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Dog ownership, the natural outdoor environment and health: a cross-sectional study

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ABSTRACT

Objectives Dog owners walking their dog in natural outdoor environments (NOE) may benefit from the physical activity facilitated by dog walking and from time spent in nature. However, it is unclear whether dog owners receive additional health benefits associated with having access to NOE above the physical activity benefit of walking with their dog. We investigated associations between dog ownership, walking, time spent in NOE and health and whether these associations differed among those with good and poor access to NOE and those living in green and less green areas.

Design Cross-sectional study.

Setting The Positive Health Effects of the Natural Outdoor Environment in Typical Populations in Different Regions in Europe project.

Participants n=3586 adults from Barcelona (Spain), Doetinchem (the Netherlands), Kaunas (Lithuania) and Stoke-on-Trent (UK).

Data collection and analysis We calculated access to NOE with land maps and residential surrounding greenness with satellite data. Leisure time walking, time spent in NOE and general and mental health status were measured using validated questionnaires. Associations were estimated using multilevel analysis with a random intercept defined at the neighbourhood level.

Results Dog ownership was associated with higher rates of leisure time walking and time spending in NOE (OR 2.17, 95% CI 1.86 to 2.54 and 2.37, 95% CI 2.02 to 2.79, respectively). These associations were stronger in those living within 300 m of a NOE and in greener areas. No consistent associations were found between dog ownership and perceived general or mental health status.

Conclusions Compared with non-dog owners, dog owners walked more and spent more time in NOE, especially those living within 300 m of a NOE and in greener areas. The health implications of these relationships should be further investigated. In a largely physically inactive society, dog walking in NOE may be a simple way of promoting physical activity and health.

Strengths and limitations of this study

- This is one of the first studies from mainland Europe, and the multicity approach revealed differences between cities concerning dog ownership and health.
- The assessment of access to natural outdoor environments suitable for physical activity using road network buffers was chosen to optimally capture the relation with people's walking behaviour.
- The use of multiple exposure indicators of natural outdoor environments enabled studying these exposure indicators simultaneously, and could help understand what metric best predicts the health benefits associated with natural outdoor environments.
- We cannot establish the direction of the observed relationships because of the cross-sectional study design.
- We had no detailed information about dog ownership (eg, level of attachment, duration of dog ownership, primary caretaker) and we did not know if the time spent in natural outdoor environments and leisure time walking was undertaken together with the dog.

INTRODUCTION

In an urbanised world, where people spend the majority of their time indoors,[1] physical inactivity is a major public health problem.[2] It leads to adverse health effects and it is a large economic burden for society.[3] Physical activity behaviour is influenced by many factors. Apart from individual-level factors including age, sex and health status, the built environment is an important determinant of physical activity.[4 5] Aspects of the built environment such as the availability of parks are associated with increased physical activity, especially walking.[6 7] It is important to identify sustainable built environment interventions for increasing physical activity and improving health.

Promotion of walking could be a population-level strategy to address physical inactivity. As such, and considering the prevalence of dog ownership (eg, 18% in the Netherlands[8]), dog walking has been identified as a simple way of promoting physical activity.[9–12] There is strong evidence to suggest that dog

owners walk more often and are more physically active than non-dog owners.[12–14] This association has been observed in adults,[15 16] adolescents and children,[17–19] in groups with potential limited mobility such as older adults[20–22] and in people with a chronic disease.[23] Consequently, dog walking may lead to better health over time, with benefits ranging from improved well-being[24] to fewer doctor visits[25] and a lower risk of cardiovascular disease and mortality.[26]

However, not all studies show health benefits of dog ownership[27–29] and a large proportion of dog owners do not walk their dog.[30 31] Of the various factors that influence dog walking behaviour, aspects of the built environment seem to be among them.[11] Supportive environments, such as neighbourhoods with parks and other types of green infrastructure, are associated with higher physical activity levels of dog owners and are important for promoting dog walking.[10 11 32] Specifically, better park access and park quality (eg, presence of dog litter bags, water sources) were related to dog walking.[11 33 34] Not all dog owners have access to parks thus improving access to parks in residential areas could be important for facilitating dog walking, especially since local parks are a common place for dog walking.[35] Parks also provide an opportunity for nature contact. Spending time in natural outdoor environments (NOE), such as parks, has been associated with health benefits, for example, through facilitating stress reduction, restoration and social contact.[36–38] Dog owners walking their dog in NOE may benefit from the physical activity facilitated by owning a dog as well as time spent in nature. However, it is unclear whether dog owners receive additional health benefits associated with having access to NOE. According to the theories of health behaviour[39] and the social ecological framework,[40] identifying the environmental factors that influence health outcomes (eg, access to NOE) could lead to potential intervention strategies that could eventually improve health.

