and levels of NO<sub>2</sub> [for each SD=10.5 µg/m<sup>3</sup> the increase was 11% (95%CI=1%, 21%)]. On the contrary, there was a statistically significantly reduction in the minutes walking per week with the further distance from the 1<sup>st</sup> public transport station [for each SD=117 m the decrease was -6% (95%CI=-11%, 0%)] and the more surrounding greenness [for each IQR=0.26 NDVI increase the statistically significantly reduction was -20% (95%CI=-30%, -10%)]. The rest of the variables were not statistically significantly associated with the outcome of interest, although the magnitude of the effect varied across the different variables evaluated (Table 3).

Regarding the factor analysis for the residential built environment, we obtained two main factors, which were labelled based on the factor loadings and the correlations we observed between the factors and each single built environment characteristic (Table S5). Factor 1 (explaining 75% of the total variance) was labelled “high density residential area” and factor 2 (11% of the total variance explained) was labelled “low density residential area”. While this labelling might seem to be defining two factors with totally opposite characteristics this is not completely true. For instance, we observed positive correlations between Factor 1 and street length density and connectivity and negative correlations between these two variables and Factor 2. However, building area density and population density were both positively correlated with both factors, but with much stronger correlations for Factor 1. Air pollutants (NO<sub>2</sub> and PM<sub>2.5</sub>) were also positively and strongly correlated with both factors (Table S5)”. “High density residential area” was statistically significantly associated with more walking [IRR (95%CI)=1.12 (1.03, 1.22)], whereas

the IRR for “low density residential area” was not statistically significant [IRR (95%CI)=0.97 (0.88, 1.06)] (Table 3).

Sensitivity analyses using built environment indicators within a 500 m (Table S6) or excluding each city one by one (Table S7) provided similar results. However, data from Antwerp seemed somewhat influential, although results remained in the same direction. For instance, the association between street length density and minutes walked per week was 1.11 (1.03, 1.19) when including all cities, and 1.05 (0.98, 1.13) when excluding Antwerp (Table S7).

#### *Social norms and mobility culture in the neighbourhood*

Increasing agreement with “*Most people who are important to me think that I should walk for travel*” and “*In my neighbourhood it is common for people to walk for travel*” was statistically significantly associated with more minutes walking per week [e.g. 97% increase (95%CI=42%, 172%) for “very much agree” vs. “very much disagree”, and 65% (33% and 105%) for “very much agree” vs. “very much disagree or disagree”, respectively]. No significant associations were observed with “*In my neighbourhood walking is well regarded*” [e.g. 11% (-11%, 38%)] for “very much agree” vs. “very much disagree or disagree” (Table S8).

A PCA of the social and mobility culture variables resulted into one single principal component (53% of total variance explained), which we named “*the walk-friendly social environment*”, as all the three items for social norms and mobility culture in the neighbourhood are positively correlated with it (Table S9). This principal component was

associated with more minutes walking per week [9% increase (95%CI=5%, 14%)] (Table 4).

#### *Values and attitude towards walking for travel*

Regarding the importance of different criteria for choosing a method of travel, minutes of walking per week were significantly lower in relation to the importance of short travel time [e.g., -32% (95%CI=-45%, -15%) for “very important” vs. “not important or less important”], flexible departure time [-27% (95%CI=-38%, -14%) for “very important” vs. “not important, less important, or neutral”], and more predictable time and journey reliability [-21% (95%CI=-44%, -6%) for “very important” vs. “not important, less important, or neutral”], with monotonic trends in IRRs as importance increased for all predictors except predictable time and reliability (Table S10)”. On the contrary, “very important” responses for safer travel with regard to traffic [25% (95%CI=3%, 52%) vs. “not important or less important”] and crime [44% (95%CI=16%, 78%) vs. “not important”], lower exposure to air pollution [40% (95%CI=16%, 68%) vs. “not important or less important”] and privacy [59% (95%CI=17%, 115%) vs. “not important”] were statistically significantly associated with increasing minutes of walking per week, with monotonic trends as importance increased. Other variables, such as lower travel cost, personal health benefits, low environmental impact, or travel comfort were not statistically significantly or consistently associated with amount of walking (Table S10).

A PCA of the criteria variables when choosing a mode of transport for travel led to four principal components (Table S11); the first describes those that value safety (traffic and crime), low exposure to air pollution, privacy, health benefits, and low environmental impact (named “Safe, healthy, sustainable and private travel”, 26% of the total variance

explained). It was associated with more minutes walking per week [6% (95%CI=2%, 9%)] (Table 4). The second describes those that value short travel time, predictability, reliability and flexibility, whereas health and environment are not important (named “Short, flexible and predictable travel, do not care about health or environment”, 15% of the total variance explained). It was associated with fewer minutes walking per week [-7% (95%CI=-11%, -3%)]. The third principal component describes those that value flexibility and predictability, but also low exposure to air pollution and health benefits; comfort, safety or privacy are not important (named “Flexible and predictable travel. Health and environment are relevant, but not comfort or safety”, 12% of the total variance explained). It was associated with fewer minutes walking per week [-13% (95%CI=-17%, -8%)] (Table 4). The last component, named “Cheap and short travel” (9% of the total variance explained), basically described those who value the cost and a short travel, but no flexibility, privacy and predictability. “Cheap and short travel” was not associated with minutes walking per week [3% (95%CI=-2%, 9%)] (Table 4).

Regarding the opinion that participants had about walking for travel, minutes of walking increased monotonically with greater agreement that walking “saves time” [142% higher (95% CI: 100%, 193%) for “agree” and 181% higher (95% CI: 110%, 276%) for “very much agree”, relative to “very much disagree” (Table S12). Increasing agreement with the statement that “walking is comfortable” also was monotonically associated with higher minutes of walking [e.g. 116% higher (95% CI: 73%, 170%) for “very much agree” vs. “very much disagree or disagree”] (Table S12)”. Increased associations with “very much agree” responses regarding opinions about walking for travel were weaker but statistically significant for safety with regard to traffic and privacy (both relative to “very much disagree or disagree” responses) and personal health benefits (relative to

“very much disagree, disagree, or neutral”) (Table S12). Minutes of walking were significantly higher among those who responded “agree” vs. “very much disagree or disagree” that walking “is unpleasant due to high levels of air pollution”, but walking was not associated with “very much agree” responses to the same question. Safety with regard to crime, flexibility, and predictable travel time were not clearly associated with minutes walking per week.

