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Active commuting through natural environments is associated with better mental health: Results from the PHENOTYPE project

Wilma L. Zijlema[a,b,c,*], Ione Avila-Palencia[a,b,c], Margarita Triguero-Mas[a,b,c], Christopher Gidlow[d], Jolanda Maas[e], Hanneke Kruize[f], Sandra Andrusaityte[g], Regina Grazuleviciene[g], Mark J. Nieuwenhuijsen[a,b,c]

[a] Barcelona Institute for Global Health (ISGlobal), Doctor Aiguader 88, 08003 Barcelona, Spain
[b] Universitat Pompeu Fabra (UPF), Doctor Aiguader 88, 08003 Barcelona, Spain
[c] CIBER Epidemiología y Salud Pública (CIBERESP), Melchor Fernández Almagro, 3-5, 28029 Madrid, Spain
[d] Centre for Health and Development, Staffordshire University, Leek Road, Stoke-on-Trent ST4 2DF, United Kingdom
[e] Vrije Universiteit Amsterdam, Department of Clinical Psychology, Van der Boechorstraat 1, 1081 BT Amsterdam, the Netherlands
[f] Center for Sustainability, Environment and Health, National Institute for Public Health and the Environment (RIVM), Antonie van Leeuwenhoeklaan 9, 3721 MA Bilthoven, the Netherlands
[g] Department of Environmental Sciences, Vytautas Magnus University, K. Donelaicio str. 58, 44248 Kaunas, Lithuania

A B S T R A C T

Background: Commuting routes with natural features could promote walking or cycling for commuting. Commuting through natural environments (NE) could have mental health benefits as exposure to NE can reduce stress and improve mental health, but there is little evidence. This study evaluates the association between NE and commuting, whether active or not, and the association between commuting (through NE), whether active or not, and mental health. We also evaluate the moderating effect of NE quality on the association between NE commuting and mental health.

Methods: This cross-sectional study was based on adult respondents (n = 3599) of the Positive Health Effects of the Natural Outdoor Environment in Typical Populations in Different Regions in Europe (PHENOTYPE) project. Data were collected in four European cities in Spain, the Netherlands, Lithuania and the United Kingdom. Data on commuting behavior (active commuting at least one day/week, daily NE commuting) and mental health were collected with questionnaires. Associations were estimated with multilevel analyses including random intercepts at city- and neighborhood level.

Results: Adjusted multilevel analyses showed that daily NE commuters were more often active commuters (OR 1.42; 95% CI 1.19, 1.70). There was no association between active commuting and mental health, but daily NE commuters had on average a 2.74 (95% CI 1.66, 3.82) point higher mental health score than those not commuting through NE. The association with mental health was stronger among active commuters (4.03, 95% CI 2.13, 5.94) compared to non-active commuters (2.21; 95% CI 0.90, 3.51) when daily commuting through NE, but NE quality did not have a moderating effect.

Conclusions: Daily NE commuting was associated with better mental health, especially for active commuters. Daily NE commuters were likely to be active commuters. Active commuting itself was not associated with mental health. These findings suggest that cities should invest in commuting routes with nature for cycling and walking.

1. Introduction

The proportion of the global population who live in urban areas continues to grow. One of today's greatest challenges is to ensure that urban dwellers can live a long and healthy life in a sustainable way (UN Habitat, 2016). Urgent public health problems associated with the urban built environment include physical inactivity and mental health problems. First, urban dwellers are largely physically inactive in these urban environments that are often dominated by cars (Sallis et al., 2016). Second, mental disorders seem to be more prevalent in urban environments (Peen et al., 2010; Zijlema et al., 2015).

Urban design could contribute to healthy urban living and potentially improve physical activity and mental health (Christian et al., 2017; Cole-Hunter et al., 2015; Giles-Corti et al., 2016; Mair et al., 2008; Nieuwenhuijsen and Khreis, 2016). A recent, worldwide study showed that levels of physical activity are higher in walkable cities (Althoff et al., 2017). Natural ('green and blue') environments within cities, such as parks and street trees also seem to increase physical activity, but evidence is inconsistent (Christian et al., 2017; Cole-Hunter et al., 2015; Hunter et al., 2015; Sallis et al., 2016). For example,

* Corresponding author at: Barcelona Institute for Global Health (ISGlobal), Barcelona Biomedical Research Park (PRBB), Doctor Aiguader 88, 08003 Barcelona, Spain.
E-mail address: wilma.zijlema@isglobal.org (W.L. Zijlema).

