Is Living in a High-Rise Building Bad for Your Self-Rated Health?

Pieter-Paul Verhaeghe , Ad Coenen, and
Bart Van de Putte

ABSTRACT While the construction of high-rise buildings is a popular policy strategy for accommodating population growth in cities, there is still much debate about the health consequences of living in high flats. This study examines the relationship between living in high-rise buildings and self-rated health in Belgium. We use data from the Belgian Census of 2001, merged with the National Register of Belgium (N = 6,102,820). Results from multilevel, binary logistic regression analyses show that residents living in high-rise buildings have considerable lower odds to have a good or very good self-rated health in comparison with residents in low-rise buildings (OR 0.67; 95 % CI 0.67–0.68). However, this negative relationship disappears completely after adjusting for socioeconomic and demographic variables (OR 1.04; 95 % CI 1.03–1.05), which suggests that residents' worse self-rated health in high-rise buildings can be explained by the strong demographic and socioeconomic segregation between high- and low-rise buildings in Belgium. In addition, there is a weak, but robust curvilinear relationship between floor level and self-rated health within high-rise buildings. Self-rated health increases until the sixth floor (OR 1.19; 95 % CI 1.15–1.24) and remains stable from the seventh floor and upwards. These findings refute one of the central ideas in architectural sciences that living in high buildings is bad for one's health.

KEYWORDS Self-rated health, Floor level, Segregation, Housing, High-rise building, Belgium

INTRODUCTION

While the construction of high-rise buildings is a popular policy strategy for accommodating population growth in cities,¹ there is still much debate about the health consequences of living in high flats.² Some architects claim that high buildings 'make people crazy',³ p. 115 or 'create an unhealthy density',⁴ p. 68. However, most health studies testing these kinds of architectural claims are fairly old.^{5–9} As a consequence, they do not control for known health correlates such as age or socioeconomic position.^{10–12} Moreover, they do not take the neighbourhood context into account. Finally, they pay little attention to potential curvilinear relations between floor level and health. Especially the lack of attention for socioeconomic factors is problematic, since most high-rise buildings in Europe are built by the social (or public) sector during the post-war construction boom and are located in more deprived areas.¹

An exception is the excellent, longitudinal study of Panczak and his colleagues.¹³ They found among the Swiss population that mortality decreased steeply with increasing floor level between ground floor and fourth floor and levelled off from

Verhaeghe, Coenen, and Van de Putte are with the Ghent University, Ghent, Belgium.

Correspondence: Pieter-Paul Verhaeghe, Ghent University, Ghent, Belgium. (E-mail: pieterpaul.verhaeghe@ugent.be)

the fourth floor upwards. However, the housing situation in Switzerland is quite unique, since most Swiss rent a home instead of owning one. According to Eurostat statistics,¹⁴ approximately 56 % of the Swiss rent a dwelling versus 30 % of the European population. Moreover, approximately 60 % of the Swiss population lives in a flat versus 41 % of the European population. In countries with much less renters or flat inhabitants, it is likely that the degree of socioeconomic and age segregation between high- and low-rise buildings is much higher (for example, poor or older people are more likely to rent a home or to live in a flat). As a consequence, the relationship between living in a high-rise building and health may be different.

In the literature, several explanations for the adverse impact of living in high-rise buildings and on high floors can be found. Evans and his colleagues¹¹ refer to difficulties with the development and maintenance of social networks. In the same vein, the architect Gehl⁴ makes reference to the human capabilities to make visual contact with the social environment. The opportunities to follow and interact with social life in the surrounding are excellent from the two lower stories and feasible until the fifth floor. Above the fifth floor, people on the ground can neither be recognised nor contacted. Moreover, Panczak and his colleagues¹³ suggest that until the fourth floor, residents have a higher level of physical activity, due to regularly climbing the stairs to the apartment. People who live on the fifth floor or higher would, however, take the elevators. Both physical activity^{15–17} and social networks^{18, 19} are important correlates with several health outcomes. In addition, residents' health can be worse in high-rise buildings, because they live separated from the natural environment, resulting in lower possibilities for stress reduction and mental recovery.²⁰ Previous research has, indeed, shown that the floor level of the dwelling affects the satisfaction with and perception of the environment.^{21, 22}