The aim of this study was to investigate the relationships between dog ownership, walking the NOE and health. In line with above-mentioned studies and health behaviour theories, we hypothesised that dog owners walk more, spend more time in NOE and are healthier than non-dog owners, and that the health benefits are more apparent in dog owners within green neighbourhoods and with access to NOE compared with those in less green areas and with poor NOE access. We therefore investigated the associations between dog ownership, leisure time walking, time spent in NOE and general and mental health status, and whether these associations differed among those with good and poor access to NOE and those living in green and less green areas.

METHOD

Study design and participants

This study analysed data from the Positive Health Effects of the Natural Outdoor environment in Typical Populations in different regions in Europe project. Respondents were recruited from 30 different neighbourhoods in Barcelona (Spain), Doetinchem (the Netherlands), Kaunas (Lithuania), and Stoke-on-Trent (UK).[41 42] Neighbourhoods were selected to maximise variability in access to NOE and socioeconomic status. In order to arrive at a final sample of approximately 1000 respondents per city, a random sample of 30–35 addresses per neighbourhood were mailed with a letter explaining the purpose of the project after which they were visited by interviewers. In Doetinchem, persons were asked to send back an answer card to indicate their willingness to participate before they were visited by the interviewers; and in Kaunas, persons were approached by mail to fill out postal questionnaires. Respondents needed to have an age between 18 and 75 years and to be able to speak the local language. Data were collected using interview-administered questionnaires (except in Kaunas, where self-administered questionnaires were used) at respondents' residences during May–November 2013. The study was conducted in accordance with the Declaration of Helsinki. All respondents provided written informed consent.

Patient and public involvement

Participant and stakeholder involvement and dissemination of results was organised in multiple ways through symposia, workshops, online media channels and newsletters. Members of the public were not directly involved in the design or conception of the study.

Explanatory variables

Dog ownership

Dog ownership was assessed using the question: "Do you own a dog" (yes; no).

Natural outdoor environment

Access to NOE was estimated with land use maps from local sources in each city (details in the study by Smith *et al*[42]). Only NOE that were publicly available; suitable for physical activity and at least 0.5 hectare (eg, parks, semi-natural/natural land, formal recreation grounds) or 0.25 hectare (natural/green corridors) were selected as these were relevant for physical activity[42] and therefore potentially relevant in terms of the health benefits of NOE for dog owners. Road network buffers were chosen over circular buffers in order to capture a more realistic measure of NOE accessibility on foot,[43] which may be most relevant to dog walking. We furthermore used three predetermined buffer sizes to obtain a better understanding of what distance to NOE is most beneficial to health.[44] Using GIS we constructed three indicators: (1) the number of, and (2) the total surface area NOE within road network buffers of 300, 500 and 1000 m, and (3) the road network distance to the nearest NOE (figure 1). The number of and area of NOE were dichotomised using the city-specific median values. Distance to nearest NOE was dichotomised using a 300 m cut-off according to guidelines.[45]

Residential surrounding greenness was assessed using the normalised difference vegetation index (NDVI). The NDVI is a measure of vegetation and represents the photosynthetic activity in an area.[42 46] Healthy vegetation

