ORIGINAL RESEARCH

The impact of housing conditions on mortality in Belgium (1991–2016)

Joan Damiens[1] [ORCID]

Abstract

In the Western countries, including Belgium, life expectancy has increased over the last decades, as well as social inequalities in health and mortality. Existing research tends to approximate socioeconomic status with the educational level, occupational status or income. Housing is yet another socioeconomic factor that is much less considered when studying inequalities in mortality. Indeed, housing is a complex and multidimensional element impacting several aspects of a person's health and well-being (physical, mental and social). The data used in this research are the result of the coupling of the population censuses of 1991, 2001 and 2011 and the National Register. They cover the entire population of Belgium over 25 years. Through life tables analysis and multivariate logistic regression models, this research contributes to existing research by setting trends in housing conditions between 1991 and 2016 in relation to social inequalities in health and mortality over this period in Belgium. It shows that housing conditions have a specific effect on the risk of death, in addition to other socio-economic characteristics. On the 2011–2015 period, once controlling for demographic and socioeconomic characteristics (education, professional status and income), a 25% higher mortality rate separates tenants from owners on the one hand, and population living in low quality housing from those living in better quality housing on the other hand. Ensuring good housing conditions seems a necessary step to reduce inequalities that should be considered in social policies.

Keywords Housing · Mortality · Health inequalities · Register data · Belgium

✉   Joan Damiens
    joan.damiens@uclouvain.be

[1]   Institute for Demographic Research, Université Catholique de Louvain, Louvain-la-Neuve, Belgium

Introduction

In the Western countries, including Belgium, better socioeconomic and working conditions, as well as improvements in food, hygiene and environment have led to an increase in life expectancy over the last decades. Nevertheless, inter-personal variation in life expectancy remains substantial (Trannoy 2012). Health and mortality inequalities have increased in recent decades (Jusot 2010; Deboosere and Fiszman 2009): socioeconomic status is a strong determinant of mortality at every age, more than ever before in European countries (Valkonen 2002).

One's living environment includes all the exogenous elements, natural or artificial, that make up the place in which the individual lives and spends most of their time (Herjean 2006). Among the factors affecting exposure to health risks, it plays a key role. Housing, whether through access, location or quality, matters in social inequalities in health. Its physical, social and mental aspects have multiple impacts on health and mortality (Bonnefoy 2007). The living environment can generate or feed diseases or infections, through the air quality, the humidity that prevails, or through its density of occupation, a vector for the spread of diseases. It is also a central element in one's psychological and social well-being. However, social and health-related public policies rarely target the housing issues, and focus instead on employment, education or healthcare (Emelianoff 2008; Krieger and Higgins 2002).

A bunch of studies have examined the socioeconomics determinants of mortality (for Belgium: Deboosere et al. 2009; Gadeyne 2006), but very few have included the housing aspect. Although some research has shown the variation in life expectancy according to housing quality and housing tenure (owner/tenant), in Belgium (Eggerickx et al. 2018; Gadeyne 2006), and elsewhere (e.g. in the UK: Dunn 2002; or in Vancouver: Hiscock et al. 2003), these results were confronted with the fact that the living environment is also strongly linked to a person's socio-economic framework, namely their income level, socio-cultural context, among other things (Bugeja-Bloch 2013).

The objective of this research is to measure the impact of the housing conditions on mortality in Belgium from 1991 to 2016. Using data from the three censuses of 1991, 2001 and 2011, as well as data from the Belgian National Register, a first portrait will be drawn of the socio-economic and demographic characteristics of the populations defined by their housing quality and tenure. Then, a contextualization of the relationship between living environment and mortality will be carried out, using life tables and life expectancy. Finally, a multivariate analysis will make it possible to identify the specific effect of the living environment on mortality, with equal demographic and socio-economic characteristics.

The impact of housing on health and survival

A context of social inequalities in health and mortality

Belgium is going through an important moment in its health transition, a process marked by four stages (Rollet 2011; Vallin et al. 2002). First, centuries ago, epidemics and infectious and contagious diseases affected everyone, regardless wealth or poverty (Rollet 2011). With the industrial revolution, medical and technological progress and the overall improvement in living conditions have led to a rise in life expectancy. Epidemics were more controlled and child mortality has decreased in Western countries (Rollet 2011; Vallin et al. 2002). Thirdly, the epidemiological transition was characterized by the development of chronic diseases, or so-called "societal" diseases (cardiovascular diseases, cancer, diabetes), because they are associated with people's lifestyles, namely nutrition, smoking, alcoholism, sedentary lifestyle and a polluted environment. Currently, Western countries are gradually emerging from this third phase through prevention campaigns and the adoption of healthier behaviours, conducive to the reduction of chronic diseases. They are entering a fourth phase, characterized by a lengthening of life in good health and the development of degenerative diseases, typical of old age, such as Alzheimer's and Parkinson's diseases (Vallin et al. 2002; Mackenbach 2012). This transition to a fourth phase is far from being homogeneous, since it is taking place at the pace of social inequalities in health and mortality.

Depending on their income, level of education and professional activity, individuals do not have the same level of health and mortality. There is a social gradient in health: the higher on the social scale, the better the health status. This gradient integrates social, economic, professional, psychosocial and political factors in a multidimensional way (Chatelard et al. 2012). In industrialized countries, improvements in hygiene, food, security and working conditions did not have the same consequences on the whole population (Trannoy 2012). Now more than ever before in European countries, an individual's social category influences his or her risk of dying at different ages (Valkonen 2002). Macintyre et al. (1998) defined the three interdependent levels of interaction between socioeconomic characteristics and health: individual, political and environmental.

Among the environmental issues that influence the health and survival of the individual, housing is central and complex. It is both a reflection of a socio-economic reality (Lejeune et al. 2012), but it also presents its own physical, psychological and social risks that can impair the quality of life. To measure environmental inequalities, variables related to external risks or neighbourhood amenities can be chosen, such as means of transport, green spaces, or local services. Nevertheless, housing is one factor that come under scrutiny with regard to the notion of environmental inequalities (Lejeune et al. 2012). A survey conducted about housing in Wallonia in 2006 and 2007 showed that good housing quality was strongly associated with a good socio-economic status (Lejeune et al. 2012).

Since February 27th 1994, the Right to housing has been enshrined in the 23rd article of the Belgian Constitution. Housing is the basis of social integration: it

is necessary to live in dignity and security. However, the implementation of this right to decent, accessible and stable housing is all the more difficult when the household is of low socio-economic status, particularly in a context of policy liberalization (Coburn 2004; Leonard 2012; De Keersmaecker 1997; Krieger and Higgins 2002; Bonnefoy 2007). The family composition, the proximity to the workplace, the budgetary constraints, are interfering factors. The housing crisis is widening, policies are failing to reduce it, and some populations are forced to live in substandard or inadequate housing (De Keersmaecker 1997; Ginot and Peyr 2010).

In this context, a first hypothesis of this research assumes that housing-driven inequalities in mortality have increased over time, following the trend of other sociodemographic variables.

Definitions and consequences of housing quality

Housing is a physical and social construction including four dimensions: home, a place of personal and family refuge; housing in its facilities and equipment; community, and the social relationships it allows: the immediate environment, or urban design, with the places and services that the surrounding community provides (Bonnefoy 2007). These four dimensions are interdependent and play on health, which is itself defined as a three-fold—physical, psychological and social—well-being (Bonnefoy 2007). Among the housing factors influencing one or more of these dimensions, Bonnefoy (2007) identifies: autonomous accessibility of housing; surrounding spaces; heating and energy; psychological well-being through lighting on the one hand, and privatization of the place on the other; propensity to domestic accidents; air quality and ventilation; feelings of insecurity and crime; the residential and community environment; animal and pollen infestations (Bonnefoy 2007).

