The effect of urban green on small-area (healthy) life expectancy

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▸ Additional material is published online only. To view please visit the journal online (http://dx.doi.org/10.1136/jech-2014-203847).

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Received 14 January 2014
Revised 14 May 2014
Accepted 30 June 2014
Published Online First 22 July 2014

ABSTRACT

Background Several epidemiological studies have investigated the effect of the quantity of green space on health outcomes such as self-rated health, morbidity and mortality ratios. These studies have consistently found positive associations between the quantity of green and health. However, the impact of other aspects, such as the perceived quality and average distance to public green, and the effect of urban green on population health are still largely unknown.
Methods Linear regression models were used to investigate the impact of three different measures of urban green on small-area life expectancy (LE) and healthy life expectancy (HLE) in The Netherlands. All regressions corrected for average neighbourhood household income, accommodated spatial autocorrelation, and took measurement uncertainty of LE, HLE as well as the quality of urban green into account.
Results Both the quantity and the perceived quality of urban green are modestly related to small-area LE and HLE: an increase of 1 SD in the percentage of urban green space is associated with a 0.1-year higher LE, and, in the case of quality of green, with an approximately 0.3-year higher LE and HLE. The average distance to the nearest public green is unrelated to population health.
Conclusions The quantity and particularly quality of urban green are positively associated with small-area LE and HLE. This concurs with a growing body of evidence that urban green reduces stress, stimulates physical activity, improves the microclimate and reduces ambient air pollution. Accordingly, urban green development deserves a more prominent place in urban regeneration and neighbourhood renewal programmes.

BACKGROUND

Urban regeneration and neighbourhood renewal programmes often comprise urban green space developments. These are primarily aimed at creating more attractive neighbourhoods, but increasingly also at affecting and improving population health. The latter is based on a growing number of studies that show that urban green spaces are positively associated with physical activity,[1] mental health and well-being,[2 3] self-reported health,[4–6] longevity of senior citizens[7] and (all-cause) mortality.[6 8] The established evidence about the effect of green on population health, however, is still scarce and would benefit from further research using other health outcomes.[9] Particularly life expectancy (LE) measures are attractive in this respect.[10–15] Based on recently developed methodology to reliably estimate LE and healthy life expectancy (HLE) at the small-area level, we investigate the effect of urban green on small-area LE and HLE.

DATA AND METHODS

Population health data

Standard 5-year abridged life table data for the estimation of male and female LE and HLE for neighbourhoods in all 22 metropolitan agglomerations in the Netherlands in the 2006–2009 period were obtained from Statistics Netherlands. Together, the included metropolitan agglomerations comprise roughly 40% of the Dutch population and cover all major urban regions in the Netherlands (figure 1). Male and female LE and HLE at birth were subsequently calculated for all neighbourhoods within the 22 agglomerations that met the minimum required population size of 1750 person-years at risk and minimum survey sample size of 10 respondents per sex using the small-area methodology as developed and validated by Jonker *et al*[15] and Jonker *et al* (submitted: MF Jonker, B Donkers, F Peters, *et al*. Estimating healthy life expectancy for small geographic areas, Erasmus MC Department of Public Health Working Paper, Rotterdam, 2014). To avoid confounding from the migration of frail elderly to nursing homes prior to their death, the LE and HLE estimates were corrected for the location of nursing homes based on previous residential address information.[12]

Green space data

Three different urban green space measures were included in the analyses. The first is the percentage of green space per neighbourhood, which was calculated using SAGA GIS based on the Dutch Land Use Database (BBG) for the year 2008. Our definition of green space included all types of green (excluding horticulture) and the percentage of green was calculated using grid cells of 25 m×25 m. Similar to Maas *et al*,[3 4] gardens and small-scale green spaces, such as road-side trees and grassy verges were therefore not classified as urban green. The second green measure is the average distance in kilometers, calculated over the road network, from all addresses in the neighbourhood to the nearest public green (eg, a park, public garden or forest). This measure was obtained directly from Statistics Netherlands for the year 2008.[16] The third green measure is a subjective measure of the quality of the urban green in each neighbourhood. Responses from two consecutive surveys (ie, Woon 2006 and Woon 2009) were combined to acquire a sufficiently large sample size. In both surveys, respondents were asked to evaluate the quality of urban green spaces in their own neighbourhood on a 5-point Likert scale. To be able to take the measurement uncertainty into account, the survey information was summarised by (1) the total number of respondents per neighbourhood and (2) the number of respondents who were 'satisfied' or

To cite: Jonker MF, van Lenthe FJ, Donkers B, *et al*. *J Epidemiol Community Health* 2014;**68**:999–1002.

