Inequalities in mortality associated with housing conditions in Belgium between 1991 and 2020

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Abstract

Background

Poor housing conditions have been associated with increased mortality. Our main objective is to investigate association between housing inequality and increased mortality and to estimate the number of deaths that could be prevented if the population of Belgium faced the mortality rates of the least deprived housing deprivation decile.

Methods

We utilized individual-level mortality data extracted from the National Register in Belgium and relative to deaths that occurred between Jan 1, 1991 and Dec 31, 2020. Spatial and time-specific housing deprivation indices (1991, 2001, and 2011) were created at the level of the smallest geographical unit in Belgium, assigning these units into deciles from the most to least deprived. We calculated mortality attributable to housing inequality as the difference between the observed and expected deaths by applying mortality of the least deprived decile to other deciles. We also used standard life table calculations to estimate the potential years of life lost due housing inequality.

Results

18.5% (95% CI 17.7-19.3) of all deaths between 1991 and 2020 were attributable to housing inequality, corresponding to 584,875 deaths. Over time, life expectancy at birth increased for the most and least deprived deciles by about 3.5 years. The gap in life expectancy between the two deciles remained high, on average 4.6 years. Life expectancy in Belgium is reduced by approximately 3 years lost due to housing inequality.

Conclusions

Thousands of deaths in Belgium could be avoided if housing inequality was reduced. Hotspots of housing inequalities need to be localized and targeted with tailored public actions.

Background

According to the United Nations, every human being has a right to adequate housing that not only provides four walls and a roof, but also includes legal security of tenure, availability of services, materials, facilities and infrastructure, affordability, habitability, accessibility, location and cultural adequacy [1]. Although there have been many improvements in living conditions over the last century, over a billion people worldwide are still not adequately housed [2].

Epidemiological research suggests that inadequate housing is strongly associated with adverse health effects and premature mortality [3]. For instance, cold and humid environment caused by inadequate ventilation allow the growth of mould and fungi that are associated with respiratory diseases, fewer, diarrhoea and headaches [4–6]. On the contrary, exposure to extreme cold and the absence of central heating is associated with a higher risk of dying in winter, whereas lack of air conditioning during extreme heat waves results in increased mortality during summer months [7, 8]. Among other adverse health outcomes linked to poor housing conditions are mental disorders, insomnia, and obesity [9]. In addition to being a causal mechanism, we should acknowledge the association between housing conditions with other elements that affect health, such as having a safe home, living in a good area, and affordability.

In terms of mortality, there have only been a handful of studies that have considered the relationship between housing tenure or housing conditions and variation in life expectancy. In England and Wales, Filakti et al. reported that premature mortality was 35% lower for home owners in the 1980s compared with results from the 1970s [10]. More recently, a study from Portugal reported that disadvantaged housing is a major risk factor for mortality [11]. Strong associations between poor housing condition and increased mortality or poor health were also reported by studies from Scotland [12] and the US [13].

In Belgium, a recent study showed that mortality among tenants was about 25% higher than among home owners, and a similar excess mortality was observed among those living in low quality housing, even after controlling for education, professional status and income [14]. An increase in the number of inadequately housed people has also been observed in certain parts of Belgium. For example, a ten-year study by Horvat and Quittelier showed that a number of homeless and inadequately housed people in the Brussels-Capital Region has more than doubled since 2008 [15]. Although the Belgian Constitution includes the right to decent housing, and Wallonia, Flanders and the Brussels-Capital Region share a common social policy, access to housing – either public, private, rented or owner-occupied – remains a major social differentiator [16–18]. The differences in housing quality among the three regions are large -with housing inequality being lowest in the Flemish region, and greatest in the Brussels-Capital Region [14, 19–21].