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research has shown that in areas with a large amount of nature, facilities may be sparser and areas may be set out more spaciously, resulting in less walking or cycling (den Hertog et al., 2006; Maas et al., 2008).

Increasing physical activity may be most successful when it can be incorporated in daily life habits. This may make it easier to be physically active regularly (Yang et al., 2018). Switching from private vehicle use to active transportation (cycling, walking) could be a sustainable strategy for promoting physical activity (Mueller et al., 2015), maintaining a healthy weight (Flint et al., 2016), and improving mental health (Avila-Palencia et al., 2018, 2017). It will also result in other benefits with regards to air quality, traffic noise, and urban temperature exposure. Private vehicles take up a lot of space that could instead be allocated to urban greening and infrastructure for active transportation (Khreis et al., 2017; Otero et al., 2018; Rojas-Rueda et al., 2011).

Commuting routes with natural features or routes along natural environments may invite people to commute actively and could simultaneously promote physical activity with additional mental health benefits (Gascon et al., 2015). From previous experimental studies we know that physical activity in natural environments can reduce stress, improve mood and mental restoration when compared to the equivalent activity in urban environments (Bowler et al., 2010; Gidlow et al., 2016). Although results from studies seem promising and plausible, many of them had poor methodological quality and further studies with better quality are needed (Thompson Coon et al., 2011). In addition, natural environments that are positively evaluated by people and that have certain qualities (e.g. variety, serenity, and safety) might strengthen the health benefits of nature (Annerstedt et al., 2012; de Vries et al., 2013; Zhang et al., 2017) and such qualities should also be addressed (Frumkin et al., 2017).

Although there is evidence suggestive of a relationship between natural environments (NE) and active commuting and between NE and mental health, little is known about the determinants and mental health benefits of active commuting through NE. Neither have there been studies evaluating this in multiple cities at the same time with different urban designs and travel behaviors. Therefore, our aims were to investigate (1) the association between commuting in NE and commuting, whether active or not; (2) the association between active commuting and mental health; (3) the association between commuting in NE and mental health; and (4) whether the association between commuting in NE and mental health is stronger for high quality NE and for active commuters.

We hypothesized that commuting in NE would be more likely to be active commuting, that active commuting would be associated with better mental health, and that commuting in NE would be associated with better mental health, particularly for active commuters and high quality NE. We investigated these relationships in an adult general population sample from four European cities that have different urban designs and travel behaviors.

2. Methods

2.1. Study design and population

This cross-sectional study was based on adults of the Positive Health Effects of the Natural Outdoor Environment in Typical Populations in Different Regions in Europe (PHENOTYPE) project. Data were collected in four European cities: Barcelona (Spain), Doetinchem (the Netherlands), Kaunas (Lithuania), and Stoke-on-Trent (the United Kingdom) (Nieuwenhuijsen et al., 2014). The four case cities offer divers study areas in terms of size, population density, climate and land cover (Smith et al., 2017). Barcelona, the largest city (1.6 million inhabitants) is a densely built city (population density 16 thousand inhabitants/km^2) and has a Mediterranean climate. Doetinchem, the smallest city (56 thousand inhabitants) has a much lower population density (706 inhabitants/km^2) and has a moderate maritime climate. Kaunas (319 thousand inhabitants) has a humid continental climate and has a population density of 2046 inhabitants/km^2. Stoke-on-Trent (363 thousand inhabitants) has a population density of 1194 inhabitants/km^2 and has a moderate maritime climate. Greenness and access to NE varies per city, with in general Doetinchem being the greenest city with the best NE access, and Barcelona the least green city with poorest NE access (Smith et al., 2017). We used survey data from respondents that were recruited from 30 neighborhoods per city. These neighborhoods were selected based on their variability in socioeconomic status and access to NE. A random sample of 30–35 adults (age range 18–75 years) in each neighborhood was invited to participate in the survey. Response rates were 46.9% in Barcelona; 8.4% in Doetinchem; 21.3% in Kaunas; and 36.9% in Stoke-on-Trent. The final sample contained approximately 1000 respondents per city. Data were collected by means of a face-to-face questionnaire administered at respondents' residences during May–November 2013. In Kaunas (Lithuania), data were collected using a postal questionnaire. The study was conducted in accordance with the Declaration of Helsinki. Ethical approvals were obtained from the relevant bodies of each institution and all respondents provided written informed consent before taking part.