Regarding the PCA of the attitude towards walking, three principal components were obtained (Table S13). The first, explaining 32% of the total variability, described those who think that walking is comfortable, safe (with regard to traffic and crime), flexible and predictable, saves time and is good for health. Basically, these are those who have a “very good opinion about walking”. This factor was associated with more minutes walking per week [10% (95%CI=7%, 14%)] (Table 4). The second principal component (13% of the total variability), describes those who think it is unpleasant due to high levels of air pollution, and it is not particularly safe (with regard to traffic and crime), but think that it saves time (Table S13). The “walking is unpleasant, but it is fast” principal factor was even more strongly associated with walking than the first principal component [23% (95%CI=16%, 30%)] (Table 4). Finally, the third principal component describes those who think that walking is not flexible nor predictable, and does not offer personal health benefits. However, they think it is safe (with regard to traffic and crime), comfortable, and, in a lesser extent, saves time (12% of the total variability) (Table S13). This principal component, named “walk is not flexible, but it is comfortable” was also associated with more minutes walking per week [13% (95%CI=7%, 19%)] (Table 4).

*Transport habits*

We obtained five principal components describing five patterns of transport habits (Table S14); those who walk and use public transport (32% of the total variability), which was strongly associated with increasing minutes walking per week [70% (95%CI=59%, 82%) (Table 4). Those who use the motorbike and the car, but not the bike (24% of the total variability), which was also associated with increasing minutes walking per week [18% (95%CI=10%, 27%)]. Those who use the motorbike but not the car (19% of the total variability), which was associated with fewer minutes walking per week [-8% (95%CI=-14%, -2%)]. Those who mainly walk but can also use other modes of transport, except the public transport (15% of the total variability), and that was also associated with increasing minutes walking per week [32% (95%CI=22%, 42%)]. Finally, those who combine public transport and the bike and do not walk (9% of the total variability), which was associated with fewer minutes walking per week [-19% (95%CI=-27%, -12%)] (Table 4).

#### *All correlates in the same model*

When we included all the different factors and principal components into one single model (Model A, Table 5), we observed that the association with having access to a car lost statistical significance, although it went towards the same direction. In contrast, the association with having access to a bike also lost statistical significance but changed direction (Model A, Table 5). The rest of associations evaluated remained similar in relation to the magnitude observed, with two exceptions: the association between “high density residential built environment” and minutes walking per week was closer to the null and lost statistical significance, and the inverse association between “low density residential built environment” and minutes walking per week became stronger but still

not statistically significant [-8% (95%CI=-16%, 1%)] [6% (95%CI)=-2%, 16%)] (Model A, Table 5).

We did not observe evidence of collinearity among the variables included in Model A, as the mean VIF value obtained was 1.28 and the highest individual VIF was 1.91 (for the variable car access). However, we observed that certain principal components of transport habits were moderately correlated with other correlates evaluated (Table S15). Model B (Table 5), which excluded transport habits principal components, produced estimates that were very similar to those from models that included the base variables and only one predictor at a time (Tables 2–4).

### ***The working/studying population***

#### *Residential built environment characteristics and other correlates*

Besides the fact that on average the working/studying population walked fewer minutes than those not working, the associations between the different correlates of walking for travel and the minutes walking per week for the working/studying population (N=6957) (Table S16, Table S17, Table S18) were consistent with the ones obtained for the whole study population (N=7875).

#### *Work/study built environment characteristics and other correlates*

Within the working/studying population, street length density of the work/study built environment was associated with minutes walking per week, with a similar magnitude [1.10 (1.03, 1.18)] to that of the residential built environment [1.11 (1.03, 1.19)] (Table S16). The magnitude of the effect was a little bit smaller for other characteristics of the work/study built environment as compared to the residential built environment (Table



S16), and in some case the association lost statistical significance. The magnitude of the effect was particularly closer to the null and not statistically significant for facility richness [1.04 (0.98, 1.11)] and density of public transport stations [1.02 (0.95, 1.09)] in the work/study environment as compared to the residential built environment [1.11 (1.03, 1.19) and 1.08 (1.02, 1.16), respectively] (Table S16). The factor analysis for the work/study built environment characteristics provided similar factors to the ones obtained for the characteristics of the residential address. The first factor described a “high density work/study area” (66% of the total variance) and the second one a “low density work/study area” (14% of the total variability) (Table S19). When these factors were included in the base model, “high density work/study area” was statistically significantly associated with increasing minutes walking per week [12% (95%CI=3%, 21%)], but not “low density work/study area” [8% (95%CI=-6%, 23%)] (Table S16). When including all correlates together in a model, results were very much alike to those obtained in previous models including the residential address (Table S20). However, both in Model A and B the importance of “short, flexible and predictable travel, don’t care about health or environment” lost statistical significance. In Model A “high density work/study area” also lost statistical significance [5% (95%CI=-3%, 13%)], whereas in Model B statistical significance remained [9% (95%CI=0%, 18%)] (Table S20).

#### *Residential and work/study built environment characteristics and other correlates*

Most participants worked or studied further than 300 m from their residence (only 263 participants lived 300 m or less from their work/study place), and only 37 further than 100 km. Distance [for each SD=23486 m the association was 5% (95%CI=-3%, 14%)], altitude difference [for each one SD=59.4 m the association was of -3% (95%CI=-7%, 2%)], and slope [for each one SD=1.08 the association was of -5% (95%CI=-11%, 1%)]

between both addresses was not statistically significantly associated with minutes walking per week.

When we conducted a factor analysis combining both the residential and the work/study built environment characteristics we obtained two main factors. The first characterized “high density residential and work/study areas” (44% of the total variability), whereas the second characterized “low density residential areas, but high density work/study areas” (19% of the total variability) (Table S19). The model only including these factors in the base model showed that the “high density residential and work/study areas” factor was associated with increasing minutes walking per week [21% (95%CI=10%, 32%)], whereas the “low density residential areas, but high density work/study areas” factor was not [-2% (95%CI=-8%, 5%)] (Table S16). When the rest of the correlates were included in the model, independently of whether principal components for transport habits were included in the model (A) or not (B), the association between “high density residential and work/study areas” and minutes walking per week remained very stable [Model A=14% (95%CI=4%, 25%), Model B=15% (95%CI=5%, 26%)] (Table 6).