Figure 1 Geographic location of the 22 Dutch metropolitan agglomerations.

'very satisfied' with the quality of green in their neighbourhood, as opposed to being 'neutral', 'dissatisfied' or 'very dissatisfied'.

Neighbourhood income data

The average household income per neighbourhood is a potentially important confounding factor in the relationship between urban green spaces and small-area population health. Hence, based on standardised disposable household income data as obtained from Statistics Netherlands, all neighbourhoods in the 22 Dutch metropolitan agglomerations with a minimum population size of 1750 person-years at risk were divided into average disposable household income quintiles. In the statistical analyses, the first quintile (ie, the one with the lowest average household income) was used as the reference category.

Statistical analyses

The impact of the measures of urban green space on small-area LE and HLE was evaluated using linear regression models. To increase the efficiency of the estimations and alleviate problems with heteroskedasticity, the implemented specifications accommodate spatially autocorrelated errors as well as measurement uncertainty of the (healthy) life expectancy estimates. In the specifications that included the quality of urban green, the statistical uncertainty of the percentage of respondents who were 'satisfied' or 'very satisfied' with the quality of green in their neighbourhood was also taken into account (using a binomial specification).

The models were programmed in the BUGS language and fitted in WinBUGS using Bayesian MCMC methods. This involves selecting prior densities for the unknown model parameters and updating those densities via the likelihood of the observed data. Online supplementary appendix A contains the model code and specification of the prior distributions. Proper priors were used that were much more diffuse than the posterior distributions. All estimations used 25 000 MCMC iterations to let the chains converge and 25 000 MCMC iterations with a thinning of 5 to reliably approximate the posterior distributions. Convergence was evaluated using the diagnostics implemented in the R CODA package.[17]

RESULTS

Table 1 contains the descriptive statistics of the included dependent and independent variables for the 1190 included neighbourhoods. As can be seen, there is substantial variation in the LE, HLE and urban green space measurements. There is also significant variation in the precision of the LE, HLE and the perceived quality of green space measurements, which was, as mentioned, taken into account in the regressions. Furthermore, the number of neighbourhoods is smaller for the highest income quintiles. Neighbourhoods with less than 10 survey respondents per sex are predominantly affluent, which is explained by the smaller number of properties per square km, smaller population and consequently smaller survey sample sizes.

Table 2 contains the estimation results for the different model specifications, with each specification containing one of the three urban green space measures. All estimates are corrected for average neighbourhood income, which has a strong impact on small-area population health. The differences between the lowest and highest income quintiles are 2.5–3 and 7.5–8.5 years for LE and HLE, respectively. Turning to the impact of urban green, the distance to public green is unrelated to small-area LE and HLE. The percentage of green space is unrelated to HLE but statistically significantly related to LE whereas the quality of the green space is significantly associated with LE and HLE. Overall, an increase of 1 SD in the percentage of urban green is associated with a 0.10–0.14-year higher LE and for the quality of urban green with a 0.28–0.29-year higher LE and 0.26–0.33-year higher HLE.

DISCUSSION

Using three different measures of urban green, recently developed methodology to reliably estimate LE and HLE at the small-area level, and relatively sophisticated regression models, this short report has investigated the impact of urban green on small-area population health in the Netherlands. Having corrected for differences in average household income, we find evidence that the quantity and quality of urban green space are modestly related to small-area LE and HLE: an increase of 1 SD in the percentage of urban green is associated with a 0.1-year higher LE, and, in the case of the perceived quality of green, with an approximately 0.3-year higher LE and HLE.

The presented estimates are corrected for the impact of average household income. In regressions without such correction, the percentage of green and distance to public green estimates remain similar whereas the impact of quality of urban green approximately doubles. The latter implies that the perceived quality of green space is higher in more affluent neighbourhoods (which may also reflect differences in accessibility and safety[9]) and suggests that the impact of the percentage of green space on LE is independent of neighbourhood income. The degree of urbanity was not included as a potential confounder; as mentioned, only metropolitan neighbourhoods were included in the analyses.