2.2. Data

In the questionnaire, NE 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.

2.3. NE commuting

NE commuting (active or non-active) was assessed with the *question* "*How often in the last 4 weeks did you pass through (walking, biking, by car, train etc.) green/blue environments when commuting to and/or from work/school/other daily activities?*" with five response categories (*never*; *1 time or less in past month*; *2–3 times in past month*; *1–4 times weekly*; and (*almost*) *daily*). The variable was dichotomized as those who passed through NE (almost) daily (*daily NE commuting*) versus those who did not (i.e., any other response category).

2.4. Perceived quality of NE commuting

Perceived quality of NE during commuting was answered by all respondents that reported to pass through natural environments during their commute (active or non-active) at least once in the past month (n = 2711). There were seven questions (e.g. regarding the sounds, colors, view, variety, safety) which were answered on a five point scale ('strongly disagree' (1) to 'strongly agree' (5)), and were combined into a sum score with higher scores indicating a higher quality of NE during commuting (range 7–35). The Cronbach's alpha of this scale was 0.85 indicating high internal consistency. The variable was also used as a dichotomous variable and was divided in high and low using the median value (28) as cut off.

2.5. Perceived amount of neighborhood NE

Perceived amount of neighborhood NE was determined by asking how respondents would describe their neighborhood in terms of green and blue. Answers on the five point scale ('not at all' (0) to 'very' (4)) were dichotomized into fairly/very and not at all/a little/neutral. Although commuting routes of respondents probably extent to outside their neighborhoods, it was assumed that at least a significant part of the commute takes place in the neighborhood.

2.6. Active commuting

Active commuting was assessed by asking respondents to think about a normal week in the past month, and then whether they walked

or cycled from/to work and/or school and was based on the Short Questionnaire to Assess Health Enhancing Physical Activity (SQUASH) (Wendel-Vos et al., 2003). These active commuters were then asked on how many days per week they cycled or walked. We considered respondents that walked or cycled to/from work and/or school (or both) at least once a week to be active commuters, and the remaining respondents to be non-active commuters.

2.7. Mental health

Mental health was assessed with the Medical Outcome Study Short Form (SF-36) mental health subscale (version 1) (Ware and Sherbourne, 1992). The SF-36 mental health subscale is a validated and widely used questionnaire to assess mental wellbeing. It contains five questions about how the respondent felt in the past four weeks: Have you been a very nervous person?; Have you felt so down in the dumps nothing could cheer you up?; Have you felt calm and peaceful?; Have you felt downhearted and blue?; Have you been a happy person? Questions were scored on a 6-point scale ranging from 'all of the time' (1) to 'none of the time' (6). A sum score was calculated by summing all items together. If a maximum of two out of five items were missing, these missing values were replaced by the average of the other items. This was done for 17 respondents. If more than two items were missing, no sum score was calculated. Finally, the sum score was transformed into a scale ranging from 0 to 100 according to guidelines, with higher scores indicating better mental health (van den Berg et al., 2016; Ware and Sherbourne, 1992).

2.8. Covariates

Information on age, sex, education level (primary school or no education; secondary school/further education (up to 18 years); university degree or higher), perceived income situation (cannot make ends meet; enough to get along; comfortable), disability restricting mobility (yes; no), perceived safety of neighborhood NE (very satisfied; satisfied; neutral; dissatisfied; very dissatisfied), car/motorcycle at disposal (yes; no), and access to public transport within 15 min (yes; no) was collected with the face-to-face questionnaire. Neighborhood socioeconomic status (SES) (low; intermediate; high) was based on country-specific data (Barcelona: the deprivation index MEDEA Index (Domínguez-Berjón et al., 2008); Doetinchem: the average monthly household income per 6-digit zip code level (Statistics Netherlands, 2013); Kaunas: neighborhood education level (Statistics Lithuania, 2013); Stoke-on-Trent: the English Indices of Multiple Deprivation 2010 (Department for Communities and Local Government, 2010). Based on the tertiles of the country specific distributions of SES, three categories of neighborhood SES were defined. The minutes per week of physical activity at work/school and during leisure time (used in sensitivity analyses) were based on the SQUASH (Wendel-Vos et al., 2003).