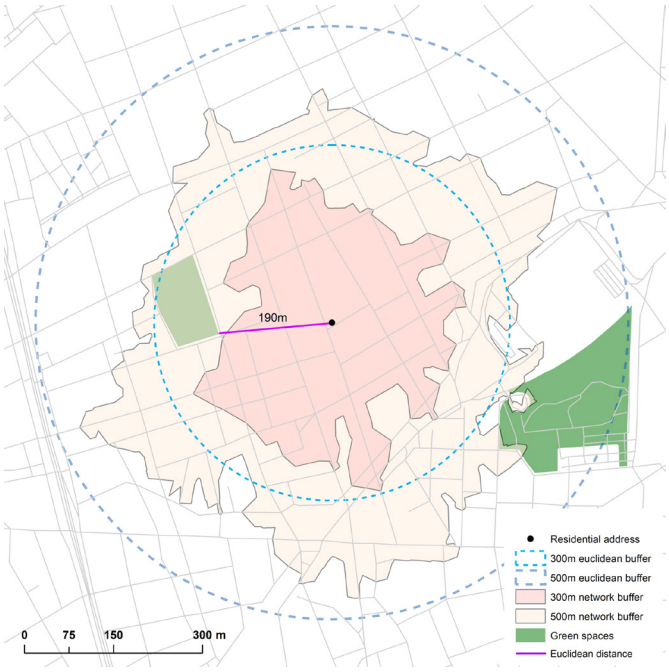

Figure 1 Example of different buffer types and the distance to natural outdoor environments from a residential address.

absorbs most visible light and reflects large parts of near-infrared light, while sparse vegetation reflects more visible light and less near-infrared light. Based on this distinction a value between −1 and +1 is calculated, with higher values indicating a higher density of green vegetation.[46] The NDVI was derived from Landsat 5 and 8 satellite images at a resolution of 30 m×30 m on cloud-free images within the greenest season (April to September) in the relevant period for this study (2011–2013). Average NDVI values were calculated within (Euclidean) buffers of 100, 300 and 500 m around the residence, as used in previous research[47 48] and dichotomised using the city-specific median value.

Outcome variables

Leisure time walking

Walking in leisure time was assessed by the following questions: "When thinking about a normal week in the past month how many days per week do you walk in your leisure time" and "How much time (minutes) per day do you spend walking in your leisure time". These items were derived from the short questionnaire to assess health-enhancing physical activity (SQUASH).[49] The SQUASH is a valid measure of physical activity.[49 50] Duration and frequency of walking was multiplied to create a composite variable of minutes per week of leisure time walking. This composite variable was then dichotomised using the median (120 min/week) as a cut point. City-specific cut points were made for city-specific analyses (Barcelona: 120 min/week; Doetinchem: 120 min/week; Kaunas: 240 min/week and Stoke-on-Trent: 20 min/week).

Time spent in NOE

NOE were defined as all public and private outdoor spaces that contain 'green' and/or 'blue' natural elements such as street trees, forests, city parks and natural parks/reserves, and also included all types of waterbodies such as canals, ponds, creeks, rivers, beaches. Time spent in NOE was assessed using two questions: "How often did you visit/go in the last 4 weeks on purpose to green or blue space near your home?" (5-point response scale ranging from 'never' (1) to 'almost daily' (5)); and "How much time did you spend in a green or blue space near your home?" (4-point response scale ranging from <1 hour (1) to 6–10 hours (4)). A composite variable was created to determine the amount of time (frequency of visits multiplied by average duration per visit) respondents spent in NOE near home per month. As frequency and duration were assessed with questions with categorical response scales, the central value of each answer category for frequency were multiplied with central value of each answer category for duration (eg, 3–5 hours/month was coded as 4 hours/month). The composite variable was then dichotomised using the median (4 hours/month) as a cut point. City-specific cut points were made for city-specific analyses (Barcelona: 3.75 hours/month; Doetinchem: 10 hours/month; Kaunas: 4 hours/month and Stoke-on-Trent: 1 hour/month).

General health status

General health status was assessed using the question: "In general what would you say your health is?" (5-point response scale: excellent to poor), which was derived from the Medical Outcome Study Short Form Health Survey (SF-36).[51] Scores were dichotomised into 'fair or poor' (0) and 'excellent, very good and good' (1). This single question has been found to be associated with poor health outcomes in the general population.[52 53]

Mental health

Mental health was assessed using the SF-36 mental health subscale, including five items (eg, nervousness, depression), and is a valid and reliable measure of mental health.[54] Respondents rated the occurrence of symptoms in the past 4 weeks on a 6-point scale ranging from 'all of the time' (1) to 'none of the time' (6). A sum score was calculated and transformed into a scale ranging from 0 to 100 according to guidelines,[51] with higher scores indicating better mental health. When ≥3 items were missing, respondents were excluded from the analyses, but when one to two items were missing, missing values were replaced by the average score of the other items. We did this for 17 respondents. Analyses including and excluding these 17 respondents did not alter the results.