## **Discussion**

The PASTA project is a unique opportunity to evaluate a number of correlates of walking for travel in different urban and cultural contexts. The study considers individual characteristics, social norms and mobility culture of the neighbourhood, values and attitude towards walking, transport habits, and the built environment characteristics to provide a complete picture of transport-related decision making (Götschi et al. 2017). Moreover, to our knowledge, this is the first study to incorporate not only the characteristics of the residential built environment but also those of the work/study built

environment, thus providing rich information about the built environment to which participants are exposed. The present study provides a number of important and innovative findings, which can be summarized in the following statements that will be discussed below: 1) living in high density residential areas, with richness of facilities, and density of public transport was associated with increased walking for travel, 2) although the presence of similar characteristics at the work/study area also associated with walking for travel, we observed that for some characteristics of the built environment the magnitude of the effect was bigger for the residential area than for the work/study area, 3) a “walk-friendly social environment” was associated with increased walking for travel, 4) minutes of walking for travel were higher among participants who valued safety, privacy, and low exposure to air pollution; on the contrary, those who tend to value flexibility, predictability, and short travel time, 5) all three factors describing different opinions about walking (ranging from good to bad) were associated with increasing minutes walking per week, 6) those who mostly used the bike or motorized vehicles (particularly the motorbike) to travel were less likely to walk for travel, while being a public transport user was strongly associated with the outcome, and 7) people who do not work or study walk for travel more than those working (full or part-time) or studying.

We used several objective (GIS-based) indicators to define the characteristics of the built environment. We observed that a number of built environment characteristics typically related to urban dense areas were associated with more minutes walking per week, particularly those related to density (e.g. street length density and connectivity), richness of facilities, and availability of public transport, which are results similar to those obtained in previous studies (Knuiman et al. 2014; Smith et al. 2017; Sugiyama et al. 2012), including a multi-country study involving data from 14 cities worldwide (Christiansen et

al. 2016). The fact that these characteristics are highly correlated with each other (r between 0.60 and 0.94 in our study) might indicate that, in order to be a “walkable” urban area, these characteristics need to somehow coexist to provide the maximum benefits of each of these characteristics, as previous studies have also suggested (Bentley et al. 2018; Christiansen et al. 2016; Knuiman et al. 2014). However, given the high correlation between them, it is difficult to disentangle the actual relevance of each characteristic and the degree of co-existence needed to achieve “walkable” urban areas. In fact, our results are in line with those observed in studies using different walkability indexes, which commonly include the built environment indicators associated with walking in the present study (Duncan et al. 2011; Frank et al. 2010). We also observed that increasing levels of NO<sub>2</sub> were associated with increasing minutes walking per week, while the opposite was true for surrounding greenness (NDVI). These two associations are also indicators of urban dense areas, as higher levels of air pollution, and lower availability of green spaces are typical characteristics of these areas. For instance, in our study the correlation between street length density and NO<sub>2</sub> was 0.64, and with surrounding greenness -0.70. Some researchers suggest that greener cities have higher rates of all-cause mortality than less green cities because the former tend to be more spread out, which requires greater car use and leads to unhealthy lifestyles (de Nazelle et al. 2011; Marquet et al. 2018). However, a large number of studies have shown the health benefits of exposure to green spaces, through mechanisms beyond the promotion of physical activity (de Keijzer et al. 2016; WHO Regional Office for Europe 2016), which highlights the necessity to pursue strategies to integrate more vegetation in the urban environment without penalizing its walkability. Similarly, air pollution has been proven to be a major health problem in cities worldwide (Giles-Corti et al. 2016; WHO 2014). Our study showed that urban dense areas are not only associated with more walking, but also with higher levels of air pollution. In

order to maximize the benefits of walking, and as motorized vehicles are the major source of exposure to air pollution in cities, it is urgent to reduce the use of these vehicles, and thereby air pollution and noise exposure, and move towards sustainable and active modes of transport. Moreover, reducing cars and motorbikes in cities could also be a way, and an opportunity, to increase greenness in public spaces and improve traffic safety (Giles-Corti et al. 2016; Nieuwenhuijsen and Khreis 2019).

In our study we observed that reporting to live in a “*walk-friendly social environment*” was associated with increased minutes of walking per week, and in fact, this principal component was moderately correlated with having a very good opinion about walking for travel ( $r=0.24$ ) and living in a built environment (high density urban area,  $r=0.22$ ) that supports such activity (Table S15). However, as our study design is cross-sectional, we cannot discard reverse causality due to self-selection. An Australian longitudinal study evaluated the association between built environment neighbourhood characteristics (1600m buffer) and transport-related walking (Knuiman et al. 2014). In the study, over 1800 participants moving to new housing developments were followed-up for 7 years; the design allowed controlling for self-selection. The results were in line with those observed in the present study: street connectivity, residential density and land-use mix were associated with increasing transport-related walking (Knuiman et al. 2014). Indeed, even if participants of the present study would have moved to areas with these desired characteristics so that they could easily walk to and from places, the results of the present study might be suggesting that these built environment characteristics in a neighbourhood facilitate walking for travel (otherwise people prone to walk would also live in places without these characteristics).

Although results pointed towards the same direction, fewer work/study built environment indicators were associated with minutes walking per week, as compared to the number of residential built environment indicators associated with the outcome of interest. However, in line with recent research (Marquet et al. 2018), once both the residential and the work/study built environments were considered, results of the present study suggest that a high density residential area is essential to facilitate or promote walking for travel, whereas a high density work/study area might help but is not as strongly associated. These results somehow make sense; where people work or study can be an area where people only go for one single purpose (to work or study), but not to do other activities that can significantly contribute to the total minutes walking per week due to transport (e.g. doing the groceries, going to organized activities, visiting friends, going to a restaurant, walk the dog, etc). In fact, in the city of Barcelona 80% of all proximity trips have a personal purpose other than work (Marquet and Miralles-Guasch 2015), which highlights the need for exploring the role of the built environment characteristics of non-residential places visited, besides work (Chaix et al. 2017).