2.9. Statistical analyses

Descriptive statistics were used to characterize the study population, and are shown for the pooled sample and by city. To investigate the associations between the active commuting, the natural environment and mental health, we investigated the following:

1. The associations between NE commuting, quality of NE commuting, perceived amount of neighborhood NE, and active commuting.
2. The association between active commuting and mental health.
3. The association between NE commuting and mental health.
4. The association described at 3, in active commuters and non-active commuters; and in those who perceive the quality of NE during commuting as high and low.

Associations were estimated using multilevel analysis with random intercepts defined at two levels: the city and neighborhood level. Models were adjusted for the covariates described previously. As the PHENOTYPE study was designed to include cities with regional, social and cultural differences, we also analyzed city-specific multilevel models with random intercepts at the neighborhood level to evaluate differences between cities. Analyses were based on complete cases (total sample was n = 3599, see Supplemental Material Fig. 1 for a flow chart). Associations were considered statistically significant if the 95% confidence intervals did not include zero (β) or one (odds ratios). All analyses were performed in STATA 14.2 (StataCorp, 2015).

2.10. Sensitivity analysis

All models were additionally adjusted for physical activity at work/school and during leisure time to investigate potential confounding. We also performed sensitivity analyses with a different cut off for active commuting: respondents that walk or cycle on at least three days per week were considered to be active commuters (instead of at least one day per week in the main analyses). Analyses of all models were repeated with this stricter criterion for active commuting.

3. Results

3.1. Population characteristics

The sample consisted of 3599 respondents from 124 neighborhoods with on average 29 respondents (range 6–58) per neighborhood. The respondents had a mean age of 51.7 (SD 15.9) years and 54.9% was female. Active commuting at least once a week was reported by 997 (27.7%) respondents and was highest in Kaunas (44.5%) and lowest in Stoke-on-Trent (9.6%). Daily NE commuting was reported by 1593 (44.3%) respondents and was highest in Doetinchem (71.9%) and lowest in Stoke-on-Trent (25.4%) (Table 1).

3.2. NE and active commuting

Daily NE commuting, compared to 1–4 days per week or less, was associated with higher odds of active commuting in the pooled sample (OR = 1.42, 95% CI 1.19, 1.70). Similar associations were observed for the city-specific analyses, but none of them were statistically significant. The quality of NE commute was not associated with active commuting, except for Barcelona respondents, where a higher quality of NE during commuting was related to lower odds of active commuting (OR 0.94, 95% CI 0.90, 0.98). Finally, the perceived amount of neighborhood NE was not associated with active commuting (Table 2).

3.3. Active commuting, NE commuting and mental health

Active commuting was not associated with mental health in the pooled sample, nor in models for the cities separately (Table 3). Table 4 presents the associations between daily NE commuting (vs. not daily) and mental health in all respondents and by active commuters and non-active commuters. Respondents commuting through NE on a daily basis had on average a 2.74 (95% CI 1.66, 3.82) point higher score on the mental health scale than those not commuting through NE daily. City-specific analyses showed positive associations between NE commuting and mental health in all four cities, but were only statistically significant in Doetinchem and Kaunas (Table 4).

3.4. NE commuting and mental health stratified by (non-)active commuting and NE quality

Stratified analyses for active and non-active commuters showed that in both groups daily NE commuting was associated with better mental health. Active commuters that passed through NE on a daily basis, had on average a 4.03 (95% CI 2.13, 5.94) point higher score on the mental

Table 1
Population characteristics.