Covariates and other variables

Information about sociodemographic factors included sex, age, educational level (primary school or no education; secondary school/further education (up to 18 years); university degree or higher), household composition

(alone; with partner (without children); with children aged <12 years with children aged >12 years and other), perceived income situation (cannot make ends meet; enough to get by; comfortable), frequency of contact with family and/or friends (almost daily; ≥1 per week; 1–3 per month or less) and whether respondents feel part of a group of friends ((totally) agree; neutral, (totally) disagree). We also included perceived safety of neighbourhood NOE (very satisfied; satisfied; neutral; dissatisfied; very dissatisfied). Health-related factors included disability restricting mobility (yes; no), one or more chronic diseases (yes; no), body mass index (BMI) (based on self-reported height and weight: healthy weight ≤25 kg/m^2; overweight 25–30 kg/m^2; obese >30 kg/m^2) and smoking status (current; former; never). Neighbourhood socioeconomic status (SES, low; intermediate; high) was based on country-specific data (Barcelona: deprivation index based on census data 2001[55]; Doetinchem: average monthly household income per 6-digit zip code level[56]; Kaunas: neighbourhood education level[57]; Stoke-on-Trent: English indices of deprivation 2010[58]).

Statistical analyses

Equivalence tests with Benjamini-Hochberg adjustments for false discovery rates (5%)[59] were used to test for differences between dog owner and non-dog owner characteristics. To investigate the association between dog ownership, and outcomes leisure time walking, time spent in NOE and general and mental health status, and whether these associations differed for respondents with good/poor access to NOE and high/low residential surrounding greenness, we investigated:

1. The associations between dog ownership, and outcomes leisure time walking, time spent in NOE, general health status and mental health.
2. The associations specified at 1, stratified by NOE access (good and poor) and by residential surrounding greenness (high and low) to investigate whether the associations between dog ownership and the outcomes differ in these subgroups.

Associations were estimated using multilevel analysis with a random intercept defined at the neighbourhood level. Associations with leisure time walking, time spent in NOE and general health status were estimated with logistic regression because of the dichotomisation of the data; and since mental health scores were normally distributed, associations were estimated with linear regression. Models were adjusted for age, sex, education level, household composition, perceived income situation, neighbourhood SES, NOE safety, disability restricting mobility and chronic diseases and were selected because of an assumed relation with dog ownership, walking, time spent in NOE and health. The main associations (as specified at 1) were also estimated for the cities separately. Stratified analyses by access to NOE and residential surrounding greenness were undertaken with indicators in all buffer sizes, but the 500 m buffer was reported in the main table and the remaining buffer sizes in the online supplementary file. Analyses were based on complete cases (missing data differed by outcome and ranged between n=360 and 416). All analyses were performed in STATA V.14.2 (StataCorp, Release 14 April 2015).

Sensitivity analyses were undertaken to investigate whether additional adjustment for covariates changed the associations. Additional adjustments were carried out for characteristics that were found to differ between dog owners and non-dog owners and that may relate to health (smoking and BMI), or that have been found to be mediators of the dog ownership-health relationship (frequency of contact with family and/or friends, and whether respondents feel part of a group of friends).[60 61]

RESULTS

Population characteristics

Respondents were on average aged 51.4 (SD 15.9) years and 54.9% were female. A total of 1109 (30.9%) respondents were dog owners. Dog owners compared with non-dog owners were on average the same age, had similar educational attainment but more were female (59.6% vs 53.3%) and reported lower perceived income security. Dog ownership varied across cities, with it being highest in Kaunas (41.1%) and lowest in Doetinchem (16.5%). Dog owners walked more and spent more time in NOE compared with non-dog owners. However, dog owners had a lower perceived general and mental health status compared with non-dog owners. Dog owners also reported more frequently that physical constraints restricted their mobility, had more often a chronic disease and had higher BMI than non-dog owners (table 1).

Dog ownership, leisure time walking, time spent in NOE and health

Adjusted multilevel models showed that dog ownership was associated with increased odds of walking ≥121 min per week (ie, higher than the median amount of walking) (OR 2.17, 95% CI 1.86 to 2.54) compared with non-dog owners. Dog ownership was also associated with increased odds of spending ≥4 hours/month in NOE (ie, higher than the median amount of time in NOE) (OR 2.37, 95% CI 2.02 to 2.79) compared with non-dog owners. There were no differences in perceived general health status and mental health between dog owners and non-dog owners. City-specific analyses showed similar results, with some exceptions: a positive association between dog ownership and perceived general health in Barcelona (OR 1.90, 95% CI 1.01 to 3.56); and a positive association between dog ownership and mental health in Stoke-on-Trent (β=2.61, 95% CI 0.35 to 4.86) (table 2 and online supplemental table S1).