Participants who walked more for travel had different priorities when traveling as compared to those who walked less. Valuing safety (traffic and crime), privacy, low exposure to air pollution and, to a lesser extent, low environmental impact and health benefits was associated with increasing minutes walking per week, whereas those valuing short travel, predictability, and flexibility walked less, independently of whether they cared about health and the environment. Lower travel cost did not seem to be an important criterion for either walkers or non-walkers, as we did not find associations, either when evaluating the criteria alone or when including it in a principal factor. However, we observed a moderate correlation between the principal components “cost and short travel”

and transport habit “walk and public transport” ( $r=0.21$ ), suggesting that the cost might be an important aspect for those who use public transport. On the other hand, even if participants had a negative opinion about walking, it did not seem to be important for walking for travel. Furthermore, when we conducted the PCA for opinion about walking when traveling, we found three principal components, all of which positively associated with minutes walking per week; one of the principal components described people who were very positive about walking [which moderately correlated with reporting a “walk-friendly social environment” ( $r=0.24$ )], whereas the other two described people who had a negative opinion about walking regarding certain aspects, but who also positively valued other aspects of this activity. We could not determine a principal component capturing a very negative opinion about walking. Our results might indicate that opinion about walking is important but not the main driver when choosing (or not) walking as a mode of transport. In this sense, in a study evaluating car, bike and public transport choices, Kroesen et al. suggested that, in terms of transport choice, behaviour (transport habits) influences much more the attitude (importance of criteria and opinion about modes of transport) than the other way around (Kroesen et al. 2017). In fact, in our study, when introducing all the correlates in the model, principal components of transport habits had a stronger (and more consistent) association with minutes walking per week than values and attitude towards walking. Finally, we observed that considering walking as unpleasant due to high levels of air pollution was associated with more minutes walking per week; these results may indicate that those who walk more are also more annoyed by the pollution emitted by the nearby motorized vehicles than those who (e.g.) drive these vehicles. These results are in accordance with the association observed between urban density,  $\text{NO}_2$  and more walking, as exposure to air pollution (and therefore annoyance by it) is more intense in dense urban areas. In fact, in a previous PASTA study, researchers

741 already observed that increasing NO<sub>2</sub> at the home address was associated with concern  
742 over health effects of air pollution (Dons et al. 2018). These findings reinforce the  
743 necessity to reduce motorized vehicles in cities.

744  
745 We observed that having access to a bike, and that the principal component describing  
746 those who combine public transport and the bike, were associated with less walking.  
747 However, these are expected results (substitution of walk for bike) and, in terms of  
748 pursuing policies to increase the levels of physical activity among the general population,  
749 these are not bad news. Similarly, those who mostly used a motorbike also walked fewer  
750 minutes per week on average. We identified a transport habit profile of people who  
751 combine the use of the motorbike ( $r$  with the profile=0.53) and the car ( $r$ =0.38), but do  
752 not walk ( $r$ =-0.15) and definitely do not use the bike ( $r$ =-0.73) (profile “PC2” in Table  
753 S14). People in this profile, moreover, had a poor opinion of walking for travel ( $r$ =-0.19)  
754 (Table S15). We observed, however, a positive association between belonging to this  
755 profile and minutes walked per week, which are unexpected results, or at least  
756 counterintuitive. However, associations between walking and other profiles were  
757 consistent with expectation. In addition, although walking for travel does not seem to be  
758 a common option for people with moderate motorbike/car use, when they do walk, they  
759 do it for longer periods than those who never use the motorbike or the car or, on the  
760 contrary, use them daily. For instance, we observed that as compared to those who never  
761 use the motorbike (179.4 minutes walking per week), those who reported using it less  
762 than once a month (234.7 min/week), 1-3 days/month (176.3 min/week) or 1-3 days/week  
763 (183.0 min/week) walked similar or more minutes per week. As expected, those who  
764 reported daily use of the motorbike walked less (140.0 min/week). In any case, our results



require further insight in this profile of people in future research to better understand the implications of their transport habits in relation to walking.

Another finding of our study is that the use of public transport and living nearby public transport stations appear to promote walking. Several results support these conclusions: first, and as already discussed, a higher density of public transport stations, and living nearer to them, was associated with increasing minutes walking per week. Also, we identified a profile of people who combine walk and public transport which is associated with more walking as well. In fact, a natural intervention study conducted in Salt Lake City (US) observed that the extension of the light-rail service increased the number of new light-rail users, as well as the amount of physical activity among the study participants that started using this service after the intervention (Brown et al. 2015; Miller et al. 2015; Werner et al. 2016). Therefore, promoting public transport is also a way to promote walking and reach the recommended levels of physical activity. In this sense, it is important to note that in our study valuing flexibility and predictability when travelling was negatively associated with walking. However, among those valuing flexibility and predictability, there was this profile of people who also valued low exposure to air pollution and health benefits. Therefore, if the public transport service improved in terms of providing more flexibility and predictability, and if the health benefits of using public transport were promoted, this type of people may increase walking for travel.

In our study we observed that working (full or part-time) or studying was associated with fewer minutes walking per week, as compared to not working. However, when looking at the descriptive analysis we observed that (e.g.) full-time workers were, on a daily basis, less prone to walk (71.1%) but more prone to use the bike (45.1%) as compared to non-

workers (82.3% and 29.3%, respectively). This means that different profiles of people use different modes of transport and that full-time workers seem to substitute walk for bike. Somehow these results are good news, in the sense that workers are quite physically active by using the bike, and that those who are not working are physically active in their everyday life through walking. In further studies it would be interesting to evaluate to which extent physical activity levels are interchanged between both modes of transport. Higher education was also associated with less walking but, again, this could be due to the substitution of walking for biking in the highly educated group; in fact, 43.2% of the participants in this group reported daily use of the bike, whereas this percentage dropped to 32.3% among less educated people (there was a difference of 47 minutes walking per week between both groups).