We are cautious to interpret our findings as causal effects. There are likely other confounders and selection effects that are insufficiently captured by the age standardisation and nursing

Table 1 Descriptive statistics

Dimension	Variable	N	Mean	SD	Minimum	Maximum
Population health	Life expectancy at birth (male)	1190	78.1	2.04	68.8	85.6
	Life expectancy at birth (female)	1190	82.2	2.06	72.3	91.5
	Healthy life expectancy at birth (male)	1190	65.1	5.25	46.1	81.2
	Healthy life expectancy at birth (female)	1190	64.2	5.64	42.2	83.0
Measurement uncertainty	Life expectancy at birth (male—SD)	1190	1.28	0.35	0.53	5.39
	Life expectancy at birth (female—SD)	1190	1.37	0.45	0.55	8.12
	Healthy life expectancy at birth (male—SD)	1190	3.33	1.06	1.38	8.56
	Healthy life expectancy at birth (female—SD)	1190	3.78	1.12	1.47	9.20
	Total number of survey respondents for the perceived quality of green	1190	46.8	58.4	5	646
Green	Percentage of green surface per neighbourhood	1190	11.4	11.5	0.00	72.3
	Average distance to nearest public green (in km)	1178	0.45	0.27	0.10	2.60
	Percentage of survey respondents who consider the quality of the green spaces in their neighbourhood as 'good'	1190	74.8	16.6	12.1	100
Income*	Average standardised disposable household income (quintile 1)	270	17 035	1148	11 194	18 451
	Average standardised disposable household income (quintile 2)	272	19 524	577	18 460	20 477
	Average standardised disposable household income (quintile 3)	278	21 588	642	20 483	22 766
	Average standardised disposable household income (quintile 4)	223	24 044	744	22 769	25 630
	Average standardised disposable household income (quintile 5)	147	29 743	5948	25 652	75 940

*The income quintiles are included as binary indicator (ie, dummy) variables in the regressions.

home correction of the outcome measures and the inclusion of the income quintiles and spatial error term in the regression models. For example, the neighbourhood microclimate (ie, temperature and humidity), air pollution and degree of social cohesion were not explicitly controlled for. However, these variables reflect some of the most important pathways from green to urban health.[18–20] The cross-sectional setting of the analysis, which implicitly assumes that current neighbourhood exposures are indicative of cumulative exposures, is also a methodological limitation. Risk factor exposures may have changed over time and the effect of geographical mobility might not have been adequately taken into account. On the other hand, the implemented nursing home correction explicitly corrects for the selective migration to nursing home addresses and there is no clear evidence that migration between Dutch neighbourhoods enlarged inequalities in health outcomes.[21]

Table 2 The effect of urban green on small-area LE and HLE, the Netherlands, 2006–2009*