Stratified analyses by access to NOE and residential surrounding greenness

Generally, stratified analyses showed that the associations between dog ownership and leisure time walking by number and area of NOE were similar. The OR for

Table 1 Population characteristics by dog ownership

	Total n=3586	Non-dog owner n=2478	Dog owner n=1108	Adjusted p value*
Age, mean (SD)	51.4 (15.9)	51.3 (15.9)	51.7 (16.0)	0.474
Sex, n (females %)	1967 (54.9)	1314 (53.0)	653 (58.9)	0.001
Household composition, n (%)				0.001
Alone	614 (17.1)	461 (18.6)	153 (13.8)	
With partner (without children)	1239 (34.5)	864 (34.9)	375 (33.8)	
With children aged <12 years	535 (14.9)	383 (15.5)	152 (13.7)	
With children aged >12 years	602 (16.8)	368 (14.9)	234 (2112)	
Other	597 (16.6)	402 (16.2)	195 (17.6)	
City, n (%)				0.001
Barcelona	979 (27.3)	790 (31.9)	189 (17.1)	
Doetinchem	851 (23.7)	668 (27.0)	183 (16.5)	
Kaunas	892 (24.9)	436 (17.6)	456 (41.1)	
Stoke-on-Trent	864 (24.1)	584 (23.6)	280 (25.3)	
Education, n (%)				0.530
Low	251 (7.0)	163 (6.6)	88 (7.9)	
Medium	1568 (43.7)	1087 (43.9)	481 (43.5)	
High	1767 (49.3)	1228 (49.6)	539 (48.6)	
Perceived income situation, n (%)				0.001
Cannot make ends meet	385 (10.7)	276 (11.1)	109 (9.8)	
Enough to get by	1800 (50.2)	1165 (47.0)	635 (57.3)	
Comfortable	1401 (39.1)	1037 (41.9)	364 (32.9)	
Weight status (BMI categories), n (%)				0.001
Healthy weight	1610 (44.9)	1165 (47.0)	445 (40.2)	
Overweight	1192 (33.2)	819 (33.1)	373 (33.6)	
Obese	784 (21.9)	494 (19.9)	290 (26.2)	
Physical constraint restricting mobility, n (%)	1003 (25.4)	536 (19.9)	467 (37.3)	0.001
One or more chronic diseases, n (%)	1313 (36.6)	860 (34.7)	453 (40.9)	0.001
Smoking, n (%)				0.020
Current	733 (20.5)	478 (19.3)	255 (23.0)	
Former	1008 (28.1)	724 (29.2)	284 (25.6)	
Never	1843 (51.4)	1275 (51.5)	568 (51.3)	
Frequency of contact with family and/or friends, n (%)				0.299
(Almost) daily	2135 (59.5)	1470 (59.3)	665 (60.0)	
≥1 per week	1114 (31.1)	781 (31.1)	333 (30.0)	
1–3 per month or less	392 (9.4)	227 (9.2)	111 (10.0)	
Feeling part of a group of friends, n %				0.001
(Totally) agree	2414 (67.5)	1754 (70.9)	660 (59.7)	
Neutral, (totally) disagree	1165 (32.5)	719 (29.1)	446 (40.3)	
Perceived safety of NOE in NBH, n (%)				0.016
(Very) satisfied	2123 (59.2)	1486 (60.0)	637 (57.5)	
Neutral	776 (21.6)	542 (21.9)	234 (21.1)	
(Very) dissatisfied	687 (19.2)	450 (18.2)	237 (21.4)	
NBH SES, n (%)				0.474