	Total n = 3599	Barcelona n = 983	Doetinchem n = 849	Kaunas n = 896	Stoke-on-Trent n = 871
Age, mean (SD)	51.7 (15.9)	45.1 (15.5)	56.4 (12.1)	59.9 (13.7)	45.9 (16.0)
Female sex, n (%)	1975 (54.9)	514 (52.3)	478 (56.3)	535 (59.7)	448 (51.4)
Daily NE commuting, n (%)	1593 (44.3)	370 (37.6)	610 (71.9)	392 (43.6)	221 (25.4)
Active commuting ≥1 day/week, n (%)	997 (27.7)	260 (26.5)	254 (29.9)	399 (44.5)	84 (9.64)
Active commuting ≥3 days/week, n (%)	874 (24.3)	240 (24.4)	185 (21.8)	380 (42.4)	69 (7.92)
Education level, n (%)					
Low	253 (7.03)	145 (14.8)	10 (1.18)	16 (1.79)	82 (9.41)
Medium	1577 (43.8)	379 (38.6)	399 (47.0)	240 (26.8)	559 (64.2)
High	1769 (49.2)	459 (46.7)	440 (51.8)	640 (71.4)	230 (26.4)
SF-36 mental health score (scale 0–100), median (IQR)	76 (20)	72 (24)	84 (12)	72 (24)	76 (20)
Neighborhood SES, n (%)					
Low	1137 (31.6)	328 (33.4)	266 (31.3)	229 (25.6)	314 (36.1)
Medium	1382 (38.4)	332 (33.8)	333 (39.2)	427 (47.7)	290 (33.3)
High	1080 (30.0)	323 (32.9)	250 (29.5)	240 (26.8)	267 (30.7)
Perceived income situation, n (%)					
Cannot make ends meet	387 (10.8)	126 (12.8)	147 (17.3)	45 (5.02)	69 (7.92)
Enough to get along	1809 (50.3)	488 (49.6)	259 (30.5)	642 (71.7)	420 (48.2)
Comfortable	1403 (39.0)	443 (52.2)	209 (23.3)	382 (43.9)	443 (52.2)
Perceived safety of NE, n (%)					
Very satisfied	301 (8.36)	67 (6.82)	79 (9.31)	23 (2.57)	132 (15.2)
Satisfied	1832 (50.9)	470 (47.8)	488 (57.5)	405 (45.2)	469 (53.9)
Neutral	779 (21.6)	243 (24.7)	167 (19.7)	210 (23.4)	159 (18.3)
Dissatisfied	572 (15.9)	156 (15.9)	96 (11.3)	232 (25.9)	88 (10.1)
Very dissatisfied	115 (3.20)	47 (4.78)	19 (2.24)	26 (2.90)	23 (2.64)
Disabilities restricting mobility, n (%)	889 (24.7)	78 (7.94)	242 (28.5)	433 (48.3)	136 (15.6)
Car/motor ownership, n (%)	2534 (70.4)	594 (60.4)	781 (92.0)	544 (60.7)	615 (70.6)
Public transport within 15 min, n (%)	3015 (83.8)	948 (96.4)	762 (89.8)	708 (79.0)	597 (68.5)
Perceived neighborhood greenness, n (%)					
Not at all, a little, neutral	1354 (37.6)	522 (53.1)	102 (12.0)	330 (36.8)	400 (45.9)
Fairly, very	2245 (62.4)	461 (46.9)	747 (88.0)	566 (63.2)	471 (54.1)
Quality of NE during commute, median (IQR)[a]	28 (5)	27 (5)	28 (4)	26 (6)	28 (4)
Physical activity at work/school minutes/week, mean (SD)	543 (907)	411 (793)	861 (1030)	699 (1057)	222 (512)
Physical activity leisure time minutes/week, mean (SD)	509 (503)	339 (347)	722 (495)	670 (628)	328 (361)

NE = natural environment; SD = standard deviation; SES = socioeconomic status; IQR = interquartile range; NA = not applicable.
[a] n = 2711.

health scale than those not commuting through NE every day. We observed a similar association for respondents that did not commute actively, albeit smaller when compared to the active commuting group (β = 2.21; 95% CI 0.90, 3.51). Compared to the non-active commuters, associations between daily NE commuting and mental health were stronger for the active commuters from Barcelona and Kaunas, but not for those from Doetinchem and Stoke-on-Trent (Table 4). Stratified analyses for high (β = 2.47; 95% CI 0.47, 4.47) and low (β = 2.67; 95% CI 1.22, 4.11) quality of NE during commuting showed that in both groups daily NE commuting was associated with better mental health, but associations in the two groups did not seem to differ. For Barcelona and Doetinchem respondents, effect estimates were larger for the high quality NE than for the low quality NE, but estimates were only statistically significant in the low quality group from Doetinchem. For Kaunas and Stoke-on-Trent respondents, effect estimates were only statistically significant for the low quality NE and were larger compared to the high quality NE (Table 4).