The impact of housing on health is multifarious. First, an energy or ventilation deficit in the accommodation may result in infectious diseases (Boomsma et al. 2017; Shaw 2004). The spread of diseases can be fuelled by high housing density (Krieger and Higgins 2002). The habitat can also be responsible for long-term pathologies, related to a lack of heating, ventilation and airing. Household heating absence of inefficiency are responsible for many physical as well as psychological problems, although they are poorly studied (Boomsma et al. 2017; Shaw 2004). Moisture can lead to a range of chronic diseases such as pain, nervous disorders, and allergies, especially in children, while exposure to cold increases blood pressure, cholesterol and the risk of heart attacks, especially in older people (Krieger and Higgins 2002; Shaw 2004). The layout of the dwelling and its location can also be responsible for injuries and household accidents, linked to falls or lack of storage for dangerous products (drugs, knives, cleaning products), especially for the youngest (Shaw 2004). Mental health also suffers from poor quality housing, due to sleep disorders, depression and anxiety related to the frustration of living in unsatisfactory housing (Lawrence 1998; Hiscock et al. 2001; Macintyre et al. 1998). According to Evans et al. (2003), various mediators make the link between housing quality and one's mental health: a sense of belonging and identity; perceived security and

stability of housing; the social connection made possible by housing (neighbourhood, proximity to the social circle); parenting, since the discomfort of younger people is through that of their parents (Coley et al. 2013); and a sense of control, adaptability of their space (Evans et al. 2003).

As a second hypothesis in this research, we assume that poor housing quality in Belgium is positively associated with mortality rates and shorter life expectancies.

Definition and consequences of housing tenure

Another component of housing well-being lies in its financial constraint. The weight of housing in a household's economy depends on the structure of the household, its socio-economic characteristics, but also on the housing tenure. Tenants face greater budgetary constraints and spend a higher share of the monthly budget devoted to housing (Bugeja-Bloch 2013). But the opposite is true: the socio-economic and financial level of a household will determine its occupation status. In Belgium, the risk of living under the poverty threshold of a homeowner with a loan or mortgage is 8%, compared to 40.3% for tenants paying rent at market prices (Lahaye et al. 2013). Homeownership is a segregating and unequal phenomenon, strongly linked to social class and position on the labour market (Hiscock et al. 2003; Mulder and Lauster 2010). Housing tenure is, therefore, a reflection of the socio-economic living conditions of the household living in it. Homeownership is valued, despite the sacrifices required, such as the cost of social and spatial isolation, the distance from the workplace, and even a loss of housing quality (Bugeja-Bloch 2013; Mulder and Lauster 2010). In Belgium, the Housing Bonus (tax reduction on mortgage loans) is a tax advantage that encourages home ownership. As it is not income-based, it does nothing to reduce inequalities in access to property, and mainly helps social categories who already had the plan and the possibility to buy their accommodation (Lahaye et al. 2013).

Some studies based on European censuses (United Kingdom, Italy) showed an association between a poor health and being a tenant (Hiscock et al. 2003). Homeowners are more often satisfied with their dwelling, heating, comfort, neighbourhood quality and safety (Hiscock et al. 2003). Ownership can also be associated with having better quality housing in terms of facilities (Macintyre et al. 1998). The psychosocial aspect is also highlighted: owners are more often proud of their housing and their feeling of privacy and security is stronger than tenants' (Hiscock et al. 2003). According to a study conducted in Scotland on 6500 adults, moisture problems, noise, crime and vandalism, are more recurrent in rentals, particularly social rentals (Macintyre et al. 1998) and definitely deteriorates well-being. The composition factor of the two sub-populations can also interferer. On average, tenants are more often single, which are characteristics conducive to a less favorable state of health (Hiscock et al. 2003).

Ownership, when financially assumed without too much difficulty, affects the well-being (Herbert and Belsky 2008). First, the owner can modify their accommodation and improve its equipment and structures as they will (Herbert and Belsky 2008). On the contrary, the tenant will be less likely to complete home

renovations or maintenance, either because they will not be authorized to do so, or because they will not wish to carry out work at their own expense and for a dwelling that may only be temporary. A tenant will also fear a rent increase subsequent to a renovation of the accommodation. In addition, property provides security and a sense of control and attachment to the place, which optimizes a person's well-being (Lawrence 1998; Bernard 1998; Hiscock et al. 2003; Macintyre et al. 1998). Finally, renting is often accompanied by a sense of social devaluation and stigmatization, especially in the public sector. This can lead to social withdrawal and marginalization (Lawrence 1998).

A third hypothesis in this research claims that tenants face higher mortality rates and shorter life expectancies than homeowners.

Housing conditions: a socioeconomic proxy and an immediate factor

Socio-economic level impacts both mortality trends and housing conditions. The quality of food, leisure, goods and services available to the household, as well as access to health care, depend on the level of income which is often correlated with educational level, which in turn is representative of people's habits and attitudes and of their level of information about the best practices for an optimal health status and life expectancy. Studies in Belgium can confirm that the most educated are not only those with the highest life expectancy of the population but also those with the highest increase of life expectancy in recent decades (Deboosere et al. 2009). The occupational category is also an indicator of housing options and health status. Unemployment is an important factor in the deterioration of physical health, but also mental well-being (Mesrine 2000; Gadeyne 2006). Among the employed, manual workers—with more dangerous working conditions and low valuation—suffer most from early mortality (Ravesteijn et al. 2013). Even if the socio-professional category is an estimate of a certain level of income, this variable remains imprecise and silent regarding the professional career as a whole, and its transitions. Similarly, terms such as "unemployed" or "retired" do not reflect the economic reality of a person according to their previous activity, and their possibilities to rebound more or less easily.

Similarly, the socioeconomic situation conditions the access to a good quality housing and to homeownership, through the income and the professional occupation. While housing quality and housing tenure clearly impacts the health status and life expectancy of individuals, the question of the interaction of other socioeconomic factors arises. The contribution of this research is to show the impact of housing conditions on life expectancy in Belgium and their evolution between 1991 and 2016, as well as to estimate their net impact on mortality, regardless of individual characteristics.

As a fourth and last hypothesis, this research assumes that housing conditions have their own impact on mortality that persists after controlling for socioeconomics background (education, socio-professional category, income).

Data and method

A linkage of register and census data

This research data are the result of the coupling of the population census of 1991, 2001 and 2011 and the National Register. They cover the entire population of Belgium over three periods (1992–1996, 2002–2006, 2011–2015), i.e. 25 years of observation. The censuses will provide access to data related to housing—quality and tenure—and socio-economic characteristics on the dates of each of the censuses (1991, 2001 and 2011). The National Register provides information related to deaths that occurred within 5 years after each census (1992–1996, 2002–2006, 2012–2016) and demographic data at the time of death, such as household type, age, sex, marital status, nationality, region of residence. The two databases have the main advantage of covering the entire "legal" population, thus excluding people in an irregular situation or asylum seekers. It should be noted that migration is considered in the calculation of life expectancies: mortality rates use mid-period populations. In the multivariate analysis, this is not the case. Anyone who arrived after the census is not retained in the population, and the mortality of emigrants within 5 years after the census is not counted.

How to measure housing conditions

In order to assess the overall quality of housing conditions in Belgium, a composite variable was created (Eggerickx et al. 2018). Its purpose is to give each individual a score out of 4, relating to different elements that come into play in housing: occupancy status of the dwelling, presence of a bathroom, central heating, separate kitchen, double glazing, garage, but also the type of dwelling and occupancy density of the dwelling. In the 1991 census, the housing score also included the presence of a fixed telephone line, which no longer makes sense since the advent of mobile telephony (Eggerickx et al. 2018). As the score was far from a regular distribution among the population (see Appendix 1), the creation of a categorisation was necessary. Two types of division of this score were carried out, following two different objectives.

The first division aimed at drawing a meaningful distinction between the poor-quality housing and the high-quality housing and at describing the characteristics of the population living in poor quality housing and was also used in the multivariate analysis, to assess situations based on experiences instead of statistical issues, like quartiles do. Three categories were defined: poor housing (score under 2.2 out of 4, gathering the first decile of the population according to housing score), intermediate housing quality (score between 2.2 and 3 included) and high-quality housing (score over 3 out of 4).

The second division into quartiles was defined to keep equal numbers of population between categories and across time. This was used for life tables analysis and comparison between the 1992–1996 and 2011–2015 periods. As the demographic

and socioeconomic conditions differed between the two extreme quartiles and could not be controlled, distinguishing a very disadvantaged population meant taking the risk to consider a very marginalised and particular population.

Housing tenure holds a special place among housing conditions variables. It indicates whether the dwelling is inhabited under a lease or a property title and it is the same for all the members of the household. Renting one's accommodation can refer to two types of situations: private rental or public rental of social housing. The latter category provides access to affordable, capped and market-independent housing for low-income households (Ghekière 2008). People living in free housing have been counted as tenants, due to their low representation in the population—for example, less than 2% in 2001 (Vanneste et al. 2007).