Continued

Table 1 Continued

	Total n=3586	Non-dog owner n=2478	Dog owner n=1108	Adjusted p value*
Low	1131 (31.5)	791 (31.9)	340 (30.7)	
Medium	1379 (38.4)	938 (37.9)	441 (39.8)	
High	1076 (30.0)	749 (30.2)	327 (29.5)	
Minutes/week walking (leisure), median (IQR)	120 (300)	90 (240)	180 (420)	0.001
Hours spent in NOE near home in last 4 weeks, median (IQR)	4 (11.8)	3.75 (10)	10 (29.3)	0.001
General health, n (%)				0.001
Excellent, (very) good	2662 (74.2)	1939 (78.3)	723 (65.2)	
(Very) bad	924 (25.8)	539 (21.8)	385 (34.8)	
Mental health (SF-36), mean (SD)	73.5 (16.3)	73.9 (16.2)	72.5 (16.3)	0.01
Distance to nearest NOE (m), median (IQR)	161.0 (214)	155.7 (205.6)	172.4 (232.4)	0.001
Number of NOE in 300 m NWB, median (IQR)	1 (1)	1 (2)	1 (2)	0.001
Number of NOE in 500 m NWB, median (IQR)	1 (1)	3 (3)	3 (3)	0.001
Number of NOE in 1000 m NWB, median (IQR)	10 (10)	11 (10)	8 (10)	0.001
Area of NOE in 300 m NWB (m^2), median (IQR)	38 013 (136 092)	36 007 (132 239)	41 241 (154 377)	0.58
Area of NOE in 500 m NWB (m^2), median (IQR)	140 281 (286 917)	137 862 (261 453)	150 758 (402 966)	0.03
Area of NOE in 1000 m NWB (m^2), median (IQR)	588 516 (975 551)	557 191 (890 303)	720 366 (239 293)	0.001
Distance to nearest NOE (m), median (IQR)	161.0 (214)	155.7 (205.6)	172.4 (232.4)	0.001
Average residential surrounding greenness in 100 m buffer, median (IQR)	0.46 (0.16)	0.44 (0.28)	0.50 (0.16)	0.001
Average residential surrounding greenness in 300 m buffer, median (IQR)	0.49 (0.23)	0.47 (0.30)	0.51 (0.13)	0.001
Average residential surrounding greenness in 500 m buffer, median (IQR)	0.49 (0.23)	0.48 (0.31)	0.51 (0.11)	0.001

*Based on t-tests, X^2, Kruskal-Wallis and rank-sum tests and with p values adjusted for the false discovery rate with the Benjamini-Hochberg procedure.
BMI, body mass index; NBH, neighbourhood; NOE, natural outdoor environments; NWB, network buffer; SES, socioeconomic status; SF-36, 36-item Short Form Health Survey.

dog ownership and leisure time walking was larger for those living within 300 m of a NOE (OR 2.36, 95% CI 1.97 to 2.83) compared with those living within >300 m of a NOE (OR 1.86, 95% CI 1.36 to 2.55; table 3). Similar results were observed for those with a high amount of residential surrounding greenness (100 and 300 m buffer, online supplemental table S2) compared with low residential surrounding greenness.

The associations between dog ownership and time spent in NOE were larger for those with a lower number or area of NOE than for those with a higher number or area of NOE (table 3 and online supplemental table S2). We observed a larger OR for the association between dog ownership and time spent in NOE for those living within 300 m of a NOE (OR 2.64, 95% CI 2.18 to 3.20) compared with those living within >300 m of a NOE (OR 1.82, 95% CI 1.31 to 2.55; table 3). A larger OR for the association between dog ownership and time spent in NOE for those with more residential surrounding greenness were consistent across buffer sizes 300 and 500 m, but not for residential surrounding greenness within 100 m (table 3 and online supplemental table S2).

There were no statistically significant associations between dog ownership and perceived general health status when stratifying by access to NOE or residential surrounding greenness. Similarly, there was no indication for an association between dog ownership and mental health in groups with high or low access to NOE and with high or low residential surrounding greenness (table 3).

Sensitivity analysis

Additional adjustments for smoking, BMI, frequency of contact with family and/or friends, and whether respondents feel part of a group of friends, did not change the results (results available on request).