Regarding limitations of the present study, the first is the cross-sectional design of the study and the risk of self-selection, with implications discussed above. Also, we used self-reported (and not objectively measured) information to quantify the amount of physical activity and particularly the amount of minutes walking for travel among participants; according to a study of Herrmann et al., the short-term reliability for travel of the GPAQ is 0.83, whereas the long-term reliability is 0.54 (Herrmann et al. 2013). However, the GPAQ, and the protocol to discard non-valid answers, is a validated and common questionnaire used in many research studies on physical activity. Furthermore, it is one of the tools used to track the evolution of levels of physical activity worldwide (Guthold et al. 2018). Thirdly, we could not include information on access to a motorbike in the models because this information was not collected; however, use of motorbike was captured by the transport habits data. Fourth, for the reasons explained in methods, we used a buffer of 300m. In other countries, with different urban designs (e.g. Australia or

the US), this distance might not be determinant as it might be too small (James et al. 2014; Knuiman et al. 2014; Sugiyama et al. 2012), or in other contexts smaller buffers would be more relevant (e.g. 100m). However, our study showed similar results when using a buffer of 500 m. In addition, due to limited resources we had to conduct all the analyses, we could not apply network buffers. However, previous research indicates that results are similar to those obtained applying other buffer techniques (Forsyth et al. 2012). Fifth, in our study we conducted a factor analysis that included the individual characteristics of both the residential and the work/study environments. Our aim was to obtain factors that would consider both aspects, however further in-depth analyses would be ideal to assess differences in the specific role of residential vs work/study addresses. Although certainly of great value, such added complexity in the analysis is beyond the scope of this publication. Sixth, because the main purpose of the study was to identify generalizable insights for planning measures, and given the complexity of the present work, we did not run city-specific analysis. To address concerns of potential city-effects on our results, we conducted sensitivity analyses in which we excluded each city one by one. Although, encouragingly, effect estimates were similar to those obtained in the main analyses, we recognize that the possibility of bias due to effect modification by city cannot be discarded. Finally, and probably one of the most important limitations, compared to the cities census data, the composition of the PASTA participants is broadly representative in terms of gender distribution, however it includes younger and better educated participants (Gaupp-Berghausen et al. 2018). This is not representative of the general population from the sociodemographic point of view, and probably also not from the behavioural. Indeed, our analyses showed that the level of education is strongly associated with walking for travel, although the reduction observed is probably due to a substitution of walking for biking in the highly educated group. It is interesting that our findings are

different from those observed in a study conducted in Australia, in which the authors reported that having a higher education was associated with more walking for travel (Bentley et al. 2018). The authors hypothesized that possibly this was reflecting the influence of health promotion, which could be the same motivation in our study to move towards biking in European cities, in addition to environmental concerns.

## **Conclusions**

Walking in our everyday life for travel purposes is a way to achieve the recommended daily levels of physical activity, and therefore strategies to promote it should be pursued. The present study supports findings from previous research regarding the role of the built environment in the promotion of walk for travel, and provides new findings to help achieving sustainable, healthy, liveable, and walkable cities, in accordance with the Sustainable Development Goals (SDGs) for cities and communities (United Nations 2017). These strategies include the improvement of the nearby residential (and also the work/study) built environment, by promoting the typical characteristics of dense urban areas, with a good and balanced street length density and connectivity, as well as building area density, a good public transport service and a diverse offer of facilities.

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**Table 1.** Description on how each built environment indicator was defined.

Indicator	Source
<b>Street length density</b> - length of streets ( $\text{m}/\text{km}^2$ )	Navteq <sup>a</sup> street data (2012)
<b>Connectivity</b> - number of junctions with node degree >1 (in order to exclude the cul-de-sac) ( $\text{n}^\circ/\text{km}^2$ )	Navteq <sup>a</sup> street intersections data (2012)
<b>Building area density</b> ( $\text{m}^2/\text{km}^2$ )	OSM / local layers (2015-2017) <sup>b</sup>
<b>Population density</b> (inhabitants/ $\text{km}^2$ )	Census / neighbourhood data (2011-2016) <sup>c</sup>
<b>Facility density index</b> - number of points of interest (POI) ( $\text{n}^\circ$ facilities/ $\text{km}^2$ )	Navteq <sup>a</sup> POI dataset (2012). For full list of POIs see <a href="https://tinyurl.com/PASTA-POI">https://tinyurl.com/PASTA-POI</a>
<b>Facility richness index</b> - number of different facility types (POI) present, divided by the maximum potential number of facility types specified ( $\text{n}^\circ$ facility types/74)	Navteq <sup>a</sup> POI data (2012). For full list of POIs see <a href="https://tinyurl.com/PASTA-POI">https://tinyurl.com/PASTA-POI</a>
<b>Density of public transport stations</b> ( $\text{n}^\circ$ of public transport stations/ $\text{km}^2$ )	OSM (and local data if available; 2015-2017) <sup>d</sup>
<b>Distance to the 1<sup>st</sup> public transport station</b> (m)	OSM (and local data if available; 2015-2017) <sup>d</sup>
<b>PM<sub>2.5</sub></b> ( $\mu\text{g}/\text{m}^3$ )	PM <sub>2.5</sub> land use regression models incorporating satellite-derived and chemical transport modelling data (de Hoogh et al. 2016) <sup>e</sup>
<b>NO<sub>2</sub></b> ( $\mu\text{g}/\text{m}^3$ )	NO <sub>2</sub> land use regression models incorporating satellite-derived and chemical transport modelling data (de Hoogh et al. 2016) <sup>e</sup>
<b>Surrounding greenness</b> (NDVI)	Landsat Satellite Images (2015-16) <sup>f</sup>
<b>Green and blue spaces indicators</b>	Land-cover map Corine 2006 (available for the whole of Europe for both urban and rural areas)

OSM: Open Street Maps (<https://www.openstreetmap.org/export>)

<sup>a</sup>Navteq is licensed data under ArcGIS software. This data is prepared for routing analysis over Europe. It contains data on Streets and Points of Interest (POI) so it identifies a wide range of categories in which the different POI (e.g. schools, libraries, cinemas, banks, restaurants, etc) are included. See the full list in this link: <https://tinyurl.com/PASTA-POI>.

<sup>b</sup>The source of information varied across cities: Antwerp: Local layer (2015) for city center and OSM (2016) for addresses outside the city, Barcelona: local layer (2013) and OSM (2017) for addresses outside the city, London: local layer (2016), Orebro, Rome, Vienna and Zurich: OSM (2017).

<sup>c</sup>The source of information varied across cities: Antwerp, Barcelona, London, Rome and Vienna: National Census (2011), Orebro: Local layer (2015) and Zurich Local and Regional layer (2016).

<sup>d</sup>The source of information varied across cities: Antwerp: OSM (2016), Barcelona: local layer (2011) and OSM (2017) for addresses outside the city, London: local layer (2011), Orebro: OSM (2017) but local layer (2015) for bus stations, Rome: OSM (2017), Vienna: OSM (2017), and Zurich: OSM (2017).