Findings from existing studies on the association between poor housing conditions in Belgium and adverse health outcomes are concurrent with findings reported worldwide [14, 20, 22]. In contrast with these individual-level studies, we aim to investigate the association between inequality in mortality and housing conditions on the aggregated level. In our study, we use housing conditions as a concrete manifestation of socioeconomic deprivation and create a composite, spatial and time-specific housing deprivation index (1991, 2001, and 2011) that encompasses multiple aspects of housing deprivation. These aspects are represented by indicators selected based on literature review or on previous studies [20, 23]. As these indicators are based on information obtained from the only existing sources on housing, the 1991, 2001 and 2011 censuses, we assume that they are fairly stable over time, especially at the level of statistical sector, less so at the individual level. Deprivation indices group sectors into deciles from most to least deprived and are computed for each Belgian neighborhood, formally defined as a statistical sector.

We use multiple measures of health inequality. First, we calculate mortality attributable to housing inequality introduced as the absolute number or proportion of deaths that are attributable to housing inequality. Secondly, we compute life expectancy at birth and potential years of life lost to housing inequality. Mortality rates and housing deprivation indices are computed based on the whole population of Belgium over the period 1991–2020, avoiding selection bias. Or main objective is to assess whether housing inequality is associated with increased mortality and to estimate the number of deaths that could be prevented if population of Belgium had the mortality rates of the least deprived housing deprivation decile.

Methods

Data

We used the pseudonymized Causineq dataset, built upon DEMOBEL, the demographic database produced by the Belgian Statistical Office [24, 25]. The Causineq database covers the observation period 1991–2020, and includes several administrative data sources, such as the National Register, the 1991, 2001, and 2011 Belgian population censuses, and the death certificates from the Civil Registry. Individuals in these data sources are linked by a multi-digit code specific to the Causineq. The pseudonymization prevents linkages of the Causineq data with other administrative databases or databases located in other research centres.

Housing Deprivation Indices (HDI)

We used data on housing characteristics from the 1991, 2001, and 2011 Belgian population censuses to develop area-level housing deprivation indices at the level of statistical sector for every respective year. Each index is built on a group of indicators encompassing multiple deprivation aspects. The selection of indicators was based on our literature review, and on the premises that the indicators must be the best possible measure of housing deprivation in Belgium for the given time period. The indicators retained vary across the selected years due to their relevance at the time, accessibility and availability, and they always represent only the proportion of population who is deprived, not affluent (Table 1).

For each indicator, the proportion of deprived population in a statistical sector was calculated, for instance a proportion of individuals without central heating or internet connection per statistical sector. Maximum likelihood factor analysis (FA) was used to combine these indicators at the level of statistical sector. Then, statistical sectors were ranked based on the resulting FA scores and assigned to deciles in a way that the most deprived statistical sectors fell into the first decile. This methodology was applied independently for the 1991, 2001, and 2011 indices. See the Supplementary Information for more details.

Statistical sectors with none or less than 10 inhabitants were excluded from the analysis to ensure obtaining stable estimates, to limit potential bias, and to safeguard data privacy. We excluded 1,464 (7.5%), 1,486 (7.5%), and 1,018 (5.1%) statistical sectors in years 1991, 2001 and 2011. The final number of statistical sectors included in the analysis was therefore 17,909 for the period 1991–2000, 18,295 for the period 2001–2010, and 18,764 for the period 2011–2020.

Missing data

The amount of missing information varied greatly across indicators and censuses - being 4–12% in 1991, 6–17% in 2001, and 2–12% in 2011. The availability of National Register data and the 1991, 2001, 2011 census data within the Causineq dataset allowed us to identify individuals within the same household and impute missing information based on other family members. Additionally, we imputed values based on the same housing profile – individuals in the same statistical sector had to share at least 75% of housing characteristics. These two approaches resulted in a reduction of missing values to 2–5% in 1991, 4–9% in 2001, and 1–6% in 2011 (Table S2 in Supplementary Information)

Table 1
Overview of indicators used in the 1991, 2001, and 2011 housing deprivation indices