This study examines the impact of living in a high-rise building with census data about self-rated health of the Belgian population. Belgium is an interesting case, because it has—in contrast to Switzerland in Panczak and his colleagues' study—¹³very low percentages of renters and flat inhabitants.^{14, 23} Therefore, this study reveals whether the detrimental effects of living in high-rise buildings can also be found in countries where high-rise building inhabitants are, in contrast to their Swiss counterparts, a more specific population. Self-rated health is a widely used comprehensive health measure, with a strong predictive value on mortality.^{24–27} Moreover, both the World Health Organization and the European Union recommend its use to measure population health.^{28, 29}

METHODS

Belgian Census and National Register Data

In this study, we use data from the Belgian Census of 2001 merged with official data from the National Register of Belgium. The National Register is used to aid municipality administration and contains crude demographic information. The Census collects additional information about all officially registered inhabitants of Belgium.³⁰ Participation in the census is compulsory in Belgium, and the response rate was 96.9 % of all the official Belgian inhabitants in Belgium in 2001. The combination of these two data sources offers highly accurate information about self-rated health, demographic characteristics, socioeconomic status, household composition, housing conditions and the place of residence. Of the 9,333,428 inhabitants that participated, 1,988,211 inhabitants were list-wise deleted because of missing

information on the variables used in this study. Of the remaining 7,345,217 cases, another 1,242,397 cases were removed, because they were younger than 18. This left a total of 6,102,820 cases.

Self-Rated Health

The dependent variable in this study is 'self-rated health'. To assess self-rated health, respondents were asked to rate their own general health condition. There were five response categories: 'very poor', 'poor', 'fair', 'good' and 'very good'. This version of self-rated health measurement shows strong correlations with other versions.³¹ Although the categories of self-rated health can be ranked, the distances between the categories are unknown. Therefore, we dichotomized the variable into good health (very good and good) and poor health (fair, poor and very poor) categories.

Individual Variables

Our two key independent variables are 'type of building' and 'floor level'. In line with previous studies,^{12, 13, 22} we defined high-rise buildings as buildings with at least four floors. Both the number of stories in the building and the floor level of the respondent were asked in the census questionnaire. We treat floor level as a categorical variable. Because the number of people per floor level is steeply declining from the 15th floor, we grouped all people living on the 15th floor or higher together.

In addition, we controlled for gender, age, civil status, ethnicity, highest educational degree, professional status, type of tenure, household size and household crowding. We excluded people aged below 18 because most of them are still in full-time education (in contrast to the adult population at working age; e.g. only 4.9 % of the 19–60 years old population in our data were full-time students). We distinguished between four civil status categories: 'single', 'married', 'widowed' and 'divorced'. Ethnic origin is assessed by looking at the current nationality, first nationality at registration and country of birth of both the respondent and his/her (grand)parents. We distinguished between three ethnic categories: 'Belgian', 'European Union members' and 'non-European Union members'.^{*} Highest educational degree contains four categories: 'primary education', 'lower secondary education', 'higher secondary education' and 'tertiary education'.[†] Professional status is a variable with six categories: 'full-time employed', 'part-time employed', 'unemployed', 'retired', 'student' and 'unknown/other'. We differentiated between four tenure tracks: 'owner', 'private renter', 'social renter' and 'other'. Household size is a metric variable counting the total number of household members living in the dwelling. Household crowding is calculated by dividing the household size by the number of rooms of the dwelling.

^{*}'European Union members' are defined as all members of the EU28 (without Belgians) and including people with Andorran, Gibraltar, Icelandic, Liechtenstein, Monaco, Norwegian, Sanmarinese, Swiss and Vatican origin. This includes people with roots in former Czechoslovakia but excludes people with roots in former Yugoslavia or the USSR if it was impossible to determine in which current day country these people were born.

[†]The category 'higher secondary education' also includes the people with post-secondary, but no higher education degrees.

Neighbourhood Variable

In this study, we considered statistical sectors as neighbourhoods. Belgium has 19,011 statistical sectors, dispersed over 589 municipalities. The number of neighbourhoods in a city ranges from 2 to 284. Statistical sectors are urban structure types, based on homogenous social, economic and urban characteristics of the area, such as housing types, spatial planning, built environment, ecological structure, socioeconomic composition, demographic structure and other morphological indicators,³² and resemble the census tracts used in Anglo-Saxon research. To assess the socioeconomic position of the neighbourhood, we used data from the Belgian tax administration: the median fiscal income per capita in a statistical sector. Figure 1 gives a geographical overview of this socioeconomic neighbourhood variable in Belgium.