<sup>e</sup>The NO<sub>2</sub> and PM<sub>2.5</sub> air pollution grids (100m resolution; annual means,  $\mu\text{g}/\text{m}^3$ ) used are from the European wide models for these pollutants, developed for 2010. Models are based on routine air pollution monitoring data (AIRBASE database) incorporating satellite-derived and chemical transport model estimates, and road and land use data. Both NO<sub>2</sub> and PM<sub>2.5</sub> models explained ~60% of spatial variation in measured NO<sub>2</sub> and PM<sub>2.5</sub> concentrations (de Hoogh et al. 2016). Website: <http://www.sahsu.org/content/data-download>

<sup>f</sup>We followed the PHENOTYPE project (Nieuwenhuijsen et al. 2014) protocol to select the images from LANDSAT within the greenest period and having the lowest cloud cover. Green season was considered from March to July 2015. However, if there was the need to get additional usable images, these were obtained from the following year, 2016. Different images were merged to cover all the study area, and if different images overlapped in the same area, we selected the one without clouds and having the highest pixel value. Following this process, we were able to completely cover the area of study.

**Table 2.** Description of the variables included in the base model<sup>a</sup> of the associations between correlates of walking for travel and minutes walking per week (whole study population, N=7875)

	Description	Minutes walking per week (mean, SD) by category	IRR (95%CI)	Association p-val
<b>Age (mean years, min-max)</b>	39.6 (16.1-91.4)	NA	1.00 (0.99, 1.00)	0.76
<b>Gender (%)</b>				
<b>Male</b>	47.1	172 (382)	1	
<b>Female</b>	52.9	186 (352)	1.03 (0.91, 1.15)	0.66
<b>High level of education (%)<sup>b</sup></b>				
<b>No</b>	27.3	213 (406)	1	
<b>Yes</b>	72.7	166 (350)	0.82 (0.72, 0.93)	<0.001
<b>Employment status (%)</b>				
<b>Full-time worker</b>	61.6	164 (368)	1	
<b>Part-time worker</b>	16.6	150 (293)	0.91 (0.77, 1.07)	0.24
<b>Student</b>	14.1	215 (333)	0.98 (0.81, 1.18)	0.81
<b>Not working<sup>c</sup></b>	7.8	275 (417)	1.65 (1.32, 2.06)	<0.001
<b>Access to a car or van (%)</b>				
<b>Never</b>	22.7	247 (432)	1	
<b>Sometimes</b>	26.6	179 (379)	0.80 (0.68, 0.94)	0.01
<b>Always</b>	50.7	149 (323)	0.73 (0.62, 0.84)	<0.001
<b>Access to a bike (%)</b>				
<b>No</b>	19.2	303 (472)	1	
<b>Yes</b>	80.8	150 (331)	0.66 (0.57, 0.77)	<0.001

See Table S1 for proportions of observations in each variable category.

<sup>a</sup>All variables are included in the model at the same time (base model), and city included as random effect.

<sup>b</sup>No: no degree, primary school or secondary school, Yes: education above secondary school

<sup>c</sup>Home duties/ unemployed/ retired/sickness leave/ parental leave

**Table 3.** Associations between residential built environment characteristics (300 m buffer) and minutes walking per week (whole study population, N=7875).

	Exposure contrast <sup>a</sup>	IRR (95%CI)	p-val
<b>Built environment correlates (300 m buffer)<sup>b</sup></b>			
Street length density (m/km <sup>2</sup> )	7031	1.11 (1.03, 1.19)	<0.001
Street connectivity (intersections/km <sup>2</sup> )	108	1.08 (1.01, 1.16)	0.03
Building area density (m <sup>2</sup> /km <sup>2</sup> )	157735	1.08 (1.00, 1.16)	0.04
Population density (inhabitants/km <sup>2</sup> )	12822	1.09 (1.01, 1.19)	0.03
Facilities <sup>c</sup> density (n° facilities/km <sup>2</sup> )	244	1.05 (0.98, 1.12)	0.15
Facilities <sup>c</sup> richness (n° facilities types/n° facilities)	0.09	1.09 (1.03, 1.17)	0.01
Density of public transport stations (n°stations/km <sup>2</sup> )	20.2	1.07 (1.01, 1.14)	0.02
Distance to the 1 <sup>st</sup> public transport station (m)	117	0.94 (0.89, 1.00)	0.04
PM <sub>2.5</sub> (µg/m <sup>3</sup> )	3.5	1.11 (0.93, 1.31)	0.24
NO <sub>2</sub> (µg/m <sup>3</sup> )	10.5	1.11 (1.01, 1.21)	0.03
Surrounding greenness (NDVI)	0.26	0.80 (0.70, 0.90)	<0.001
Distance to the closest major GS (m)	1179	1.01 (0.94, 1.07)	0.87
Area of the closest GS (km <sup>2</sup> )	186	1.00 (0.94, 1.06)	0.96
Access to major GS (within 300m)	Yes	0.93 (0.80, 1.08)	0.35
Distance to the closest major BS (m)	2712	0.98 (0.93, 1.04)	0.54
Area of the closest BS (km <sup>2</sup> )	37506	1.07 (0.99, 1.16)	0.09
Access to major BS (within 300m)	Yes	0.96 (0.71, 1.31)	0.80
<b>Factors for built environment correlates obtained through factor analysis<sup>d</sup> (% of the total variance explained by each factor)</b>			
1) High density residential area (75%) <sup>e</sup>		1.12 (1.03, 1.22)	0.01
2) Low density residential area (11%) <sup>f</sup>		0.97 (0.88, 1.06)	0.49

GS: green spaces, BS: blue spaces; NDVI: normalized difference vegetation index.

<sup>a</sup>All variables were scaled based on the mean and standard deviation (SD) (all cities together) and therefore the unit of contrast is the SD, with the exception of access to green and blue spaces (binary variables) and surrounding greenness (we used the interquartile range - IQR).

<sup>b</sup>Variables were included one by one to the base model (base model: age, gender, employment status, access to a car and access to a bike). City was included as random effect.

<sup>c</sup>Definition of "facilities": private and public points of interest including shops, schools, theatres and leisure activities, supermarkets, administration offices, banks, hospitals...motorized vehicle related points were excluded (e.g. parking lots, petrol stations...).

<sup>d</sup>Variables (none scaled) included in the factor analysis: Residential street length density, connectivity, built area density, population density, density and richness of facilities, public transport station distance and density, PM<sub>2.5</sub>, NO<sub>2</sub>, surrounding greenness and area of and distance to the closest green and blue spaces. See Table S5 for factor loadings.

<sup>e</sup>High density residential area: high street length density and connectivity, building area density, population density, density and richness of facilities, density of public transport stations and high air pollution but low surrounding greenness.