	1991			2001			2011		
	% of deprived	**Missing (%)**	**Total**	**% of deprived**	**Missing (%)**	**Total**	**% of deprived**	**Missing (%)**	**Total**
Tenants	29.6	3.8	9 469 913	26.5	4	9 726 611	30.5	1.03	10 985 250
Property size less than 35m²	2.8	3.6	9 486 459	6.1	7.8	9 348 105			
No central heating	36.5	4.2	9 427 568	25.4	4.7	9 655 456	12.8	5.8	10 361 725
No toilet	6.5	3.6	9 487 524	2.9	5.4	9 586 814			
No bathroom	8.5	3.8	9 467 117	2.9	4.7	9 655 346	1.1	4.2	10 538 313
No landline	10.7	5.2	9 332 268						
No insulation				25.1	5.7	9 554 520			
No internet				65.9	9.4	9 175 109			
No kitchen	4.1	2.0	9 644 084	14.9	7.9	9 325 967			
Less than 0.5 rooms per person							5.1	2.7	10 704 763

Mortality data

We utilized pseudonymized individual-level all-cause mortality data extracted from the National Register in Belgium and relative to deaths that occurred between Jan 1, 1991 and Dec 31, 2020. Data included age, sex, and a unique, personal identification number of deceased individuals. The multi-digit identification numbers were used for record linkage within the Causineq database to derive the lastly registered statistical sector of deceased. Mid-year population estimates by statistical sector, sex, single-year of age from 1991 to 2020 were obtained from the National Register data, which includes all legal residents of Belgium, excluding irregular migrants and asylum seekers.

Inequality indices

First, we stratified the mortality and population data according to 5-year age group, sex, housing deprivation decile, and 10-year period (1991–2000, 2001–2010, 2010–2020), yielding 1260 strata. Housing deprivation indices were used as follows: the HDI 1991 was applied to periods 1991–2000, the HDI 2001 to 2001–2010, and the HDI 2011 to 2011–2020. We then computed sex-and age-standardized mortality rates (ASMR) per 100,000 person-years and 95% confidence intervals (CI) in each stratum using the sex and age structure of the Belgian population in 2019. To show the changes over time, we calculated the absolute change in ASMR between the first (1991–2000) and last period (2011–2020).

Secondly, within each 5-year age group, sex, and 10-year-period, the age-specific mortality rate of the least deprived decile was used as a reference group and applied to the other deciles to produce a number of expected deaths. We calculated the mortality attributable to housing deprivation as the difference between the observed and expected deaths, expressed as a population attributable fraction (PAF) and a number of excess deaths. The 95% confidence intervals (CI) were estimated by Monte Carlo simulation, in which 10,000 deaths in each stratum were sampled from a Poisson distribution.

Thirdly, we constructed period life tables for each sex, housing deprivation decile, and a 10-year period using mortality rates by 5-year age group with the open-ended age interval 95+ [26]. The Arriaga method was used to decompose the differences in life expectancy between the least and most deprived deciles in men and women in all three decades separately. Finally, potential years of life lost (PYLLs) to inequality were calculated as the difference between the years lost due to death before age 75 years in each cohort and the corresponding least deprived cohort.

All analyses were done in R version 4.1.1 [27].

Results

Our study covered 310 million person-years in people aged from 0 to 95+, with 3,161,490 deaths that occurred in Belgium between 1991 and 2020. Deprivation was defined by deciles of housing deprivation indices 1991, 2001, and 2011 on the level of statistical sector (Fig. 1). During the study period, ASMRs decreased for men and women in all deprivation deciles. Reduction in absolute ASMR was greatest for males in the most deprived decile (-406 per 100,000 person-years) and females in the least deprived deciles (-293 per 100,000 person-years), whereas relative reductions were greatest for males (-31%) and females (-25%) in the least deprived deciles (Table 2). Comparing the period 2011–2020 with 1991–2000, the gap between the most and least deprived deciles has narrowed for men, but widened for women.