Statistical Analysis

To compare residents' self-rated health in low-rise and high-rise buildings (first aim), we performed multilevel, binary logistic regression analyses among the total population. Since respondents are nested in neighbourhoods, we apply multilevel models. In the first model, we examined the effect of building type on the odds to have a (very) good self-rated health. In the full model, we adjusted for all control variables. In addition, we performed multilevel, binary logistic regression analyses among all residents living in high-rise buildings in order to assess within high-rise building differences in self-rated health (second aim). In the first model, we

FIG. 1 Median annual taxable income per capita for each neighbourhood in Belgium.

TABLE 1 Descriptive and bivariate statistics

	Range	Full sample		Low-rise buildings		High-rise buildings	
		Mean/ freq.	(SD/%)	Mean/ freq.	(SD/%)	Mean/ freq.	(SD/%)
Building type	0–1						
Low-rise		5,689,635	(93.23)				
High-rise		413,185	(6.77)				
Floor level	–1–15+						
–1						1873	(0.45)
0						30,737	(7.44)
1						67,312	(16.29)
2						67,663	(16.38)
3						67,661	(16.38)
4						62,550	(15.14)
5						36,957	(8.94)
6						23,100	(5.59)
7						16,120	(3.90)
8						10,777	(2.61)
9						6889	(1.67)
10						5310	(1.29)
11						4033	(0.98)
12						3366	(0.81)
13						1957	(0.47)
14						1683	(0.41)
15 +						5197	(1.26)
Self-rated health	0–1						
Very poor, poor or fair		1,567,226	(25.68)	1,426,998	(25.08)	140,228	(33.94)
Good or very good		4,535,594	(74.32)	4,262,637	(74.92)	272,957	(66.06)
Sex	0–1						
Man		2,998,227	(49.13)	2,815,212	(49.48)	183,015	(44.29)
Woman		3,104,593	(50.87)	2,874,423	(50.52)	230,170	(55.71)
Age	18–106	46.08	(17.53)	45.71	(17.34)	51.19	(19.33)
Marital status	1–4						
Unmarried		1,531,903	(25.10)	1,409,289	(24.77)	122,614	(29.68)
Married		3,668,747	(60.12)	3,484,160	(61.24)	184,587	(44.67)
Widowed		433,373	(7.10)	383,022	(6.73)	50,351	(12.09)
Divorced		468,797	(7.68)	413,164	(7.26)	55,633	(13.24)
Ethnicity	1–3						
Belgian		5,364,629	(87.90)	5,040,980	(88.60)	323,649	(78.33)
European Union member		492,560	(8.07)	445,278	(7.83)	47,282	(11.44)
Non-European Union member		245,631	(4.02)	203,377	(3.57)	42,254	(10.23)
Educational level	1–4						
Primary education		1,017,092	(16.67)	948,297	(16.67)	68,795	(16.65)
Lower secondary education		1,516,929	(22.83)	1,412,970	(24.83)	103,959	(25.16)
Higher secondary education		1,963,399	(32.41)	1,844,227	(32.41)	119,172	(28.84)
Tertiary education		1,605,400	(26.31)	1,484,141	(26.08)	121,259	(29.35)
Professional status	1–6						
Student		307,110	(5.03)	293,971	(5.17)	13,139	(3.18)
Employed full-time		2,761,907	(45.26)	2,611,678	(45.26)	150,229	(36.36)
Employed part-time		585,464	(9.59)	558,910	(9.82)	26,554	(6.43)
Unemployed		1,067,221	(17.49)	984,425	(17.30)	82,796	(20.04)
Retired		1,377,048	(22.56)	1,236,891	(21.74)	140,157	(33.92)
Other		4070	(0.07)	3760	(0.07)	310	(0.08)
Tenure	1–4						
Home owner		4,585,914	(75.14)	4,410,584	(77.52)	175,330	(42.43)
Private renter		1,096,515	(17.97)	937,458	(16.48)	159,057	(38.50)
Social renter		320,856	(5.26)	249,630	(4.39)	71,226	(17.24)
Other		99,535	(1.63)	91,963	(1.62)	7572	(1.83)
Household size	1–22	2.86	(1.37)	2.92	(1.37)	2.02	(1.14)
Crowding	0.07–19	2.3	1.25	2.28	1.25	2.49	1.25

Respondents living in high-rise buildings differ significantly ($p < 0.001$) from respondents living in low-rise buildings or single houses for all variables

Freq. frequency, *SD* standard deviation

examined the effect of floor level on the odds to have a (very) good self-rated health. In the full model, we adjusted again for all control variables. All statistical analyses were done using the lme4 package³³ in R version 3.2.2.