<sup>f</sup>Low density residential area: low street length density and connectivity and low density of public transport stations, certain air pollution.

1044 **Table 4.** Associations between principal components of a) social norms and mobility culture in  
1045 the neighbourhood, b) attitude towards walking (based on importance of criteria and opinion about  
1046 walking), c) transport habits, and minutes walking per week (whole study population, N=7875)

	Principal component (% of the total variance explained by each principal component)	IRR (95%CI)	p-val
<b>Model 1: Social norms and mobility culture in the neighbourhood with regard to walking<sup>a</sup></b>			
	1) "The walk-friendly social environment": most people think that I should walk "for travel", my neighbourhood walking is well regarded, and in my neighbourhood it is common for people to walk "for travel" (53%)	1.09 (1.05, 1.14)	<0.001
<b>Values and attitude towards walking for travel</b>			
<b>Model 2: Importance of (criteria)<sup>b</sup></b>			
	1) "Safe, healthy, sustainable and private travel": safety (traffic and crime), low exposure to air pollution, privacy, health benefits, and low environmental impact (26%)	1.06 (1.02, 1.09)	<0.001
	2) "Short, flexible and predictable travel, do not care about health or environment": short travel time, predictable travel time and journey reliability, and flexible departure time. Health benefits and low environmental impact are not important (15%)	0.93 (0.89, 0.97)	<0.001
	3) "Flexible and predictable travel. Health and environment are relevant, but not comfort or safety": low exposure to air pollution and health benefits are important, as well as flexibility and predictability, but not being comfortable, safe or providing privacy (12%)	0.87 (0.83, 0.92)	<0.001
	4) "Cheap and short travel": cost and short travel are very important, but not flexibility, privacy or predictability (explains 9%)	1.03 (0.98, 1.09)	0.26
<b>Model 3: Opinion about walking<sup>c</sup></b>			
	1) "Very good opinion about walking": is comfortable, safe (traffic and crime), is flexible and predictable, saves time and is good for health (32%)	1.10 (1.07, 1.14)	<0.001
	2) "Walking is unpleasant, but it is fast": is unpleasant due to high levels of air pollution, it saves time but it is not particularly safe (traffic and crime) (13%)	1.23 (1.16, 1.30)	<0.001
	3) "Walk is not flexible, but it is comfortable": it is not flexible (departure time), nor predictable, and does not offer personal health benefits. It is safe and comfortable and somehow saves time (12%)	1.13 (1.07, 1.19)	<0.001
<b>Model 4: Transport habits<sup>d</sup></b>			
	1) Walk and use public transport (32%)	1.70 (1.59, 1.82)	<0.001
	2) Use the car and motorbike, but not the bike (24%)	1.18 (1.10, 1.27)	<0.001
	3) Use the motorbike, but not the car (19%)	0.92 (0.86, 0.98)	0.02
	4) Walk but also use other modes of transport except public transport (15%)	1.32 (1.22, 1.42)	<0.001
	5) Use public transport and the bike (but do not walk) (9%)	0.81 (0.73, 0.88)	<0.001
1047	Each type of factor was included separately in the base model (base model: age, gender, employment		
1048	status, access to a car and access to a bike), so Table 4 shows the results of four separate models		
1049	(Models 1 to 4). City was included as random effect.		
1050	PCA: principal component analysis.		
1051	<sup>a</sup> Variables included in the PCA: most people who are important to me think that I should walk "for		
1052	travel", in my neighbourhood walking is well regarded, in my neighbourhood it is common for people		
1053	to walk "for travel". See Table S9 for factor loadings.		
1054	<sup>b</sup> Variables included in the PCA: "importance of" short travel time, lower travel cost, higher travel		
1055	comfort, safer travel with regard to traffic, safer travel with regard to crime, lower exposure to air		
1056	pollution, privacy, personal health benefits, low environmental impact, flexible departure time, more		
1057	predictable time and journey reliability. See Table S11 for factor loadings.		
1058	<sup>c</sup> Variables included in the PCA: "walking for travel" saves time, is comfortable, is safe with regard to		
1059	traffic, is safe with regard to crime, is unpleasant because of high levels of air pollution, offers privacy,		
1060	offers personal health benefits, offers flexibility, offers predictable travel time. See Table S13 for factor		
1061	loadings.		

1062 <sup>d</sup>Variables included in the PCA: answers provided for each type of transport (walk, (electric) bicycle,  
1063 motorcycle, public transport, car or van) to the question "*How often you use (transport type) to get to*  
1064 *and from places?*". Possible answers: daily or almost daily, on 1-3 days/week, on 1-3 days/month, less  
1065 than once a month, never, don't know. See Table S14 for factor loadings.