Table 2
Trends in mortality inequalities according to housing deprivation deciles

	1991–2000[1]	2001–2010	2011–2020	Change (%)[4]
Age-standardised mortality rates per 100 000 person-years and 95% CI				
Male				
Most deprived[2]	1649 [1634–1664]	1495 [1484–1506]	1243 [1231–1254]	-24.62
Least deprived[3]	1193 [1181–1207]	923 [911–935]	826 [815–837]	-30.76
Difference	456	572	417	-8.55
Female				
Most deprived	1402 [1389–1415]	1271 [1262–1281]	1140 [1130–1150]	-18.69
Least deprived	1156 [1144–1170]	1027 [1013–1041]	863 [851–875]	-25.34
Difference	246	244	277	12.60
Mortality attributable to housing inequality (%)				
Male	21.0 [20.12–21.85]	26.5 [25.13–27.99]	19.4 [18.33–20.47]	-7.6
Female	12.6 [11.61–13.51]	11.27 [9.48–13.02]	15.5 [14.47–16.75]	23.2
Mean number of Potential Years of Life Lost attributable to housing inequality				
Male	1.50	1.58	0.92	-38.7
Female	0.61	0.69	0.46	-24.6

Mortality is adjusted to the Belgian population structure in 2019.

[1] Housing deprivation index 1991 applied for years 1991–2000, index 2001 for 2001–2010, and index 2011 for 2011–2020

[2] Most deprived refers to the most deprived decile of the housing deprivation indices 1991, 2001, 2011.

[3] Least deprived refers to the least deprived decile of the housing deprivation index 1991, 2001, 2011.

[4] Change in mortality between 1991–2000 and 2011–2020

The proportion of mortality attributable to housing inequality varied by time period, sex and age. Across all years under study, the PAF was higher in men than in women, increasing first sharply from 21.0% (95% CI, 20.1–21.9) to 26.5% (95% CI, 25.1–28.0) in the periods 1991–2000 and 2001–2011, then decreasing to 19.4% (95% CI, 18.3–20.5) in the period 2011–2020. In women, mortality attributable to inequality has been increasing over time from 12.6% (95% CI, 11.6–13.5) to 15.5% (95% CI, 14.5–16.8) between 1991–2000 and 2011–2020. In the most deprived deciles, the proportion of deaths attributable to housing deprivation peaked in middle-aged men and women and accounted for more than a half of all deaths occurring in the middle-aged population (Figures S1, S2 and S3 in Supplementary Information).

If the whole population of Belgium presented the same risk of mortality as the least deprived groups measured by the HDI in the three reference years 1991, 2001, 2011, 568,605 fewer deaths would have occurred between 1991 and 2020. This represents about 18% of all deaths that could be attributable to housing deprivation (Fig. 2).

The results of our life table calculation suggested that on average, men and women in the least deprived deciles live longer than in the most deprived deciles in all observed periods. For the period 1991–2000, men and women in the least deprived deciles were expected to live 78.1. and 82.8 years compared to 72.7 and 79.9 years of men and women in the most deprived deciles (Table 3). The gap in life expectancy between the least and most deprived deciles was 5.4 and 2.9 years for men and women. In the following periods of 2001–2010 and 2011–2020, the gaps between the most and least deprivation groups for men and women increased to 7.1 and 4.0 years, and consequently decreased to 5 and 3.3 years, respectively.

Table 3
Life expectancies at birth in Belgium by the most and the least housing deprivation deciles in 1991–2000, 2001–2010, and 2011–2020.