RESULTS

Table 1 shows the descriptive and bivariate statistics of the population. Of the Belgian population in 2001, only 6.8 % resides in a high-rise building versus 93.2 % in low-rise buildings. From the bivariate analyses, it appears that residents living in high-rise buildings are less likely to have a good or very good health than residents in low-rise buildings (66.1 vs. 74.9 %; $p < 0.001$). Moreover, high-rise building inhabitants are more likely to be female, older, unmarried, widowed or divorced, from non-Belgian origin, unemployed or retired, a private or social renter and to have a smaller household size. Moreover, bivariate associations between floor level and self-rated health among high-rise building residents show only a very weak, but still significant relationship (see Table 2). It appears that the highest percentages of people with a (very) good health can be found in the basement (67.7 %) and on the third (67.2 %) and fourth (67.7 %) floors.

We perform multivariate, binary logistic regression analyses to compare the residents' self-rated health in low-rise and high-rise buildings. From Table 3, it appears that residents living in high-rise buildings have considerable lower odds to have a good or very good self-rated health in comparison with residents in low-rise buildings (model 1: OR 0.67; 95 % CI 0.67–0.68). However, this negative relationship disappears completely and even becomes positive after controlling for the control variables (Full model: OR 1.04; 95 % CI 1.03–1.05), which suggests that residents' worse self-rated health in high-rise buildings can be explained by the strong demographic and socioeconomic residential segregation between building types in Belgium.

To analyse differences in self-rated health within high-rise buildings, we examine the effect of floor level on self-rated health among all residents living in high-rise buildings. Multilevel, binary logistic regression analyses show that people living on higher floors

TABLE 2 Bivariate association between self-rated health and floor level among high-rise building residents

Floor level	Very poor, poor or fair self-rated health	Good or very good self-rated health
–1	32.30 %	67.70 %
0	33.77 %	66.23 %
1	34.41 %	65.59 %
2	34.07 %	65.93 %
3	32.76 %	67.24 %
4	32.34 %	67.66 %
5	34.22 %	65.78 %
6	34.94 %	65.06 %
7	35.12 %	64.88 %
8	36.15 %	63.85 %
9	36.52 %	63.48 %
10	36.27 %	63.73 %
11	37.04 %	62.96 %
12	36.72 %	63.28 %
13	35.56 %	64.44 %
14	37.08 %	62.92 %
15+	35.89 %	64.11 %

The association is significant on the $p < 0.001$ level

TABLE 3 Continued

	Null model				Model 1				Full model						
	Log odds	p	S.E.	Odds ratio	95 % CI	Log odds	p	S.E.	Odds ratio	95 % CI	Log odds	p	S.E.	Odds ratio	95 % CI
Median income neighbourhood ^c											0.374	***	0.008	1.453	1.430 1.477
Variance	0.050														
Neighbourhood	0.065					0.046					0.083				
City						0.064									

*** $p < 0.001$; ** $p < 0.01$; * $p < 0.05$
^aDivided by 10
^bDivided by 100
^cDivided by 10,000

TABLE 4 Continued

	Null model			Model 1			Full model			
	Log odds	p	S.E.	Odds ratio	95% CI	Log odds	p	S.E.	Odds ratio	95% CI
(Ref: student)										
Employed full-time						0.238	***	0.035	1.269	1.185 1.359
Employed part-time						-0.170	***	0.038	0.844	0.783 0.909
Unemployed						-1.030	***	0.035	0.357	0.333 0.382
Retired						-0.420	***	0.038	0.657	0.610 0.708
Other						-1.592	***	0.128	0.204	0.158 0.262
Educational Attainment										
(Ref: Primary education)										
Lower Secondary						0.236	***	0.011	1.266	1.239 1.294
Higher Secondary						0.471	***	0.012	1.602	1.564 1.640
Tertiary education						0.766	***	0.013	2.151	2.097 2.207
Household size ^a						1.716	***	0.054	5.562	5.004 6.183
Age ^b						-4.319	***	0.040	0.013	0.012 0.014
Crowding ^a						0.891	***	0.042	2.438	2.245 2.647
Median income						0.398	***	0.024	1.489	1.420 1.561
neighbourhood ^c										
Variance										
Neighbourhood	0.125					0.126				
City	0.086					0.087				