Descriptive analysis and life tables

This article will aim at showing the net impact of lower housing conditions on mortality in Belgium. First, a demographic and socioeconomic portrait of the populations living in poor housing conditions and of the tenants will be drawn up. This description of the housing-wise disadvantaged population according to those characteristics had never been done before in Belgium. A comparison between the 1992–1996 and 2011–2015 periods were carried out. The exclusion of the 2002–2006 is mainly due to high non-response levels. Three types of covariates are included in the analyses. The presence of a bathroom (Yes or No), of central heating (Yes or No) and the density of occupation (divided in eight categories of area per occupant) of the housing represent some aspects of the housing quality. Individuals' demographics are also considered, such as age, sex, nationality (Belgian, other European, non-European), and household composition (Married With, or Without child, Cohabitants With, or Without child, Single-parents, One-person household and Collective habitat). The region of residence also distinguished the three Belgian regions: Wallonia, Flanders and Brussels. Finally, the socioeconomic characteristics included the educational attainment (Primary, Secondary, Higher education) and the socioprofessional categories (Unemployed, Retired or inactive, Manual worker, Independent, Employees of Private sector or Public sector) of the adults over 18.

Then, the construction of life tables based on housing conditions allowed life expectancy comparisons. Based on mortality trends by age group, over the periods 1992–1996 and 2011–2015, life expectancies at birth were calculated according to housing tenure and to housing score quartiles. As the approach of the 1991 and 2011 census are more similarly constructed compared to the 2001 census, in terms of structure and selected variables, we focus especially on a comparison between the 1992–1996 and 2011–2015 periods. Attention will be paid to the evolution of these differentials over time, but also to the contribution of each age group to this evolution, using the Arriaga method. Meslé and Vallin (2002) suggested this method to compare the progress of various sub-populations in the health transition process. The more older age groups contributed to the overall increase in life expectancy, the more this sub-population is at the forefront of the health transition, through the postponement of deaths to old ages.

For example, if AGC $[x; x + n]$ is the contribution of the age group from x to $x + n$ to the difference in life expectancy between two categories A and B over a given period:

$$AGC[x; x + n] = \frac{1}{l_0^A} \left[\left(\frac{l_x^A + l_x^B}{2} \right) * \left(e_x^B - e_x^A \right) - \left(\frac{l_{x+n}^A + l_{x+n}^B}{2} \right) * \left(e_{x+n}^B - e_{x+n}^A \right) \right]$$

with l_x the number of survivors at age x and e_x the life expectancy at age x.

Multivariate analysis

Finally, in order to determine the *net* effect of housing characteristics on the risk of death, logistic regressions will be carried out. The dependent variable of these models will be the risk of death within 5 years after the census. This variable is binary and distinguishes the death (1) from the survival (0) during the three periods (1992–1996, 2002–2006, 2011–2015).

The three censuses used different modes of data collection, which can explain the decrease of the total population considered between the 2001 and 2011 census. For the 1992–1996 and 2002–2006 periods, the population living in low quality housing and the renters show higher crude death rate than the overall population. For the 2011 period, renters show very close crude death rate while people living in poor quality housing are associated with lower crude death rate, both compared to the general population.

The logistic regression estimates the probability of a binary event. In our context, the probability of dying (Y) on a considered five-year period is P(Y):

$$P(Y) = \frac{1}{1 + e^{-z}}$$

with $z = \alpha_0 + \alpha_1 X_1 + \alpha_2 X_2 + \cdots + \alpha_i X_i$

Each value of α_i indicate the relation between the dependent variable Y and the different independent variables X_i, while neutralising the relation between Y and all the other X. The interpretation of logistic regression uses the odds ratio, that is e^{α_i}. The odds are defined by the probability of an event, such as death, divided by the probability of the opposite event, such as survival in our situation. Odds-ratio compare the odds of a category to a reference modality of the same variable. With this method, we will estimate the relation between the risk of death and an interest variable (housing quality and housing tenure), considering one or more covariates. Several variables will be selected to control the relationship: age, sex, household type, marital status, nationality, region, education level, socio-professional category, and even the level of income for the 2011 census, which will receive special attention. The models will be carried out in "stepwise" mode, which highlights the evolution of the relation as variables are added to the model, and in two sets, according our interest independent variable (housing quality or tenure).

Results

A socioeconomic portrait of the poorly housed population and of the renters

The descriptive analysis presented in Table 1 shows the total number of persons for each census date and the number of death on each period, for the total population, the population living in low-quality housing (whose housing score is below 2,2 out of 4) and the renters. It also gives the crude death of rate for people living in poor quality housing and for renters, compared with the total population. Table 2 shows the distribution of some characteristics among population living in low quality housing and renting their accommodation, in 1991 and in 2011. First, this description confirms that renters are more frequent to live in low housing conditions than owners. 73.2% of population living in poorer housing quality rent their accommodation in 1991, and this proportion of renters rises to 92.9% in 2011. The lower quality dwellings are associated with more crowded housing conditions, while rented accommodations are more often in extreme situations: for both years, the proportion of very crowded or very spacious dwellings are higher for renters than the general population. The presence of a bathroom and of a central heating are other indicators of the quality of housing. In 1991, the differences between the lower quality housing and the general population is more visible than in 2011: in 1991, 43.2% of the poorly housed population have a bathroom and 12% have a central heating, versus 93.3% and 68.6% respectively in 2011. In 1991, renters also tend to have a lower presence of bathroom and central heating in their accommodation compared to general population, but this difference decreases dramatically in 2011, showing a better housing equipment in most dwelling, including for the renters.

In 1991 and 2011, people with poorer quality housing were on average older than the total population In Belgium. They were also more likely to be unmarried (divorced, widowed, single), with a foreign but European nationality, and living in Brussels.

Table 1 Populations at census, number of deaths and crude death rate for total population, people living in low quality housing (score under 2.2 out of 4) and renters

		Total numbers (at the census date)	Number of deaths on the period	Crude death rate (%)
1992–1996	Total	11,094,032	523,018	0.94
	Low quality	1,084,889	90,282	1.66
	Renters	2,786,662	145,799	1.04
2002–2006	Total	12,768,666	519,441	0.81
	Low quality	1,581,435	92,440	1.17
	Renters	2,496,765	119,762	0.96
2011–2015	Total	12,251,199	537,784	0.88
	Low quality	1,596,193	46,018	0.58
	Renters	3,124,143	140,163	0.89

Source: National Register for 1992–1996, 2002–2006 and 2011–2015 periods, 1991, 2001, 2011 Population Census—calculation by DEMO-UCL and author

Socially-speaking, they were more disadvantaged, less educated, and more often unemployed or inactive than people living in high quality housing. The housing tenure and comfort appeared to be important socio-demographic markers. However, in 2011, socioeconomic differences according to the housing global quality are decreasing. Between 1991 and 2011, people living in low quality housing are on average younger, hence a lower crude death rate for this population in 2011 (Table 1). Also, the proportion of higher education graduates living in poor housing conditions doubles, getting from 3.6 to 7.1% (Table 2). One reason may be that life course disruptions, such as a divorce or unemployment, tended to affect a larger population in 2011 than in 1991, through a loss of income and subsequent change and loss of housing quality.

In 2011, 62% of people living in Belgium were homeowners, and 26% were tenants. For remaining 12%, housing information was missing. These proportions seem stable over time, since already in 1991, Belgium had 60% of owners and 25% of tenants. Tenants have on average lower quality housing compared to owners, due to lack of bathroom, central heating, or higher occupancy density. Tenants were on average younger, more often foreigners, living in Brussels, and were less often married than owners. At the same time, tenants were on average better endowed than the total population, in terms of education and employment levels.

Life expectancies at birth according to housing conditions

On average, homeowners live longer than tenants, for both men and women (Table 3). For the period 2011–2015, male homeowners can expect to live 79.9 years, compared to 74.2 years for tenants. For women, a life expectancy of 84.8 years for homeowners is compared to 81.0 years for tenants. Over the period 2011–2015, we can therefore observe a gap of 5.7 years in life expectancy between homeowners and tenants for men and 3.8 years for women. Over the period 1992–1996, these gaps were smaller, respectively 4.2 years and 2.4 years (Table 3). Life expectancy gaps by occupation status tend to widen and follow the trends of other socioeconomic factors. This partially confirms our first hypothesis.