	LE						HLE					
	Model 1		Model 2		Model 3		Model 1		Model 2		Model 3	
Male												
Percentage green†	0.14	(0.06–0.22)	NA.		NA.		0.01	(−0.19–0.21)	NA.		NA.	
Proximity to public green†	NA.		−0.04	(−0.12–0.05)	NA.		NA.		−0.12	(−0.32–0.08)	NA.	
Perceived quality of green†	NA.		NA.		0.28	(0.19–0.37)	NA.		NA.		0.33	(0.10–0.55)
Income_q1‡	0.00		0.00		0.00		0.00		0.00		0.00	
Income_q2	0.83	(0.61–1.06)	0.82	(0.59–1.05)	0.75	(0.53–0.98)	2.55	(1.96–3.13)	2.55	(1.96–3.13)	2.47	(1.88–3.06)
Income_q3	1.66	(1.42–1.90)	1.64	(1.40–1.88)	1.60	(1.36–1.84)	4.53	(3.90–5.15)	4.53	(3.90–5.15)	4.48	(3.85–5.10)
Income_q4	2.38	(2.12–2.64)	2.38	(2.12–2.64)	2.27	(2.01–2.53)	5.98	(5.31–6.64)	5.96	(5.30–6.63)	5.83	(5.16–6.50)
Income_q5	3.12	(2.82–3.42)	3.13	(2.83–3.44)	2.97	(2.67–3.27)	7.71	(6.95–8.46)	7.70	(6.95–8.46)	7.5	(6.74–8.26)
R^2	0.67	(0.66–0.68)	0.68	(0.67–0.68)	0.67	(0.66–0.68)	0.69	(0.68–0.69)	0.69	(0.68–0.69)	0.69	(0.68–0.69)
Female												
Percentage green†	0.10	(0.01–0.19)	NA.		NA.		−0.05	(−0.38–0.08)	NA.		NA.	
Proximity to public green†	NA.		−0.04	(−0.14–0.05)	NA.		NA.		−0.07	(−0.32–0.17)	NA.	
Perceived quality of green†	NA.		NA.		0.29	(0.19–0.39)	NA.		NA.		0.26	(0.00–0.53)
Income_q1‡	0.00		0.00		0.00		0.00		0.00		0.00	
Income_q2	0.80	(0.55–1.04)	0.80	(0.56–1.05)	0.74	(0.50–0.98)	2.84	(2.16–3.50)	2.82	(2.13–3.50)	2.77	(2.09–3.46)
Income_q3	1.53	(1.27–1.79)	1.51	(1.25–1.77)	1.48	(1.22–1.74)	5.11	(4.39–5.82)	5.10	(4.37–5.83)	5.08	(4.34–5.80)
Income_q4	2.12	(1.84–2.40)	2.13	(1.85–2.41)	2.02	(1.74–2.30)	6.72	(5.95–7.50)	6.69	(5.91–7.47)	6.60	(5.81–7.39)
Income_q5	2.62	(2.29–2.94)	2.61	(2.28–2.94)	2.44	(2.12–2.77)	8.37	(7.47–9.26)	8.35	(7.45–9.24)	8.20	(7.29–9.10)
R^2	0.65	(0.63–0.65)	0.65	(0.63–0.65)	0.65	(0.63–0.65)	0.64	(0.64–0.65)	0.64	(0.63–0.64)	0.64	(0.64–0.65)

*95% Credibility intervals in parentheses.
†Standardised coefficients, reflecting the impact of 1 SD change (in years).
‡The first income quintile is taken as the reference category.
HLE, healthy life expectancy; LE, life expectancy; NA, not applicable.

The analysis also has several strengths. First, it is based on unique outcome measures (LE and HLE), which are directly age standardised and corrected for the selective migration of frail elderly to nursing homes. Furthermore, our analyses are based on a multiple city approach (ie, neighbourhoods from all 22 Dutch metropolitan agglomerations are included), on robust statistical methodology and on three different measures of green, including the perceived quality of urban green. Additionally, the results are robust to changes in model specification, insensitive to the choice of priors and potential interactions between the quantity and quality of urban green are statistically insignificant.

Conclusion

Both the quantity and quality of urban green are positively associated with neighbourhood (H)LE. This concurs with a growing body of evidence that urban green reduces stress, stimulates physical activity, improves the microclimate and reduces ambient air pollution. Accordingly, we believe that urban green development deserves a more prominent place in urban planning, with the results indicating that not only the quantity but also the quality of urban green should be considered in future interventions.

What is already known on this subject

Contact with green can have substantial health benefits. Whereas the available evidence is relatively strong at the individual level, much less is known about the effect of the proximity, quantity and quality of green spaces on population health.

What this study adds

Based on recently developed methodology to estimate small-area life expectancy (LE) and healthy life expectancy (HLE), this paper evaluates the impact of three different measures of urban green on small-area population health. In contrast to previous epidemiological studies, our statistical models account for spatially correlated unobserved determinants, measurement uncertainty and the migration of frail elderly to nursing homes. Furthermore, the included measures capture the quantity of green as well as the perceived quality and average distance to public green. Particularly the perceived quality of urban green appears to be correlated with small-area population health, which suggests that not only the quantity but also the quality of urban green should be considered in future interventions.

Contributors All authors have provided substantial contributions to the conception and the design of the work as well as the revisions of the work prior to submission. In addition, MFJ and BD have developed the modelling approach and performed the statistical analyses, with Jonker responsible for the acquisition of the required data. All authors have seen and approved the final version of the manuscript.

Competing interests None.

Provenance and peer review Not commissioned; externally peer reviewed.

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