****p* < 0.001; ***p* < 0.01; **p* < 0.05

^aDivided by 10

^bDivided by 100

^cDivided by 10,000

FIG. 2 Odds ratios to have a (very) good self-rated health per floor level among residents living in high-rise buildings.

have a higher likelihood to have a good or very good self-rated health than people living on the ground floor, adjusted for all other factors (see Table 4).[‡] Figure 2 shows the fully adjusted odd ratios to have a good or very good self-rated health, comparing residents living on the ground floor with residents living on higher floor levels. There appears to be a weak curvilinear relationship between floor level and self-rated health: self-rated health increases until approximately the sixth (OR 1.19; 95 % CI 1.15–1.24) and seventh floors (OR 1.20; 95 % CI 1.15–1.26), and remains stable from the sixth floor and upwards (all ORs for these floors are between 1.16 and 1.20, with the exception of people living on the 13th floor, which is due to outliers).[§] Moreover, the better self-rated health of people living in the basement from bivariate analyses disappears in the fully adjusted model (OR 0.91; 95 % CI 0.81–1.02).

CONCLUSION AND DISCUSSION

Although many architects and engineers have lively debates about the impact of living in high buildings on health, this is one of the first large-scale studies to genuinely examine the association. For this purpose, we used self-rated health data of about 6.2 million adult people who participated in the Belgian Census of 2001. As recommended by

[‡]Sensitivity analyses in which we treat floor level as a metric variable show also a weak curvilinear relationship (not shown, but available upon request).

[§]Sensitivity analyses show that—after deleting the outliers through boxplot statistics—the odds ratio to have a good or very good self-rated health for residents living on the 13th floor lies within the confidence interval of the odds ratios for residents on the 12th or 14th floor, both before and after adjustment (not shown, but available upon request).

Evans¹⁰ and Gifford,¹² we take socioeconomic and demographic factors into account at both individual and neighbourhood levels. People living in buildings with four or more floors appear to have lower odds to have a good or very good self-rated health than people living in buildings with three or fewer floors. This negative association disappears completely, however, after adjusting for socioeconomic and demographic variables, which suggests that residents' worse self-rated health in high-rise buildings can be explained by the strong demographic and socioeconomic residential segregation between high- and low-rise buildings in Belgium. In addition, we found a very weak, but robust curvilinear relationship between floor level and self-rated health within high-rise buildings: self-rated health increases until the sixth floor and remains stable from the seventh floor and upwards. These findings refute one of the central ideas in architectural sciences that living in high buildings is bad for one's health.^{3, 4}

Moreover, the results are in line with Panczak and his colleagues' longitudinal study¹³ on the association between floor level and mortality in Switzerland, in which mortality decreases steeply between ground floor and fourth floor and levelled off from the fourth floor upwards. The comparison with Switzerland is insightful, because Belgium has a totally different building environment. In contrast to Switzerland, most Belgian residents do not live in high-rise buildings.^{14, 23} As no negative association can be found between living in high-rise buildings and health in both countries, the conclusion of this study is convincing. Nevertheless, it is possible that the relationship between living in high-rise buildings and health is different among some specific populations. Evans¹⁰ and Gifford,¹² for example, suggest that especially high-rise dwellers with small children are dissatisfied, because of the limited play opportunities for children and social isolation of the parents.

Our findings should, however, be viewed within the confines of the used data and measures. Firstly, because of the cross-sectional design of the census, we have to be cautious about the causality of the associations. It could be argued, for example, that people with bad health choose to live in high-rise buildings or on lower floor levels. Secondly, although we assessed the socioeconomic status of people with highest educational degree and professional status, we did not have direct measures of material or financial resources. Thirdly, this study examines the association between floor level and self-rated health, but could not empirically explain the curvilinear relationship. There are several possible explanations. Panczak and his colleagues¹³ suggest that the better health of residents of higher floors is due to regularly climbing the stairs to the apartment. Although this explanation is very appealing, we did not have any information about physical activity in our data. Another explanation may be the higher levels of (nocturnal) road traffic noise^{34, 35} and traffic air pollution^{36, 37} at lower floors. Further research is needed to explain the curvilinear relationship between floor level and health. This is related to the fourth limitation: we could not control for potential health effects of the immediate environment of the building, such as the quality of view,^{20, 38} road traffic noise,^{34, 35} building infiltration of pollution,^{36, 37} the presence of green zones or natural elements^{39, 40} and other important covariates. Finally, we assessed health with the general self-rated health measure. Although this comprehensive health measure is strongly correlated with all-cause mortality,^{24–27} its associations with deaths due to accident or suicide are very weak.⁴¹ Panczak and his colleagues¹³ have found, however, significant effects of floor level on these specific causes of death (more exactly transport accidents and suicide by jumping from high place). Therefore, this study probably only partially grasps the relationships between living in high-rise buildings and health.