Analyses relied on population quartiles defined by housing quality, i.e. four population groups according to their housing score, almost identical in size. Thus the first quartile includes the 25% of the population with the lowest housing score and the 4th quartile represents the 25% of the population with the best housing. Over the period 2011–2015, men in the first quartile could expect to live an average of 75.5 years, compared to 79.2 years for men in the last quartile, a difference of 3.7 years (Table 3). Women living in poorer housing conditions have a life expectancy shortened by 3.3 years compared those living in high housing conditions (81.2 years compared to 84.6 years). These gaps between first and fourth housing score quartiles have decreased over time: they were 5.6 years for men and 4.1 years for women over the period 1992–1996 (Table 3). Unlike other socioeconomic variables, the gap between extreme quartiles has decreased over the past two decades: how to explain this paradox? As a first remark, the housing quality is on average better in 2011 than twenty years earlier (Table 2). Differences in housing quality scores, measured by items such as bathroom, or central heating, are no longer as

Table 2 Socio-demographic characteristics of the population living in poor housing conditions (score lower than 2.2 out of 4) and renters

	1991			2011		
	Score <2.2 (%)	Renters (%)	Total (%)	Score <2.2 (%)	Renters (%)	Total (%)
Total of respondents	11.4	29.6		15.6	29.2	
Housing tenure						
Owner	26.8		70.4	7.1		70.8
Renter	73.2		29.6	92.9		29.2
Density of occupation (m² per habitant)						
Lower than 10 m²	5.7	2.7	1.5	5.8	9.7	5.3
10 to 14.9 m²	17.6	8.3	5.9	12.4	12.5	9.9
15 to 19.9 m²	21.4	17.0	16.3	21.8	10.1	10.5
20 to 24.9 m²	8.9	10.8	13.6	18.0	14.4	19.6
25 to 29.9 m²	12.5	14.8	16.8	25.7	16.6	17.4
30 to 36.9 m²	12.5	12.9	14.3	5.0	7.9	9.8
37 to 47.9 m²	10.3	18.3	19.5	2.8	14.9	15.6
49 m² or more	11.0	15.1	12.2	8.5	13.9	11.9
Presence of a bathroom						
Yes	43.2	87.2	91.5	93.3	98.7	98.8
No	56.8	12.8	8.5	6.7	1.3	1.2
Presence of central heating						
Yes	12.0	56.1	63.6	68.6	86.1	86.7
No	88.0	43.9	36.4	31.4	13.9	13.3
Age						
Under 20	12.0	31.0	23.6	25.7	31.1	21.3
20–29	11.4	31.5	13.3	19.9	31.9	12.3
30–39	11.9	39.7	15.1	21.6	41.9	12.9
40–49	8.6	26.3	13.4	16.8	29.8	13.2

Table 2 (continued)

	1991			2011		
	Score <2.2 (%)	Renters (%)	Total (%)	Score <2.2 (%)	Renters (%)	Total (%)
50–59	8.2	22.9	10.2	11.5	25.2	13.5
60–69	10.0	22.6	10.2	7.5	22.7	11.2
70–79	13.0	27.6	7.4	6.2	21.3	7.6
80–89	20.3	31.1	4.4	6.9	23.7	5.8
90 and more	21.5	37.0	2.4	8.5	28.9	2.3
Nationality						
Belgian	9.9	27.7	81.7	12.8	25.9	80.3
European (non Belgian)	12.2	43.1	5.4	24.6	50.7	6.5
Non-European	8.1	61.7	12.9	8.5	73.7	13.2
Region						
Flanders	9.7	25.9	59.7	11.8	24.2	59.7
Wallonia	11.6	29.4	30.4	18.9	29.8	29.7
Brussels	16.4	55.9	9.9	28.0	56.5	10.6
Marital status						
Single	12.3	31.6	38.5	20.5	33.8	43.9
Married	9.5	25.5	50.1	11.0	19.6	40.3
Divorced	16.8	33.4	7.5	8.1	29.8	6.5
Widow. widower	17.1	56.8	3.8	18.2	48.9	9.3
Education						
No. primary	17.2	31.4	43.2	14.8	32.0	16.9
Secondary	8.3	28.5	40.5	9.9	22.9	55.6
Higher	3.6	27.6	16.3	7.1	19.0	27.5
Socio-professional category						

Table 2 (continued)

	1991			2011		
	Score <2.2 (%)	Renters (%)	Total (%)	Score <2.2 (%)	Renters (%)	Total (%)
Unemployed	17.2	35.2	16.0	21.3	38.3	29.2
Retired	13.9	26.8	33.1	6.6	22.7	23.2
Manual worker	13.1	32.4	13.6	19.2	34.9	14.7
Independent	6.1	27.2	7.8	10.3	22.9	4.7
Employed (public)	7.2	27.5	14.4	5.8	15.0	6.5
Employed (private)	5.4	30.5	15.0	9.9	23.5	21.7

Source: National Register, 1991 and 2011 Population Census—calculation by DEMO-UCL and author

In 1991, 1,084,894 persons lived in under 2.2 quality score housing, 2,786,662 were renters, out of a 11,094,032 total population. In 2011, 1,596,193 persons lived in under 2.2 quality score housing, 3,124,143 were renters and the total population counted 12,251,199 individuals

discriminating. A second explanation is that poor quality housing is less and less the monopoly of disadvantaged populations: modern lives are plagued by uncertainty, separation, job loss and mobility. This sometimes means a downgrading in terms of housing quality following a loss of income (Mulder and Lauster 2010; Painter and Lee 2009), which can concern all the categories of the population. Given the increasingly difficult access to a good quality housing—for young adults in particular (Bugeja-Bloch 2013)—and these "life disruptions", populations living in low quality housing are going through a progressive social heterogenization (Table 2). The housing score would no longer be a good proxy for socio-economic status in general and does not follow the trend of other socioeconomic factors. The first hypothesis cannot be confirmed by this score (Table 3).

The contribution of age groups to the life expectancy improvement according to housing conditions

The Arriaga method aims at comparing how age groups contributed to life expectancy changes from the 1990s to the 2010s, according to housing conditions. Over those two decades, life expectancy at birth increased for the vast majority of the population, but not in the same way for everyone. Between the 1992–1996 and 2011–2015 periods, homeowners experienced a higher gain in life expectancy at birth than renters, for both men (5.2 years versus 3.5 years) and women (3.6 years versus 2.3 years). The increase in life expectancy can be seen in all age groups, but its intensity is much higher among those aged 60 and over (Table 4). For instance, male homeowners aged 60 and over contributed 63.1% to the rise in life expectancy, compared with 53.4% for male tenants in the same age group. Among women, there is less difference in contribution among those aged 60 and over according to the housing tenure (Table 4).

In terms of overall housing quality, the gain in life expectancy for people under 60 is much higher in the first quartile than in the last. As highlighted previously, the first quartile experienced a change of composition between 1991 and 2011: on average, it is a more educated population, whose overall socio-economic situation is more heterogeneous than before. This can explain why the first quartile of housing score is associated with a significant increase in life expectancy among adults aged 40 to 59 years (Table 4). Mortality at these ages is avoidable, as it is largely related to people's lifestyles and risky behaviors (Meslé and Vallin 2002). The gain in absolute life expectancy for people aged 60 and over is quite similar for the two extreme quartiles of the housing score—as those two populations are more and more similar in terms of socioeconomic characteristics—although there is a slight superiority in life expectancy gain for those aged 80 and over for the last quartile, especially for women.