Table 3
Adjusted associations between active commuting and mental health (SF-36 score).

	SF-36 mental health score β (95% CI)
Active commuting (once/week vs. less)	
Total n = 3599	0.51 (−0.70, 1.72)
Barcelona n = 985	0.10 (−2.08, 2.29)
Doetinchem n = 849	0.16 (−1.86, 2.19)
Kaunas n = 896	1.13 (−1.45, 3.71)
Stoke-on-Trent n = 871	−0.07 (−3.58, 3.45)

NE = natural environment. Mixed model with random intercept for (city and) neighborhood and adjusted for age, sex, education level, perceived income situation, neighborhood SES, safety of NE, disabilities restricting mobility, car/motor ownership and access to public transport. Mental health is reported on a scale from 0 to 100 with higher scores indicating better mental health.

Table 2
Adjusted associations between indicators of NE and active commuting (≥1 day/week vs. not active commuting).

	Total OR (95% CI) n = 3599	Barcelona OR (95% CI) n = 983	Doetinchem OR (95% CI) n = 849	Kaunas OR (95% CI) n = 896	Stoke-on-Trent OR (95% CI) n = 871
NE commuting daily (vs. not daily)	**1.42 (1.19, 1.70)**	1.34 (0.97, 1.84)	1.47 (0.99, 2.17)	1.35 (0.96, 1.88)	1.22 (0.71, 2.09)
Quality of NE commute[a]	0.98 (0.96, 1.00)	**0.94 (0.90, 0.98)**	1.02 (0.97, 1.07)	0.96 (0.93, 1.01)	1.00 (0.92, 1.09)
Perceived amount of NE (fairly/very vs. not at all/a little/neutral)	1.01 (0.83, 1.22)	0.72 (0.51, 1.01)	1.12 (0.68, 1.83)	1.18 (0.83, 1.68)	1.21 (0.73, 2.02)

NE = natural environment; OR = odds ratio; 95% CI = 95% confidence interval. Mixed model with random intercept for (city and) neighborhood and adjusted for age, sex, education level, perceived income situation, neighborhood SES, NOE safety, disability, car/motor ownership and access to public transport. Boldface indicates statistically significant associations.
[a] n = 2711.

Table 4
Adjusted associations between commuting through NE (daily) and mental health (SF-36 score) in the total sample, by quality of NE commute and by active commuters, and non-active commuters.

	Total β (95% CI)	Active commuting β (95% CI)	Non-active commuting β (95% CI)	High quality NE commute β (95% CI)	Low quality NE commute β (95% CI)
NE commuting daily (vs. not daily)					
Total	**2.74 (1.66, 3.82)**	**4.03 (2.13, 5.94)**	**2.21 (0.90, 3.51)**	**2.47 (0.47, 4.47)**	**2.67 (1.22, 4.11)**
	n = 3599	n = 997	n = 2602	n = 934	n = 1777
Barcelona	1.67 (−0.32, 3.65)	**3.93 (0.40, 7.45)**	0.74 (−1.64, 3.12)	3.75 (−0.46, 7.95)	0.35 (−2.28, 2.97)
	n = 983	n = 260	n = 723	n = 197	n = 500
Doetinchem	**2.88 (0.87, 4.89)**	1.62 (−2.08, 5.31)	**3.09 (0.70, 5.49)**	3.23 (−0.02, 6.48)	**2.90 (0.12, 5.67)**
	n = 849	n = 254	n = 595	n = 373	n = 430
Kaunas	**4.16 (1.98, 6.34)**	**4.75 (1.50, 7.99)**	**4.18 (1.22, 7.14)**	2.66 (−1.86, 7.19)	**3.93 (1.30, 6.56)**
	n = 896	n = 399	n = 497	n = 212	n = 595
Stoke-on-Trent	2.00 (−0.57, 4.56)	0.41 (−5.27, 6.08)	1.74 (−1.04, 4.53)	0.63 (−3.84, 5.10)	**4.62 (0.65, 8.58)**
	n = 871	n = 84	n = 787	n = 152	n = 252

NE = natural environment. Mixed model with random intercept for (city and) neighborhood and adjusted for age, sex, education level, perceived income situation, neighborhood SES, safety of NE, disabilities restricting mobility, car/motor ownership and access to public transport. Mental health is reported on a scale from 0 to 100 with higher scores indicating better mental health. Boldface indicates statistically significant associations.