Notwithstanding these limitations, this study found that residents living in high-rise buildings have considerable worse self-rated health because of the strong demographic and socioeconomic residential segregation in Belgium. In addition, we observed a weak, inverse gradient of self-rated health across floors among inhabitants of high-rise buildings. These findings refute architects' beliefs in detrimental health effects of living in high buildings.

ACKNOWLEDGMENTS

This research has been funded by the Special Research Fund of Ghent University (Dr. Pieter-Paul Verhaeghe: grant number B/13836/01; and Ad Coenen: grand number BOF.PDO.14.0032.01). There are no conflicts of interest.

COMPLIANCE WITH ETHICAL STANDARDS

Ethics. The use of the Belgian Census and National Register data of 2001 was approved by the National Privacy Commission of Belgium, with the approval covering the present study (STAT 02/2014).

REFERENCES

1. Wassenberg F, Turkington R, Van Kempen R. High-rise as a European housing phenomenon. In: Turkington R, Van Kempen R, Wassenberg F, eds. *High-Rise Housing in Europe: Current Trends and Future Prospects*. Delft, South Holland: Delft University Press; 2004: 265–80.
2. Kearns A, Whitley E, Mason P, Bond L. 'Living the high life'? Residential, social and psychosocial outcomes for high-rise occupants in a deprived context. *Hous Stud.* 2002; 27: 97–126.
3. Alexander C, Ishikawa S, Silverstein M, Jacobson M, Fiksdahl-King I, Angel S. *A Pattern Language: Towns, Buildings, Construction*. New York, NY: Oxford University Press; 1977.
4. Gehl J. *Cities for People*. London, UK: Island Press; 2010.
5. Cook D, Morgan H. Families in high rise flats. *Br Med J.* 1982; 284: 846.
6. Fanning D. Families in flats. *Br Med J.* 1967; 4: 382–6.
7. Gillis A. High-rise housing and psychological strain. *J Health Soc Behav.* 1977; 18: 418–31.
8. Hannay D. Mental health and high flats. *J Chronic Dis.* 1981; 34: 431–2.
9. Wilcox B, Holahan C. Social ecology of the megadorm in university student housing. *J Educ Psychol.* 1976; 68: 453–8.
10. Evans G. The built environment and mental health. *J Urban Health.* 2003; 80: 536–55.
11. Evans G, Wells N, Moch A. Housing and mental health: a review of the evidence and a methodological and conceptual critique. *J Soc Issues.* 2003; 59: 475–500.
12. Gifford R. The consequences of living in high-rise buildings. *Archit Sci Rev.* 2007; 50: 2–17.
13. Panczak R, Galobardes B, Spoerri A, Zwahlen M, Egger M. High life in the sky? Mortality by floor of residence in Switzerland. *Eur J Epidemiol.* 2013; 28: 453–62.
14. Eurostat. *Living Conditions in Europe*. Luxembourg City, Luxembourg: Publication Office of the European Union; 2014.