The use of the Arriaga method, linked to the sanitary transition theory (Meslé and Vallin 2002), leads to some conclusions. On the one hand, if gains in life expectancy over a period are due to gains among young populations, the improvement is mainly due to early factors in health transition, such as better care for the youngest, more assiduous control of infectious diseases and greater protection in risky professional activities. On the other hand, if gains are made among older adults or seniors, the health transition is more advanced: a better

Table 3 Life expectancies at birth in Belgium according to housing quality score and housing tenure on the 1992–1996 and 2011–2015 periods

Dimensions	Modalities	Male			Female		
		1992–1996	2011–2015	Rise in time	1992–1996	2011–2015	Rise in time
Housing quality score	1st quartile	70.4	75.5	5.1	78.2	81.2	3.0
	2nd quartile	73.6	78.5	4.9	80.4	83.2	2.8
	3rd quartile	75.5	78.9	3.4	81.7	84.1	2.4
	4th quartile	76.0	79.2	3.2	82.3	84.6	2.3
	Gaps between quartiles 1 and 4	*5.6*	*3.7*		*4.1*	*3.3*	
Housing Tenure	Tenant	70.6	74.2	3.6	78.8	81.0	2.2
	Owner	74.8	79.9	5.1	81.2	84.8	3.6
	Gaps between status	*4.2*	*5.7*		*2.4*	*3.8*	

Source: National Register, 2011 Population Census—calculation by DEMO-UCL and author

Italics indicate it is a summary of the information (total or sum)

Table 4 Contribution of 20 years age groups in the evolution of life expectancy at birth between the 1992–1996 and 2011–2015 periods according to housing conditions

Contribution of age groups		Tenants		Owners	
		Absolute	Relative (%)	Absolute	Relative (%)
Male	0–19	0.5	13.1	0.5	8.7
	20–39	0.5	13.9	0.5	9.7
	40–59	0.7	19.6	1.0	18.4
	60–79	1.5	41.3	2.5	49.2
	80+	0.4	12.1	0.7	13.9
	Total gain	*3.5 years*		*5.2 years*	
Female	0–19	0.2	8.0	0.3	9.4
	20–39	0.2	9.9	0.2	5.7
	40–59	0.2	10.1	0.5	13.2
	60–79	0.8	36.4	1.4	39.5
	80+	0.8	35.6	1.2	32.2
	Total gain	*2.3 years*		*3.6 years*	
		Q1		Q4	
		Absolute	Relative (%)	Absolute	Relative (%)
Male	0–19	0.1	2.9	0.0	− 3.5
	20–39	0.8	14.9	0.3	9.1
	40–59	1.8	35.3	0.3	8.9
	60–79	2.0	38.4	2.1	65.6
	80+	0.4	8.4	0.7	19.2
	Total gain	*5.1 years*		*3.2 years*	
Female	0–19	0.0	− 0.2	0.0	− 1.6
	20–39	0.3	11.2	0.1	5.1
	40–59	0.8	26.3	0.1	4.1
	60–79	1.2	38.7	1.0	46.6
	80+	0.7	24.0	1.0	45.7
	Total gain	*3.0 years*		*2.2 years*	

Source: National Register, 2011 Population Census—calculation by DEMO-UCL and author

Italics indicate it is a summary of the information (total or sum)

control on so-called "society" diseases, thanks to prevention, and behaviours result in longer survival. In our case, owners are at the forefront in the health transition process compared to renters, as the increase in life expectancy among older people is higher among the former. In terms of housing quality score, the gap is less obvious, but it is possible to see the advance of fourth quartile within the health transition process, especially among the very elderly. This illustrates the change of composition of the population from the first housing score quartile, and explains why this variable does not follow the trend of other socioeconomic factors.

The net impact of housing conditions on mortality

What is the net effect of housing conditions on the risk of death within 5 years after the census? Over the three periods, stepwise regression models were developed. Their purpose is to observe how the relationship evolved as the different variables were integrated. In the models, housing conditions are represented not only by the housing score, but also by four of its components: tenure, occupancy density, presence of a bathroom and central heating. Various socio-demographic variables were included in the models: the 10-year age group, household type, marital status, nationality, region of residence, as well as the maximum level of education and socio-professional category. For the latter two variables, children were assigned the status of their most advantaged parent. The entire models are presented in the Appendix 2.

The large richness of data from the 2011 census by register allows the level of income per decile to be included in the model, only for this period. The first decile includes the 10% of the population with the lowest tax incomes in the country. Total net income is the sum of all net income from the various tax categories: real estate income, capital and movable property income and revenues, professional and miscellaneous income (Statbel 2019). A variable representative of the average level of income during the period 2011–2016 was generated as part of this research, in the form of a score out of 10 (Table 5).

Once age, as well as other demographic (nationality, region, gender) and life-cycle (marital status, household type) characteristics are controlled (Model 1; -a for housing quality: -b for housing tenure), there remains an excess mortality rate among the individuals living in poorer housing conditions (score under 2.2/4), compared to those living in an intermediate housing quality (score between 2.2 and 3 out of 4). People living in high quality housing (score > 3/4) are associated with a lower risk of mortality than people whose housing conditions are intermediate. Tenants are also associated with a higher mortality rate than owners (Table 5). These results are still robust, even after including in Model 2 education level and occupational category, as well as income level (time-varying) in Model 3 for the 2011–2015 period.

As already mentioned, housing conditions are strongly correlated to an individual's overall socio-economic situation, i.e. their level of income, which in turn depends on education and professional occupation. The control of the relation by socioeconomic variables is therefore important to identify the net impact of housing conditions on mortality. First, after control by education level and socio-professional category, poor housing is associated with a lower excess mortality but it persists: people living in poor quality housing (score below 2.2 out of 4) have an excess mortality of 29% compared to those in high quality housing (score above 3 out of 4). Tenants have an excess mortality of 30% compared to owners (Table 5). After controlling for income level, the excess mortality of the population in poor housing conditions is still reduced, but it persists in a significant way. Indeed, the inhabitants of poor housing are subject to a 25% higher risk of death than the people living in high quality housing. Tenants have a 25% higher risk of death than homeowners as well (Table 5).

Table 5 Odds ratio and significativity on the risk of death on the 1992–1996, 2002–2006 and 2011–2015 periods

		Model 1a	Model 2a	Model 3a	Model 1b	Model 2b	Model 3b
1992–1996							
Housing score (ref: score <2.2)	Score between 2.2 and 3	0.83	0.87				
	Score > 3	0.64	0.70				
Housing tenure (ref: Owner)	Tenant				1.19	1.19	
2002–2006							
Housing score (ref: score <2.2)	Score between 2.2 and 3	0.81	0.85				
	Score > 3	0.61	0.67				
Housing tenure (ref: Owner)	Tenant				1.35	1.31	
2011–2016							
Housing score (ref: score <2.2)	Score between 2.2 and 3	0.86	0.91	0.93			
	Score > 3	0.63	0.71	0.75			
Housing tenure (ref: Owner)	Tenant				1.38	1.31	1.25

Source: National Register, 2011 Population Census—calculation by DEMO-UCL and author

Model 1: control for age, household configuration, marital status, region, nationality; Model 2: control for previous + education, socio-professional category; Model 3: control for previous + income. Models b also control for presence of a bathroom, of a central heating and for occupancy density

Results are all significant ($p < 0.01$), as population data were used

Discussion of the results

This research focused on two major and interdependent issues Belgium is facing: inequalities in housing conditions and inequalities in death. Between 1991 and 2011, renters are, on average, less educated than homeowners and are more frequently unemployed. In 1991, poor housing is associated with lower levels of education and a more unstable (unemployment) or difficult (workers) occupational situation than high quality housing. In 2011, low quality housing is no longer a problem reserved for the most disadvantaged categories: "life disruptions", such as divorces, job losses and difficulties in social integration are part of the lives of an increasingly heterogeneous population, and affect people with higher education and better socioeconomic situations.

Comparing the 2010s to the 1990s, life expectancies had increased for the vast majority of the Belgian population, but not as the same rate for everyone, which extenuates social inequalities. Over the period 2011–2015, homeowners and tenants showed a life expectancy gap of 5.7 years for men and 3.8 years for women, which confirms our third hypothesis. Compared to the period 1992–1996, this gap has widened. In 2011, it is estimated that for men, 3.7 years of life expectancy separates the 25% of the population living in the highest housing conditions from the 25% of the population living in poor housing. This gap is 3.3 years for women. The second hypothesis can be confirmed. Compared to the period 1992–1996, this gap has narrowed, symbolizing the heterogeneity of the poorly housed population. Their now more favorable social characteristics, with higher levels of education than before, are positive factors for their life expectancy. The use of the Arriaga method shows the absolute and relative contribution of duodecimal age groups to the change in life expectancy between 1992–1996 and 2011–2015, depending on housing conditions. The age groups that have contributed to the increase in life expectancy of homeowners and those with better housing are generally older than those who rent and those with poor housing. Homeowners are ahead of the tenants in terms of health transition, expressed in the postponement of deaths to very old ages (Meslé and Vallin 2002). Our first hypothesis is partially confirmed, only when considering housing tenure.