DISCUSSION

Having a dog was associated with more leisure time walking and time spent in NOE near home compared

Table 2 Associations between dog ownership, leisure time walking, time spent in NOE near the home, general health status and mental health

	Leisure time walking (high vs low)	Time spent in NOE near home (high vs low)	General health, excellent, (very) good (reference: fair, poor)	Mental health (scale 0–100, higher is better)
Dog ownership (vs not)	**OR (95% CI)**	**OR (95% CI)**	**OR (95% CI)**	**β (95% CI)**
Total	2.17 (1.86 to 2.54) n=3586	2.37 (2.02 to 2.79) n=3530	0.92 (0.73 to 1.15) n=3586	0.24 (–0.89 to 1.37) n=3584
Barcelona	1.46 (1.03 to 2.08) n=979	2.14 (1.47 to 3.13) n=978	1.90 (1.01 to 3.56) n=979	0.13 (–2.29 to 2.55) n=979
Doetinchem	7.97 (5.18 to 12.25) n=851	1.18 (0.80 to 1.73) n=846	0.89 (0.37 to 2.17) n=851	1.61 (–0.55 to 3.78) n=849
Kaunas	1.05 (0.79 to 1.39) n=892	1.26 (0.93 to 1.69) n=844	0.71 (0.50 to 1.00) n=892	–2.17 (–4.40 to 0.06) n=892
Stoke-on-Trent	2.01 (1.44 to 2.79) n=864	2.31 (1.63 to 3.27) n=862	0.89 (0.57 to 1.37) n=864	2.61 (0.35 to 4.86) n=864

Analytical method: mixed models with random intercept for neighbourhoods and adjusted for age, sex, education, neighbourhood SES, household composition, perceived income situation, perceived NOE safety, physical constraint restricting mobility and chronic diseases. Analyses were based on complete cases.
NOE, natural outdoor environments.

Table 3 Associations between dog ownership, walking, time in NOE, perceived general and mental health status stratified by access to NOE and residential surrounding greenness

	Leisure time walking (high vs low)	Time spent in NOE near home (high vs low)	General health, excellent, (very) good (reference: fair, poor)	Mental health (scale 0–100, higher is better)
Dog ownership (vs not)	**OR (95% CI)**	**OR (95% CI)**	**OR (95% CI)**	**β (95% CI)**
Number of NOE (500 m)				
Lowest	2.13 (1.74 to 2.62) n=2084	2.57 (2.07 to 3.17) n=2051	0.89 (0.65 to 1.22) n=2084	0.55 (–0.93 to 2.03) n=2082
Highest	2.29 (1.79 to 2.94) n=1502	2.23 (1.72 to 2.89) n=1479	0.90 (0.62 to 1.29) n=1502	–0.62 (–2.36 to 1.13) n=1502
Area of NOE (500 m)				
Lowest	2.36 (1.88 to 2.97) n=1779	2.53 (2.00 to 3.20) n=1753	0.90 (0.64 to 1.27) n=1779	0.85 (–0.83 to 2.53) n=1777
Highest	2.04 (1.64 to 2.53) n=1807	2.19 (1.75 to 2.75) n=1777	0.81 (0.59 to 1.12) n=1807	–0.48 (–1.20 to 1.04) n=1807
Distance to nearest NOE				
≤300 m	2.36 (1.97 to 2.83) n=2778	2.64 (2.18 to 3.20) n=2746	0.91 (0.69 to 1.20) n=2778	0.66 (–0.61 to 1.93) n=2776
>300 m	1.86 (1.36 to 2.55) n=808	1.82 (1.31 to 2.55) n=784	0.70 (0.46 to 1.05) n=808	–1.05 (–3.45 to 1.36) n=808
Residential surrounding greenness (500 m)				
Lowest	2.15 (1.70 to 2.71) n=1786	2.29 (1.81 to 2.91) n=1765	0.86 (0.61 to 1.21) n=1786	0.38 (–1.29 to 2.05) n=1785
Highest	2.19 (1.77 to 2.72) n=1800	2.57 (2.04 to 3.24) n=1765	0.95 (0.68 to 1.33) n=1800	–0.16 (–1.69 to 1.36) n=1799

Analytical method: mixed models with random intercept for neighbourhoods and adjusted for age, sex, education, neighbourhood SES, household composition, perceived income situation, perceived NOE safety, physical constraint restricting mobility and chronic diseases. Analyses were based on complete cases.
NOE, natural outdoor environments.

with not having a dog. Moreover, the differences in walking and time spent in NOE between dog owners and non-dog owners were larger when there was a NOE within 300 m of the residence, and a high amount of residential surrounding greenness. There was no consistent evidence for an association between dog ownership and perceived general and mental health status. Only dog owners from Stoke-on-Trent had better mental health compared with non-dog owners, and dog owners from Barcelona had better perceived general health compared with non-dog owners.