3.5. Sensitivity analysis

Additional adjustment for physical activity at work/school and during leisure time generally resulted in smaller associations, but overall conclusions remained the same (Appendix Tables A1–A3 and A7–A8). We performed sensitivity analyses with a different cut off for active commuting, and associations between indicators of NE and active commuting on at least three days per week became stronger and in some cases statistically significant. Daily NE commuting was now also associated with active commuting in the samples from Barcelona, Doetinchem and Kaunas, but a higher quality of NE during commuting was associated with a lower likelihood of active commuting on at least three days per week (Appendix Table A4). Active commuting on at least three days per week was not associated with mental health (Appendix Table A5), and NE commuting was no longer associated with mental health in the active commuters group from Barcelona (Appendix Table A6).

4. Discussion

Our analyses of cross-sectional data from residents of four European cities showed that daily commuting through NE, especially active commuting, was beneficial for mental health, while active commuting itself was not. Mental health benefits of NE commuting were not larger when perceived quality of NE was higher. Daily NE commuting was also associated with a higher likelihood of active commuting, but the quality of NE during commuting and the perceived amount of neighborhood NE was not.

Our findings regarding commuting through natural environments and mental health cannot be directly compared to previous research as we are not aware of any publications with a similar focus. There are studies showing additional reductions in blood pressure and positive effects on self-esteem for exercising while viewing natural scenes compared to exercising alone, and this has led to the hypothesis that physical activity in (or with views of) nature has a synergistic benefit on health and wellbeing (Pretty et al., 2005). This 'green exercise', has been related to improved cognition, greater restoration and decreased depression in several experimental studies, when compared to exercise in urban or indoor settings (Bowler et al., 2010; Gidlow et al., 2016; Thompson Coon et al., 2011). Such benefits have also been underlined by a multi-study analysis about acute exposure to green exercise and self-esteem and mood improvement (Barton and Pretty, 2010). In addition to green exercise, greenness of the residential area has been associated with better mental wellbeing (Gascon et al., 2015), as has spending time in natural environments (Triguero-Mas et al., 2017; van den Berg et al., 2016). The restoring capacities of nature have often been named as the mechanism through which psychological benefits arise, and could explain the synergistic benefits of green exercise (Frumkin et al., 2017; Markevych et al., 2017). It is however unclear whether green exercise could be sustainable and could have long-term health benefits (Thompson Coon et al., 2011). Green exercise in the form of NE commuting could be sustainable by incorporating it into daily routines and could therefore be beneficial in the long-term.

Perceived quality of NE during commuting did not strengthen the relationship between commuting through NE and mental health. Some previous studies have shown that the subjective evaluation of NE might be as important for health benefits as the quantity of NE (de Vries et al., 2013), but most studies still focus on quantitative measures of NE (Frumkin et al., 2017). Our study could not confirm a moderating effect of NE quality, but this analysis was undertaken in a smaller subsample of respondents that commute through NE on at least one day per month, and thus excludes respondents not exposed to NE during their commute. Another explanation might be that passing through high quality NE does not evoke the same health benefits as more direct exposure during visits to high quality NE.

Although daily commuting through NE was beneficial for mental health, active commuting itself was not. In contrast to our study, previous studies have found associations between mental health and active commuting. In a study undertaken in New York, active commuting, which only included walking, was related to lower psychological stress (Tajalli and Hajbabaie, 2017). Although their outcome measure was comparable to ours, the benefits of walking over other commuting modes in a metropolis like New York may not be the same as in our sample. Our results also differed from results from the British Household Panel Survey that showed that active commuting, specified as walking or cycling as main means of transport, was related to better psychological wellbeing (Martin et al., 2014). In a sample from Barcelona, people who cycled during their commute ≥4 days per week were less stressed than those who cycled less or did not cycle at all during commuting (Avila-Palencia et al., 2017). Their sample was on average younger than ours (36 years vs. 52 years) and their outcome measure specifically targeted feelings of stress, while ours focused on mental health in general. Finally, a study from the UK reported that the time spent in active commuting was related to better physical wellbeing, but as in our study, no relationship was found for mental wellbeing (Humphreys et al., 2013).