Finally, logistic regression models allowed us to identify the own effect of housing conditions and showed an excess mortality among tenants compared to owners, and a negative association between mortality rate and the housing quality score, as soon as the demographic variables (sex, age, family and marital configuration, nationality, region) were included in the model for the three periods. As socio-economic variables are added, these relationships become less intense, reflecting the clear interaction between housing and the overall socio-economic level. Nevertheless, after controlling by education level, occupational category and average income level over the 2011–2015 period, there remains an excess mortality rate of 25% among tenants compared to homeowners, and an excess mortality rate of 25% among the poorly housed compared to the best housed population. Housing conditions show their own effects on mortality for the three periods, confirming the fourth hypothesis of this research.

The tools generated as part of the *Causineq* project made this research possible—the matching of Belgium's exhaustive databases, the creation of a synthetic housing quality score and of life tables based on housing conditions. Working with administrative and exhaustive data gives a real advantage to the research. But, even if the coupling of the databases was done with attention to detail, the comparability of the data over time cannot be perfect. The censuses, which between 1991 and 2011, all had different collection methods. In 2011, the census was conducted without any contact with the population, but on the basis of the use of registers. Similarly, exhaustiveness is not effective for all variables: high non-response rates are to be noted for some variables (housing tenure, education level in some years, etc.). Some selection bias cannot be ruled out, particularly in view of lower life expectancies in unknown categories than in others. Despite those issues, the richness of this exhaustive dataset has to be highlighted, as well as the opportunity to consider income levels for the period 2011–2016, which is the most accurate estimate of an individual's economic level, unlike an imprecise socio-professional category, and a level of education that does not fully reflect one's socio-economic future.

The data made available could not conclude to any causal relation between housing conditions and higher mortality rate. First, the causal precedence of the phenomenon is by no means guaranteed: it cannot be ruled out that a previously fragile state of health may lead to or at least participate in a certain marginalization and poor housing conditions. Then, this short-term analysis only provides information about a fixed situation, regardless of the individual's life course. A "life-course" approach was not possible in this context, but could have examined how given housing conditions, in light of past experiences, can play a role in people's health status.

The purpose of this research was to show the net effect of housing conditions on mortality gaps. Nevertheless, it may seem very artificial to separate different elements that make up a person's living environment, namely their housing quality and their socio-economic level. Living from a low social status and an insufficient level of income increases the risk of not having access to quality housing in a provided and developed neighbourhood. But this research has shown that housing conditions have its own effect on the risk of death, in addition to reflecting the overall socio-economic level. It calls for a rethinking of the political fight against social inequalities in health and mortality. Ensuring good housing conditions and a good quality living environment for everyone is a necessary step towards reducing inequalities. The accommodation, as a base of physical, psychological and social well-being, is an essential good for development in all spheres of life (Lawrence 1998; Bernard 1998; Hiscock et al. 2001).
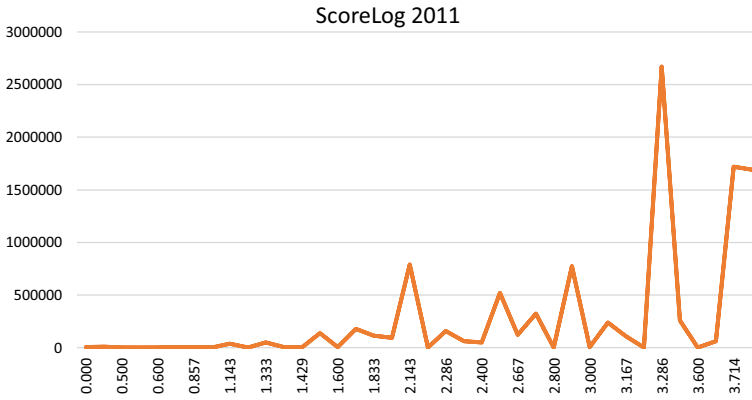
Compliance with ethical standards

Conflict of interest The authors declare that they have no conflict of interest.

Appendix 1

Distribution of the housing score in the Census Population (2011). *Source*: National Register, 2011 Population Census—calculation by DEMO-UCL and author

Housing score	Freq.	Percentage	Cumulative percentage
0.000	3334	0.03	0.03
0.429	8512	0.07	0.1
0.500	704	0.01	0.1
0.571	698	0.01	0.11
0.600	1024	0.01	0.12
0.800	3677	0.03	0.15
0.857	6163	0.05	0.2
1.000	2558	0.02	0.22
1.143	35,658	0.29	0.51
1.200	727	0.01	0.51
1.333	50,329	0.41	0.93
1.400	6103	0.05	0.98
1.429	1121	0.01	0.98
1.571	1,38,079	1.13	2.11
1.600	3908	0.03	2.14
1.714	1,77,233	1.45	3.59
1.833	1,14,821	0.94	4.53
2.000	95,189	0.78	5.3
2.143	7,87,954	6.43	11.74
2.200	2201	0.02	11.75
2.286	1,56,200	1.27	13.03
2.333	62,356	0.51	13.54
2.400	49,978	0.41	13.95

Housing score	Freq.	Percentage	Cumulative percentage
2.571	5,19,059	4.24	18.18
2.667	1,20,224	0.98	19.16
2.714	3,24,331	2.65	21.81
2.800	1630	0.01	21.82
2.857	7,74,104	6.32	28.14
3.000	5544	0.05	28.19
3.143	2,39,492	1.95	30.14
3.167	1,11,669	0.91	31.05
3.200	2959	0.02	31.08
3.286	26,70,853	21.8	52.88
3.429	2,60,227	2.12	55
3.600	2588	0.02	55.02
3.667	60,431	0.49	55.52
3.714	17,20,333	14.04	69.56
4.000	16,89,890	13.79	83.35
99.000	7,39,405	6.04	89.39
	12,99,933	10.61	100

Appendix 2: Logistic regression models

See Tables 6, 7, and 8.

Table 6 Odds ratio and significativity on the risk of death on the 1992–1996 period

1991	Model 1a	Model 2a	Model 1b	Model 2b
Housing score quality (ref: < 2.2/4)				
Entre 2.2 et 3/4	0.828***		0.867***	
>3/4	0.637***		0.699***	
Unknown	0.663***		0.891***	
Presence of a bathroom				
No		1.308***		1.254***
Unknown		1.100**		1.173**
Density (ref: < 0.5 room/inh)				
0.5 to 1 room/inh		0.849***		0.770***
1 to 1.25 room/inh		0.805***		0.739***
1.25 to 1.5 room/inh		0.979***		0.744***
1.5 to 2 rooms/inh		0.805***		0.746***
2 to 2.5 rooms/inh		0.785***		0.734***
2.5 to 3 rooms/inh		0.752***		0.705***
More than 3 rooms/inh		0.658**		0.641***
Presence of central heating				
No		1.159***		1.096***
Unknown		1.102***		1.112***
Housing tenure (ref: Owner)				
Tenant		1.194***		1.186***
Unknown		1.071***		1.122***
Household composition (ref: married couple with child)				
Married couple without child	1.385***	1.246***	1.435***	1.279***
Cohabitants with child	1.098***	1.050***	1.094***	1.045***
Cohabitants without child	1.351***	1.218***	1.391***	1.233***
Collective	3.616***	2.800***	3.567***	2.639***
Isolated	1.401***	1.279***	1.527***	1.343***
Single-parent	1.323***	1.244***	1.346***	1.257***
Others and unknown	1.642***	1.488***	1.643***	1.487***
Gender (ref: Man)				
Woman	0.511***	0.477***	0.510***	0.476***
Age group (ref: under 20 y.o.)				
20–29 y.o.	1.501***	1.517***	1.503***	1.509***
30–39 y.o.	1.868***	1.892***	1.882***	1.874***
40–49 y.o.	4.36***	4.165***	4.403***	4.141***
50–59 y.o.	9.553***	8.070***	9.679***	8.061***
60–69 y.o.	21.787***	13.460***	22.125***	13.516***
70–79 y.o.	51.513***	27.299***	52.117***	27.402***
80–89 y.o.	151.433***	80.437***	152.995***	80.529***
90 y.o. and more	208.814***	63.550***	106.462***	63.253***
Nationality (ref: Belgian)				
European (except Belgian)	0.669***	0.685***	0.665***	0.682***

Table 6 (continued)