	1991–2000[1]	2001–2010	2011–2020	Change in time (in years)
Male				
Most deprived[2]	72.72	73.90	76.98	4.26
Least deprived[3]	78.07	80.96	81.96	3.89
Difference	5.35	7.06	4.98	
Female				
Most deprived	79.88	80.68	82.53	2.65
Least deprived	82.78	84.65	85.84	3.06
Difference	2.90	3.97	3.31	
Mortality is adjusted to the Belgian population structure in 2019.				
[1] Housing deprivation index 1991 applied for years 1991–2000, index 2001 for 2001–2010, and index 2011 for 2011–2020				
[2] Most deprived refers to the most deprived decile of the housing deprivation indices 1991, 2001, 2011.				
[3] Least deprived refers to the least deprived decile of the housing deprivation index 1991, 2001, 2011.				
[4] Change in mortality between 1991–2000 and 2011–2020				

Over the three decades, life expectancy at birth increased for all deciles, but not in the same way. Using the Arriaga method, we compared how differences in age-specific mortality contributed to the life expectancy gap between the most and least deprived deciles in each period under study. The increase in life expectancy is observed in all age groups, but it is driven mostly by declines in mortality in the age group 60–69 in men and in the age group 70–79 in women in all three decades. These age groups contribute about 25% to the difference in life expectancy between the most and least deprived deciles in 1991–2000, 2001–2010, and 2011–2020 (Table S3 in Supplementary Information).

The results of our life table modeling also revealed that premature mortality due to housing deprivation caused a mean of 4.7, 3.74 and 3.1 PYLLs per person in 1991–2000, 2001–2010 and 2011–2020. Sex-stratified results showed that mean number of PYLLs has always been greater for men than women across all deciles, and it had a declining trend in both sexes (Fig. 3). The mean PYLL for men and women was 6.1 and 3.2 in the period 1991–2000, 4.8 and 2.7 in 2001–2010, and 3.9 and 2.3 years in 2011–2020, respectively. If everyone had the mortality risk of the least deprived groups measured by the HDI 1991, 2001, and 2011, the PYLLs would decrease to a 3.6, 2.6 and 2.4 years per person. The average number of PYLLs attributable to housing deprivation is shown for each sex in Table 1.

Our results also suggested that 23%, 30% and 22% of PYLLs can be attributed to inequality in years 1991, 2001 and 2011. In both sexes, this proportion peaked in the period 2001–2010, equally with 68% in men and women.

Discussion

To our knowledge, this is the first Belgian study investigating housing-driven inequalities in mortality using composite, spatial and time-specific housing deprivation indices on a level of smallest areal unit in the country, statistical sector. The housing deprivation indices were built using the only data on housing conditions available at this scale - the 1991, 2001, and 2011 population censuses. Presumably fairly stable over time, especially at the level of the statistical sector when compared to the individual level, the indices were applied to their following 10-year periods, encompassing 30 years altogether.

Our findings show that one in five deaths was attributable to inequalities in housing conditions measured by the HDI. We also provided insight into changing inequality over time, suggesting that inequalities were greatest for men in the study period of 2001–2010 and women in 2011–2020. Although mortality rates declined substantially in both sexes across deprivation groups during the study period, the least deprived groups had greater proportional reductions resulting in a slight decrease and increase in mortality for men and women attributable to housing inequality. On the other hand, reductions in absolute numbers of death differed between sexes with being greatest for the most deprived groups for men and least deprived groups for women.

Findings of our cross-sectional study are in sync with results of prior studies that investigated variations in life expectancy by housing quality and housing tenure. Eggerickx at el. (2018) showed an increase in social and spatial inequalities in Belgium between 1991 and 2016, pointing out that inequalities are greatest among individuals aged 25 to 50 [20], in line with our results depicting that mortality attributable to housing inequality peaks between the ages 40–49. The study by Damiens (2020) on the impact of housing conditions on mortality in Belgium concluded that low-quality housing may result in an increase in mortality rates by 25% after controlling for education, professional status and income, whereas in our study, the difference between the most and least deprived groups ranged between 28–40% for men and 18–25% for women [14].