15. Aune D, Norat T, Leitzmann M, Tonstad S, Vatten LJ. Physical activity and the risk of type 2 diabetes: a systematic review and dose-response meta-analysis. *Eur J Epidemiol.* 2015; 30: 529–42.
16. Samitz G, Egger M, Zwahlen M. Domains of physical activity and all-cause mortality: systematic review and dose-response meta-analysis of cohort studies. *Int J Epidemiol.* 2011; 40: 1382–400.
17. Warburton D, Nicol CW, Bredin S. Health benefits of physical activity: the evidence. *Can Med Assoc J.* 2006; 174: 801–9.
18. Kawachi I, Subramanian SV, Kim D. *Social Capital and Health.* New York, NY: Springer; 2008.
19. Verhaeghe PP, Tampubolon G. Individual social capital, neighbourhood deprivation and self-rated health in England. *Soc Sci Med.* 2012; 75: 349–57.
20. Wener R, Carmalt H. Environmental psychology and sustainability in high-rise structures. *Technol Soc.* 2006; 28: 157–67.
21. Chatterjee M. Perception of housing environment among high rise dwellers. *J Indian Acad Appl Psychol.* 2009; 35: 85–92.
22. Buys L, Miller E. Residential satisfaction in inner urban higher-density Brisbane, Australia: role of dwelling, neighbours and neighbourhood. *J Environ Plan Manag.* 2012; 55: 319–38.
23. Declerck N. Belgium: the impact of modernism in a divided country. In: Turkington R, Van Kempen R, Wassenberg F, eds. *High-Rise Housing in Europe: Current Trends and Future Prospects.* Delft, South Holland: Delft University Press; 2004: 265–80.
24. Burstrom B, Fredlund P. Self-rated health: is it as good a predictor of subsequent mortality among adults in lower as well as in higher social classes? *J Epidemiol Community Health.* 2001; 55: 836–40.
25. DeSalvo K, Bloser N, Reynolds K, He J, Muntner P. Mortality prediction with a single general self-rated health question. A meta-analysis. *J Gen Intern Med.* 2006; 21: 267–75.
26. Idler E, Benyamini Y. Self-rated health and mortality: a review of twenty-seven community studies. *J Health Soc Behav.* 1997; 38: 21–37.
27. Stenholm S, Kivimäki M, Jylhä M, Kawachi I, Westerlund H, Pentti J, Goldberg M, Zins M, Vahtera J. Trajectories of self-rated health in the last 15 years of life by cause of death. *Eur J Epidemiol.* 2016; 31: 177–85.
28. De Bruin A, Picavet H, Nossikov P. *Health Interview Surveys. Towards International Harmonization of Methods and Instruments.* Copenhagen, Denmark: World Health Organization; 1996.
29. Robine J, Jagger C, Romieu I. Selection of a coherent set of health indicators for the European Union. Phase II: final report. Montpellier, France: Euro-Reves; 2002.
30. Deboosere P, Willaert D. Codebook general socio-economic survey 2001. Working Paper 2004-1. Brussels, Belgium: VUB; 2004.
31. Jürges H, Avendano M, Mackenbach J. Are different measures of self-rated health comparable? An assessment in five European countries. *Eur J Epidemiol.* 2008; 12: 773–81.
32. Jamagne P, Lebrun L, Sajotte C. *Vademecum Statistische Sectoren.* Statistics Belgium: Brussel; 2012.
33. Bates D, Maechler M, Bolker B, Walker S. Fitting linear mixed-effects models using lme4. *J Stat Softw.* 2015; 67: 1–48.
34. Jakovljevic B, Paunovic K, Belojevic G. Road-traffic noise and factors influencing noise annoyance in an urban population. *Environ Int.* 2009; 35: 552–6.
35. Mak CM, Leung WK, Jiang GS. Measurement and prediction of road traffic noise at different building floor levels in Hong Kong. *Build Serv Eng Res Technol.* 2010; 31: 131–9.

36. Jung KH, Bernabé K, Moors K, Yan B, Chillrud SN, Whyatt R, Camann D, Kinney PL, Perera FP, Miller RL. Effects of floor level and building type on residential levels of outdoor and indoor polycyclic aromatic hydrocarbons, black carbon, and particulate matter in New York City. *Atmosphere*. 2011; 2: 96–109.
37. Junior WJR, Roig HL, Koutrakis P. A novel land use approach for assessment of human health: the relationship between urban structure types and cardiorespiratory disease risk. *Environ Int*. 2015; 85: 334–42.
38. Schmuck P, Schultz WP. *Psychology of Sustainable Development*. Boston, MA: Kluwer Academic Publishers; 2002.
39. Kellert S, Wilson EO. *The Biophilia Hypothesis*. Washington, DC: Island Press; 1993.
40. Ulrich R. View through a window may influence recovery from surgery. *Science*. 1994; 224: 420–1.
41. Benjamins MR, Hummer RA, Eberstein IW, Nam CB. Self-reported health and adult mortality risk: an analysis of cause-specific mortality. *Soc Sci Med*. 2004; 59: 1297–306.