1991	Model 1a	Model 2a	Model 1b	Model 2b
Non-European	0.337***	0.376***	0.334***	0.370***
Marital status (ref: single and unknown)				
Maried	1.022***	0.920***	1.009***	0.912***
Divorced	1.591***	1.383***	1.604***	1.395***
Widow, widower	1.276***	1.197***	1.267***	1.188***
Region of residence (ref: Flanders)				
Wallonia	1.612***	1.176***	1.155***	1.171***
Brussels	1.037***	1.132***	1.030***	1.105***
Unknown	1.035***	1.107***	1.042***	1.108***
Education (ref: no diploma, primary)				
Lower secondary			0.925***	0.928***
Higher secondary			0.806***	0.813***
Higher education			0.785***	0.796***
Unknown			0.680***	0.696***
CSP (ref: unemployed)				
Retired			1.121***	1.120***
Manual workers			0.502***	0.501***
Independants and liberals			0.568***	0.570***
Employed (public sector)			0.530***	0.529***
Employed (private sector)			0.470***	0.469***

Source: National Register, 2011 Population Census—calculation by DEMO-UCL and author

* if *p*-value > 0.05 ; ** if *p*-value > 0.01; *** if *p*-value > 0.001

Table 7 Odds ratio and significativity on the risk of death on the 2002–2006 period

2001	Model 1a	Model 2a	Model 1b	Model 2b
Housing score quality (ref: <2.2/4)				
2.2 to 3/4	0.806***		0.846***	
>3/4	0.605***		0.672***	
Unknown	1.470***		1.314***	
Presence of a bathroom				
No		1.292***		1.237***
Unknown		0.793***		0.705***
Density (ref: <0.5 room/inh)				
0.5 to 1 room/inh		0.941		0.968
1 to 1.25 room/inh		0.948		0.993
1.25 to 1.5 room/inh		0.911		0.965
1.5 to 2 rooms/inh		0.924		0.991
2 to 2.5 rooms/inh		0.916		0.986
2.5 to 3 rooms/inh		0.855**		0.925**
More than 3 rooms/inh		0.841**		0.927**
Presence of central heating				
No		1.227***		1.162***
Unknown		1.187***		1.093***
Housing tenure (ref: Owner)				
Tenant		1.346***		1.306***
Unknown		1.347***		1.283***
Household composition (ref: married couple with child)				
Married couple without child	1.312***	1.216***	1.298***	1.195***
Cohabitants with child	0.962*	0.961*	0.965*	0.961***
Cohabitants without child	1.227***	1.196***	1.206***	1.165***
Collective	2.218***	2.350***	2.235***	2.328***
Isolated	1.405***	1.336***	1.338***	1.261***
Single-parent	1.410***	1.342***	1.392***	1.314***
Others and unknown	1.479***	1.394***	1.485***	1.398***
Gender (ref: Man)				
Woman	0.483***	0.459***	0.482***	0.458***
Age group (ref: under 20 y.o.)				
20–29 y.o.	1.658***	2.193***	1.652***	2.194***
30–39 y.o.	2.227***	3.766***	2.210***	3.749***
40–49 y.o.	5.515***	8.911***	5.454***	8.872***
50–59 y.o.	14.053***	21.191***	13.912***	21.099***
60–69 y.o.	30.705***	39.042***	30.580***	39.024***
70–79 y.o.	79.715***	94.295***	79.588***	94.561***
80–89 y.o.	233.396***	276.448***	232.863***	277.033***
90 y.o. and more	850.278***	1007.327***	846.161***	1007.028***
Nationality (ref: Belgian)				
European (except Belgian)	0.796***	0.750***	0.794***	0.748***

Table 7 (continued)

2001	Model 1a	Model 2a	Model 1b	Model 2b
Non-European	0.732***	0.619***	0.725***	0.618***
Marital status (ref: single and unknown)				
Maried	0.931***	0.935***	0.940***	0.945***
Divorced	1.202***	1.167***	1.205***	1.174***
Widow, widower	1.166***	1.162***	1.167***	1.160***
Region of residence (ref: Flanders)				
Wallonia	1.248***	1.232***	1.248***	1.228***
Brussels	1.012***	1.051***	1.020***	1.045***
Unknown	1.063***	1.107***	1.067***	1.103***
Education (ref : no diploma, primary)				
Lower secondary			0.874***	0.878***
Higher secondary			0.839***	0.845***
Higher education			0.676***	0.681***
Unknown			1.036***	1.046***
CSP (ref: unemployed)				
Retired			0.891***	0.889***
Manual workers			0.558***	0.556***
Independants and liberals			0.528***	0.525***
Employed (public sector)			0.574***	0.570***
Employed (private sector)			0.468***	0.463***

Source: National Register, 2001 Population Census—calculation by DEMO-UCL and author

* if *p*-value > 0.05 ; ** if *p*-value > 0.01; *** if *p*-value > 0.001

Table 8 Odds ratio and significativity on the risk of death on the 2011–2015 period

2011	Model 1a	Model 2a	Model 1b	Model 2b	Model 1c	Model 2c
Housing score quality (ref: < 2.2/4)						
Entre 2.2 et 3/4	0.857***		0.914***		0.928***	
>3/4	0.632***		0.710***		0.752***	
Unknown	0.927***		0.973***		0.957***	
Presence of a bathroom						
No		1.272***		1.23***		1.223***
Unknown		1.029**		1.027**		1.01
Density (ref: < 0.5 room/inh)						
0.5 to 1 room/inh		1.067***		1.117***		1.05
1 to 1.25 room/inh		1.061***		1.113***		1.073*
1.25 to 1.5 room/inh		1.074***		1.168***		1.50***
1.5 to 2 rooms/inh		1.114***		1.211***		1.164***
2 to 2.5 rooms/inh		1.022		1.113***		1.085**
2.5 to 3 rooms/inh		0.959***		1.079***		1.050*
More than 3 rooms/inh		0.956**		1.077***		1.064*
Presence of central heating						
No		1.301***		1.209***		1.162***
Unknown		0.254***		1.171***		1.146***
Housing tenure (ref: Owner)						
Tenant		1.383***		1.309***		1.248***
Unknown		1.184***		1.218***		1.156***
Household composition (ref: married couple with child)						
Married couple without child	1.289***	1.331***	1.178***	1.200***	1.169***	1.195***
Cohabitants with child	0.819***	0.832***	0.856***	0.871***	0.824***	0.839***
Cohabitants without child	1.122***	1.145***	1.079***	1.093***	1.053**	1.073**
Collective	4.172***	4.521***	3.887***	3.979***	2.728***	2.817***
Isolated	1.320***	1.386***	1.234***	1.275***	1.228***	1.276***
Single-parent	1.390***	1.403***	1.307***	1.314***	1.273***	1.283***
Others and Unknown	1.430***	1.469***	1.317***	1.364***	1.249***	1.290***
Gender (ref: Man)						
Woman	0.519***	0.520***	0.492***	0.493***	0.534***	0.536***
Age group (ref: 50–59 y.o.)						
Less than 20 y.o.	0.032***	0.329***	0.017***	0.018***	0.010***	0.011***
20–29 y.o.	0.101***	0.103***	0.068***	0.071***	0.055***	0.057***
30–39 y.o.	0.156***	0.156***	0.164***	0.165***	0.156***	0.156***
40–49 y.o.	0.380***	0.383***	0.395***	0.398***	0.379***	0.382***
60–69 y.o.	2.425***	2.425***	1.985***	1.982***	1.989***	1.987***
70–79 y.o.	5.744***	5.736***	3.938***	3.943***	3.955***	3.961***
80–89 y.o.	17.557***	17.400***	11.593***	11.569***	11.327***	11.312***
90 y.o. and more	60.022***	59.469***	39.904***	39.774***	30.970***	30.853***
Nationality (ref: Belgian)						
European (except Belgian)	0.807***	0.809***	0.723***	0.729***	0.851***	0.855***

Table 8 (continued)

2011	Model 1a	Model 2a	Model 1b	Model 2b	Model 1c	Model 2c
Non-European	0.621***	0.627***	0.498***	0.514***	0.785***	0.800***
Marital status (ref: single and unknown)						
Maried	0.792***	0.801***	0.793***	0.806***	0.811***	0.824***
Divorced	1.075***	1.089***	1.057***	1.074***	1.101***	1.114***
Widow. widower	1.041***	1.046***	1.052***	1.059***	1.056***	1.062***
Region of residence (ref: Flanders)						
Wallonia	1.276***	1.266***	1.265***	1.257***	1.222***	1.212***
Brussels	1.030***	1.034***	1.061***	1.065***	1.072***	1.073***
Unknown	1.061***	1.084***	1.127***	1.139***	1.139***	1.149***
Education (ref: no diploma, primary)						
Lower secondary			0.867***	0.879***	0.882***	0.891***
Higher secondary			0.811***	0.831***	0.843***	0.858***
Higher education			0.638***	0.662***	0.719***	0.738***
Unknown			0.956***	0.964***	1.018	1.021**
CSP (ref: unemployed)						
Retired			0.898***	0.897***	0.973**	0.969**
Manual workers			0.545***	0.545***	0.653***	0.651***
Independants and liberals			0.514***	0.517***	0.540***	0.541***
Employed (public sector)			0.471***	0.471***	0.585***	0.578***
Employed (private sector)			0.446***	0.447***	0.531***	0.528***
Level of incomes					0.962***	0.964***

Source: National Register, 2011 Population Census—calculation by DEMO-UCL and author

* if *p*-value > 0.05 ; ** if *p*-value > 0.01; *** if *p*-value > 0.001

References

Bernard, Y. (1998). Du logement au chez-soi. In M. Segaud, C. Bonvalet, & J. Brun (Eds.), *Logement et habitat: l'état des savoirs* (p. 420). Paris: La découverte.