1066 **Table 5.** Associations between the different factors or principal components and minutes walking  
1067 per week (whole study population, N=7875)  
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Population characteristics, and factor or principal component <sup>a</sup>	IRR (95%CI)	p-value	IRR (95%CI)	p-val
	Model A <sup>a</sup>		Model B <sup>a</sup>	
Age	1.00 (0.99, 1.00)	0.19	1.00 (0.99, 1.00)	0.08
Gender (female)	0.96 (0.85, 1.08)	0.47	1.01 (0.90, 1.14)	0.85
High level of education (yes) <sup>b</sup>	0.75 (0.65, 0.85)	<0.001	0.82 (0.72, 0.93)	<0.001
Employment status (full-time worker is reference)				
Part-time worker	0.86 (0.73, 1.02)	0.08	0.91 (0.77, 1.06)	0.22
Student	0.91 (0.75, 1.09)	0.30	0.97 (0.80, 1.17)	0.73
Not working <sup>c</sup>	1.43 (1.15, 1.78)	<0.001	1.54 (1.23, 1.91)	<0.001
Access to a car or van (never is reference)				
Sometimes	0.92 (0.77, 1.09)	0.33	0.87 (0.74, 1.02)	0.09
Always	0.89 (0.73, 1.08)	0.22	0.82 (0.70, 0.95)	0.01
Access to a bike (yes)	1.09 (0.89, 1.32)	0.41	0.67 (0.57, 0.77)	<0.001
<b>Factors of the residential built environment characteristics (300 m buffer)</b>				
High density residential area	1.06 (0.98, 1.16)	0.15	1.09 (1.00, 1.18)	0.05
Low density residential area	0.92 (0.84, 1.01)	0.09	0.96 (0.88, 1.06)	0.46
<b>PCs of the social norms and mobility culture in the neighbourhood with regard to walking</b>				
Walk-friendly social environment	1.06 (1.01, 1.11)	0.02	1.05 (1.01, 1.10)	0.02
<b>PCs of the values and attitude towards walking for travel</b>				
<b>Importance of (criteria)</b>				
Safe, healthy, sustainable and private travel	1.05 (1.01, 1.09)	0.01	1.03 (1.00, 1.07)	0.08
Short, flexible and predictable travel, do not care about health or environment	0.96 (0.92, 1.00)	0.05	0.95 (0.91, 0.99)	0.02
Flexible and predictable travel. Health and environment are relevant, but not comfort or safety	0.88 (0.84, 0.93)	<0.001	0.85 (0.81, 0.90)	<0.001
Cheap and short travel	1.01 (0.96, 1.06)	0.76	1.03 (0.98, 1.09)	0.29
<b>Opinion about walking</b>				
Very good opinion about walking	1.09 (1.05, 1.12)	<0.001	1.11 (1.07, 1.15)	<0.001
Walking is unpleasant, but it is fast	1.15 (1.08, 1.22)	<0.001	1.19 (1.13, 1.27)	<0.001
Walk is not flexible, but it is comfortable	1.12 (1.07, 1.18)	<0.001	1.11 (1.05, 1.17)	<0.001
<b>PCs of the transport habits</b>				
Walk and use public transport	1.65 (1.54, 1.77)	<0.001	-	-
Use the car and motorbike, but not the bike	1.24 (1.15, 1.33)	<0.001	-	-
Use the motorbike, but not the car	0.92 (0.86, 0.98)	0.02	-	-
Walk but use other modes of transport except public transport	1.31 (1.22, 1.41)	<0.001	-	-
Use public transport and the bike (but do not walk)	0.82 (0.75, 0.90)	<0.001	-	-

1069: principal components

1070 Model A includes all factors, Model B excludes "Transport habits". City was included as random effect. See Table  
1071 factor loadings (built environment) and Table 4 for the description of each principal component.

1072 no degree, primary school or secondary school, Yes: education above secondary school.

1073 me duties/ unemployed/ retired/sickness leave/ parental leave

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**Table 6.** Associations between factors of residential and work/study built environment characteristics, other principal components, and minutes walking per week (working/studying study population, N=6957)

Population characteristics, and factor or principal component of each factors <sup>a</sup>	IRR (95%CI)	p-value	IRR (95%CI)	p-value
	Model A <sup>a</sup>		Model B <sup>a</sup>	
<b>Age</b>	1.00 (0.99, 1.00)	0.65	1.00 (0.99, 1.00)	0.18
<b>Gender (female)</b>	0.95 (0.84, 1.08)	0.45	1.02 (0.90, 1.16)	0.76
<b>High level of education (yes)<sup>b</sup></b>	0.73 (0.63, 0.84)	<0.001	0.81 (0.70, 0.93)	<0.001
<b>Employment status (full-time worker is reference)</b>				
Part-time worker	0.87 (0.74, 1.02)	0.08	0.92 (0.78, 1.08)	0.29
Student	0.90 (0.74, 1.09)	0.28	0.99 (0.81, 1.20)	0.91
<b>Access to a car or van (Never is reference)</b>				
Sometimes	0.94 (0.79, 1.12)	0.51	0.87 (0.73, 1.03)	0.11
Always	0.94 (0.78, 1.15)	0.57	0.81 (0.69, 0.96)	0.01
<b>Access to a bike (yes)</b>	1.21 (0.99, 1.48)	0.07	0.65 (0.55, 0.76)	<0.001
<b>Factors of the residential and work/study built environment characteristics (300m buffer)</b>				
High density residential and work/study areas	1.14 (1.04, 1.25)	<0.001	1.15 (1.05, 1.26)	<0.001
Low density residential, but high work/study areas	0.94 (0.88, 1.00)	0.06	0.99 (0.93, 1.06)	0.85
<b>PCs of the social norms and mobility culture in the neighbourhood</b>				
Walk-friendly social environment	1.06 (1.01, 1.11)	0.02	1.05 (1.00, 1.10)	0.06
<b>PCs of the values and attitude towards walking for travel</b>				
<b>Importance of (criteria)</b>				
Safe, healthy, sustainable and private travel	1.05 (1.01, 1.09)	0.01	1.04 (1.00, 1.07)	0.06
Short, flexible and predictable travel, do not care about health or environment	0.98 (0.93, 1.02)	0.35	0.96 (0.92, 1.01)	0.12
Flexible and predictable travel. Health and environment are relevant, but not comfort or safety	0.89 (0.84, 0.94)	<0.001	0.85 (0.81, 0.90)	<0.001
Cheap and short travel	1.00 (0.94, 1.06)	0.91	1.02 (0.96, 1.08)	0.62
<b>Opinion about walking</b>				
Very good opinion about walking	1.08 (1.04, 1.12)	<0.001	1.11 (1.07, 1.15)	<0.001
Walking is unpleasant, but it is fast	1.13 (1.06, 1.20)	<0.001	1.19 (1.12, 1.27)	<0.001
Walk is not flexible, but it is comfortable	1.14 (1.07, 1.20)	<0.001	1.12 (1.06, 1.19)	<0.001
<b>PCs of the transport habits</b>				
Walk and use public transport	1.78 (1.67, 1.90)	<0.001	-	-
Use the car and motorbike, but not the bike	1.31 (1.21, 1.41)	<0.001	-	-
Use the motorbike, but not the car	0.92 (0.86, 0.98)	0.01	-	-
Walk but use other modes of transport except public transport	1.32 (1.23, 1.42)	<0.001	-	-
Use public transport and the bike (but do not walk)	0.79 (0.72, 0.87)	<0.001	-	-

<sup>a</sup>PCs: principal components

<sup>b</sup>Model A includes all factors, Model B excludes "Transport habits". City was included as random effect. See Table S19 for factor loadings (built environment); the first factor "High density residential and work/study areas" (B1 in Table S19) describes participants with built characteristics related to "high density" in both the residential and the work/study addresses, while the second factor "Low density residential, but high work/study areas" (B2 in Table S19) describes participants with "low density residential" areas and "high work/study areas".

<sup>c</sup>no degree, primary school or secondary school, Yes: education above secondary school.