Daily NE commuters were more likely to commute actively on at least one day per week. Similarly, a study carried out in five large urban regions in Belgium, France, Hungary, the Netherlands and the UK reported a higher likelihood of cycling for transport in neighborhoods with more street trees (Mertens et al., 2017). Cycling was also more likely in neighborhoods with more parks and sport grounds in

Maastricht, the Netherlands (Wendel-Vos et al., 2004). A recent systematic review of environmental factors associated with active transport in older adults concluded that access to parks, open spaces and recreational destinations were related to active travel, especially walking (Cerin et al., 2017). Another study from Barcelona, that found a positive relationship between cycling and surrounding greenness of the work or study area (Cole-Hunter et al., 2015).

These previous studies underline two important limitations of our study. First, the NE of the commuting route was based on subjective reports and not on objective NE data. Second, objective NE data at the residential level has been collected within the PHENOTYPE project (Smith et al., 2017), but not at work or commuting route level, and could therefore not be used. The cut off for active commuting may be arbitrary. Therefore, we performed sensitivity analyses with a different cut off, and the overall conclusions did not change, showing that the results are robust. We did not have data on commuting distance, which may have effects on mental health as well as on commuting preferences and not taking that into account may have resulted in residual confounding (Milner et al., 2016). Although the overall sample size was relatively large, it was reduced when stratifying by commuting mode and city (e.g. n = 84 in Stoke-on-Trent). Analyses within these subsamples may lack statistical power and should therefore be interpreted with caution. Response rates were low and may have led to low external validity because of overrepresentation of healthy persons that place a high value on nature (van den Berg et al., 2016). Finally, this cross-sectional study does not allow us to imply cause and effect or rule out residential self-selection into areas with NE and that are suitable for active commuting. As such, respondents with better mental wellbeing may choose to commute through or live close to NE, rather than incurring mental health benefits from those choices.

Nonetheless, this is one of the first studies that reports on associations between (active) commuting, NE and mental health. Another important strength of our study is that data were collected in four different European cities, using similar methods. This enabled us to compare results across cities with regional, social and cultural differences. Furthermore, we adjusted our analyses for a number of important confounders (e.g. NE safety, disabilities restricting mobility, access to car/public transport, and physical activity at work/school and during leisure time). Our mental health outcome measure was assessed with the widely used and validated SF-36, enabling comparison with other studies (Hays and Morales, 2001). It should however be noted that the copyrighted version (version 2) appeared to be more reliable than the version we used (Jenkinson et al., 1999), and that the mental health subscale is, together with other SF-36 items, part of a larger latent construct reflecting the mental component summary (Ware and Sherbourne, 1992).

4.1. Future research and implications

As this is one of the first studies to indicate that commuting through NE may be beneficial to mental health, additional confirmatory evidence is needed. Future research should include objective measures and could focus on more extensive assessments of exposure to natural environments during commuting by assessing the amount of vegetation surrounding roads used for commuting. More knowledge about the type of natural environments (parks, tree-lined roads), the amount of the NE exposure, and other potentially important factors such as heavy traffic along the commuting route could inform urban planning. Further research regarding perceived quality of NE and health benefits is needed because implications may not solely be about investing in natural infrastructure but also about changing people's perceptions of their neighborhood NE. On the other hand, benefits of natural environments, as well as active transportation on health are becoming widely known (Nieuwenhuijsen et al., 2017; Rojas-Rueda et al., 2011). Thus, cities should encourage active NE commuting by providing natural commuting routes suitable for active commuting. Decreasing the number of cars in cities will leave more space for active commuting through NE (e.g. parking spaces alongside the road could be used to plant greenery). Finally, switching from private vehicle use to active transportation will have wider benefits, such as reducing exhaust and urban heat island effects, and will ultimately lead to improved health and wellbeing (Nieuwenhuijsen and Khreis, 2016).

5. Conclusions

Daily NE commuting was related to better mental health, especially for active commuters. Daily NE commuters were likely to be active commuters. These findings suggest that cities should invest in commuting routes with nature for cycling and walking.

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Appendix A. Supplementary data

Supplementary data to this article can be found online at https://doi.org/10.1016/j.envint.2018.10.002.

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