Bonnefoy, X. (2007). Inadequate housing and health: An overview. *International Journal of Environment and Pollution, 30*(3–4), 411–429.

Boomsma, C., Pahl, S., Jones, R. V., & Fuertes, A. (2017). Damp in bathroom. Damp in back room. It's very depressing!" exploring the relationship between perceived housing problems, energy affordability concerns, and health and well-being in UK social housing. *Energy Policy, 106,* 382–393.

Bugeja-Bloch, F. (2013). *Logement, la spirale des inégalités*. Paris: Puf.

Chatelard, S., Vaucher, P., Wolff, H., et al. (2012). Le médecin face aux inégalités sociales de santé: quel pouvoir d'action? *Revue médicale suisse*, *341*, 1061.

Coburn, D. (2004). Beyond the income inequality hypothesis: Class, neo-liberalism and health inequalities. *Social Science & Medicine*, *58*, 41–56.

Coley, R. L., Leventhal, T., Lynch, A. D., & Kull, M. (2013). Relations between housing characteristics and the well-being of low-income children and adolescents. *Developmental Psychology, 49*(9), 1775.

Deboosere, P., & Fiszman, P. (2009). About persistent socio-spatial inequalities in health: The Belgian example. *Space Populations Societies, 2009/1,* 149–158.

Deboosere, P., Gadeyne, S., & Van Oyen, H. (2009). The 1991–2004 evolution in life expectancy by educational level in Belgium based on linked census and population register data. *European Journal of Population/Revue européenne de Démographie, 25*(2), 175.

De Keersmaecker, M.-L. (1997). Right to housing and inequalities. In: De Keersmaecker, M.-L. (dir.). *Social inequalities in Belgium*. Bruxelles : Vie Ouvrière. 200 p.

Dunn, J. (2002). Housing and inequalities in health: A study of socioeconomic dimensions of housing and self reported health from a survey of Vancouver residents. *Journal of Epidemiology and Community Health, 56*(9), 671–681.

Eggerickx, T., Sanderson, J.-P., & Vandeschrick, C. (2018). Social and spatial inequalities of mortality in Belgium: 1991–2016. *Space Populations Societies, 2018-1*, 27.

Emelianoff, C. (2008). The problematics of ecological inequalities, a new conceptual landscape. *Écologie & Politique*, (1), 19–31.

Evans, G. W., Wells, N. M., & Moch, A. (2003). Housing and mental health: A review of the evidence and a methodological and conceptual critique. *Journal of Social Issues, 59*(3), 475–500.

Gadeyne, S. (2006). The ultimate inequality: Socio-economic differences in all-cause and cause-specific mortality in Belgium in the first part of the 1990s. Centrum voor Bevolkings-en Gezinsstudie (CBGS).

Ghekière, L. (2008). The development of the social housing in European Union. *Recherches Et Prévisions*, *94*(1), 21–34.

Herbert, C. E., & Belsky, E. S. (2008). The homeownership experience of low-income and minority households: A review and synthesis of the literature. *Cityscape, 10*, 5–59.

Herjean, P. (2006). A multilevel approach to health. *Cahiers de géographie du Québec, 50*(141), 347–355.

Hiscock, R., Kearns, A., Macintyre, S., & Ellaway, A. (2001). Ontological security and psycho-social benefits from the home: Qualitative evidence on issues of tenure. *Housing, Theory and Society, 18*(1–2), 50–66.

Hiscock, R., Macintyre, S., Kearns, A., & Ellaway, A. (2003). Residents and residence: Factors predicting the health disadvantage of social renters compared to owner-occupiers. *Journal of Social Issues, 59*(3), 527–546.

Jusot, F. (2010). *Les interventions de réduction des inégalités sociales de santé en Europe (Interventions to reduce social inequalities in health in Europe). Réduire les inégalités sociales en santé* (pp. 73–88). Paris: INPES.

Krieger, J., & Higgins, D. L. (2002). Housing and health: Time again for public health action. *American Journal of Public Health, 92*(5), 758–768.

Lahaye, W., Pannecoucke, I., Vrancken, J., & Van Rossem, R. (2013). *Belgian yearbook on poverty in Belgium 2013*. Leuven: Acco.

Lawrence, R. (1998). Habitat, écologie, santé et bien-être. In M. Segaud, C. Bonvalet, & J. Brun (Eds.), *Logement et habitat: L'état des savoirs* (p. 420). Paris: La découverte.

Lejeune, Z., Chevau, T., & Teller, J. (2012). The housing quality as an environmental variable: The example of the urban region of Liège(Wallonia). *Flux*, (3), 30–45.

Leonard, C. (2012). The empowering responsibility: A new paradigm to rebuild the welfare state? Application to the healthcare sector. *Éthique Et Économique/Ethics and Economics*, *9*(2).

Macintyre, S., Ellaway, A., Der, G., Ford, G., & Hunt, K. (1998). Do housing tenure and car access predict health because they are simply markers of income or self-esteem? A Scottish study. *Journal of Epidemiology and Community Health, 52*(10), 657–664.

Mackenbach, J. P. (2012). The persistence of health inequalities in modern welfare states: The explanation of a paradox. *Social Science and Medicine, 75*(4), 761–769.

Meslé, F., & Vallin, J. (2002). The health transitions: Trends and prospects. In G. Caselli, J. Vallin, & G. Wunsch (Eds.), *Demography: Analysis and synthesis* (3rd ed., pp. 439–461). Paris: Editions de l'INED.

Mesrine, A. (2000). La surmortalité des chômeurs: un effet catalyseur du chômage? (Overmortality of the unemployed: A catalyst effect of unemployment?). *Economie et statistique, 334*(1), 33–48.

Mulder, C. H., & Lauster, N. T. (2010). Housing and family: An introduction. *Housing Studies, 25*(4), 433–440.

Painter, G., & Lee, K. (2009). Housing tenure transitions of older households: Life cycle, demographic, and familial factors. *Regional Science and Urban Economics, 39*(6), 749–760.

Ravesteijn, B., Van Kippersluis, H., & Van Doorslaer, E. (2013). The contribution of occupation to health inequality. *Research on Economic Inequality, 21,* 311–332.

Rollet, C. (2011). *Introduction à la démographie*. Paris: Armand Colin.

Shaw, M. (2004). Housing and public health. *The Annual Review of Public Health, 25,* 397–418.

Statbel. (2019). Taxable income, online document. https://statbel.fgov.be/en/themes/households/taxable-income. Accessed 07 Nov 2020.

Trannoy, A. (2012). Inégalités de santé: le rôle des transmissions intergénérationnelles (Health Inequalities: The Role of Intergenerational Transmissions). *Économie Publique/Public Economics, 24–25,* 17–39.

Valkonen, T. (2002). Social inequalities in mortality. *Demography: Analysis and Synthesis, 3,* 351–372.

Vallin, J., Caselli, G., & Surault, P. (2002). Behavior, lifestyles and sociocultural factors of mortality. *Demography: Analysis and Synthesis, 3,* 255–305.

Vanneste, D., Thomas, I., & Goossens, L. (2007). *Le logement en Belgique*. Programme Atlas: valorisation des résultats de l'Enquêtesocioéconomique 2001. [online] https://www.belspo.be/belspo/fedra/proj.asp?l=fr&COD=AT%2F10. Accessed 07 Nov 2020.