Strengths and limitations

The key strength of our study is the development and use of spatial and time-specific indices of housing deprivation. The method we used to build our HDI 1991, 2001 and 2011 is easily replicable and can be used in future with updated data. Indices as well as our population level estimates of housing inequality in mortality were computed on the level of the smallest administrative unit of Belgium, the statistical sector, but they can be aggregated to the higher-are levels, such as municipalities. Another real advantage of our study is use of data from the whole population of Belgium to obtain the inequality measures. All-cause mortality data from death registration are exhaustive and highly reliable in Belgium.

Information on housing conditions was however collected differently in the three censuses. In 1991 and 2001, data were collected through an individual questionnaire, while in 2011 administrative databases were used to update the previously existing information. This difference in data collection can result in comparability issues. Another concern is the absence of information concerning individuals living in communal living facilities, such as nursing homes. The proportion of missing information on housing for those individuals was equal to 75%, 95%, and 89% in the 1991, 2001, and 2011 census. For this reason, we have excluded them from our analysis. The amount of missing information on individual housing indicators differed highly across the three censuses. Linking the census data with national register, we were able to impute missing information based on other family members living in the same household. In addition, we imputed values based on similar profile – matching individual profiles within a given statistical sector. Although we were able to partially impute some information, missing values ranged between 2–6% in 1991 and 2011, and 4–10% in 2001. Ignoring the missing cases in our analysis likely led to a slight underestimation of housing inequalities across Belgium.

As we use housing condition as a concrete manifestation of socioeconomic status, a question of correlation between housing quality and other factors might arise. Previous studies showed that housing conditions are closely related to differences in income or education, and it is possible that some of the inequalities observed here refer to these dimensions. We are currently working on developing the index of multiple deprivation (IMD) for Belgium that integrates the issue of housing, income, education, employment, and crime. Tool such as the IMD will enable us to isolate the specific contribution of housing conditions – a task currently beyond the scope of this study.

Our cross-sectional study does not allow us to assess the causal relationship between housing deprivation and mortality rates, as we are not able to rule out that previously impaired well-being anticipates poor housing conditions. Our goal was to measure the extent of inequality and to show a scenario in which everyone in Belgium has the same mortality of the least deprived decile, without suggesting how this scenario would be achieved.

Conclusions

Our findings provide a better understanding of how much housing inequalities affect mortality and suggest that important socio-spatial inequalities still exist in Belgium. Using composite housing deprivation indices and measures of health inequality, we showed that every year thousands of deaths in Belgium could be avoided if Belgium had mortality rates of least deprived decile. Finally, our findings can help the Belgian government and local politicians to localize the hotspots of housing and associated health inequalities for better targeting public action.

Declarations

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Author's contributions

Data preparation and analysis were performed by MO. The first draft of the manuscript was written by MO and all authors commented on previous versions of the manuscript. All authors read and approved the final manuscript.

Availability of data and materials

The Causineq database analysed during the current study was acquired through the Belgian statistical office, Statbel. Due to the data sharing agreement the authors established with Statbel, the authors are unable to share the raw data publicly, however, datasets used for this study might be acquired directly from Statbel.

Declarations

Ethics approval and consent to participate

The Causineq database was obtained from Statbel after approval by the Statistical Oversight Committee of the Privacy Commission. The confidentiality contract numbers are STAT-MA-2015-13 and STAT-MA-2016-23. On 31 May 2021 (decision no. 2021/071), the authors obtained the right to update, use and store the Causineq data until 31 December 2034.

The Causineq database is pseudonymized, and contains a multi-digit code specific to the Causineq database. It therefore does not enable linkages with other administrative databases or databases belonging to other research centres.

Consent for publication

Not applicable.

Competing interests

The authors have no competing interests to declare that are relevant to the content of this article.

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Figures

Figure 1

Distribution of housing deprivation in Belgium by the housing deprivation deciles

Figure 2

Mortality attributable to housing inequality in Belgium by the housing deprivation deciles

Figure 3

Premature years of life lost to housing inequality in Belgium by the housing deprivation deciles

Supplementary Files

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