Prior studies have also observed links between NOE, dog ownership and physical activity. In support of our findings, a UK study of older adults reported that neighbourhood greenness was associated with a smaller decline in physical activity over time, and that dog walking explained up to 50% of the variance in the relationship between greenness and outdoor physical activity.[62] Our findings were also consistent with a Danish study that found that dog ownership was a major determinant of park visits, especially those parks closest to the residence.[35] Our study adds to the evidence base by including multiple exposure indicators of NOE, which enabled studying multiple exposure indicators of NOE simultaneously, and could help understand what metric best predicts the health benefits associated with NOE.[36 37 41] We found that dog owners spent more time in NOE than non-dog owners, but dog ownership was not consistently related to perceived mental or general health status. Dog ownership was only related to better perceived general or mental health in Barcelona and Stoke-on-Trent, the two cities where respondents were the least active and spent the least time in NOE. This suggests that the health benefits of dog ownership exist when walking and time spent in NOE is low to begin with. Because we found no consistent evidence for health benefits for dog owners with better availability of NOE, future studies could also investigate subjective indicators of NOE, including satisfaction and importance, and neighbourhood aesthetics.[63]

Although the cross-sectional nature of our study does not allow for understanding the longitudinal effects of dog ownership on health, it is possible that people with physical constraints and chronic diseases more often decide to have a dog, for example, following doctor's advice, in order to stay mobile.[26] Similarly, another study reported that dog owners more often had asthma, and a higher BMI compared with non-dog owners.[28] Furthermore, an Australian study found that although pet ownership was associated with higher levels of physical activity, it was also associated with higher self-reported BMI, higher diastolic blood pressure and smoking.[27] We found that despite the physical constraints and chronic diseases, dog owners engaged in more leisure time walking than non-dog owners. We hypothesise that the extra physical activity facilitated by dog walking may offset some of the other negative health risk factors dog owners have, and could eventually yield long-term health benefits. This may especially occur in green neighbourhoods, when there is access to NOE and when the residential environment promotes walking.

Limitations of this study include the lack of information about the dog (eg, breed, age, temperament), the dog owner's level of attachment to their dog, the duration of dog ownership and if the respondent was the primary carer of the dog. Such factors may have influenced the potential health benefits of dog ownership, but we were unable to take these factors into account. We further did not know if the time spent in NOE and leisure time walking was undertaken together with the dog, and whether time spent in NOE was time spent walking. Future research should measure specific aspects of dog ownership and should use measures of behaviour such as time spent in NOE with and without dog and leisure time walking undertaken with and without the dog. A limitation of self-reporting walking habits is potential overstatement of the amount of walking. Minutes of walking and time in NOE were dichotomised because of non-normal distributions and although this resulted in easier interpretation of data, it also resulted in information loss. Although data collection was similar in each city, data on neighbourhood SES were based on country-specific data and this might have complicated comparisons between cities. Finally, we cannot establish the direction of the observed relationships because of the cross-sectional study design. For example, people who are already physically active and visit NOE may decide to get a dog, instead of dogs motivating their owners to walk and visit NOE more. Strengths include the multicity approach, which revealed differences between cities concerning dog ownership and health. It is also one of the first studies from mainland Europe, since the majority of research has been carried out in North America, Australia and in the UK. More international studies about dog ownership and health are needed. Finally, our measure of access to NOE was specific to environments that were suitable for physical activity. Also, for access to NOE, we used road network buffers over circular buffers which better capture people's walking behaviour; and we used varying buffer sizes to obtain a better understanding of what distance to NOE is most beneficial to health.[44]

CONCLUSIONS

Dog owners performed more leisure time walking and spent more time in NOE compared with non-dog owners, especially when they lived within 300 m of a NOE and when they lived in green areas. There was no consistent relationship between dog ownership and better perceived general or mental health status. In a largely physically inactive society where many people remain indoors, dog walking in parks or other NOE may be an opportunity to engage people in walking behaviour as a path towards better health. Cities should therefore ensure that there is access to NOE for dog owners and provide green infrastructure in order to promote dog walking. Future research should focus on natural experiments and evaluation of intervention strategies to increase dog owners' access to NOE.

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