INTRODUCTION

Background: Neighbourhoods, spatial inequality, and health

A substantial body of research demonstrates that the neighbourhoods where people live influence their opportunities for health through material, social, and environmental conditions (Diez Roux, 2018; Diez Roux & Mair, 2010; Krieger et al., 2020). These neighbourhood conditions are however unevenly distributed across space, reflecting broader social and economic hierarchies shaped by processes such as discrimination, migration, and housing affordability (Devakumar et al., 2022; Krieger, 2014). As a result, spatial inequality operates as a structural mechanism through which social stratification translates into health inequality.

One of the clearest manifestations of spatial inequality in European cities is the residential segregation of immigrant populations, and ultimately ethnoracial segregation, which both reflects and reinforces broader social and economic hierarchies. This process can be understood as a spatial expression of structural racism, wherein interconnected systems such as housing, labour markets, and urban policy, systematically disadvantage racialised and migrant-origin groups. Immigrants, particularly those from outside Europe, often enter the labour market through low-wage and insecure sectors, partly because their qualifications are not recognised and partly due to discrimination in hiring practices (Andersson et al., 2014). Limited and unstable income thus substantially constrains housing choices, concentrating immigrant households in low-cost or marginalised urban areas (Musterd, 2005). Discrimination within the housing market further exacerbates this pattern, as landlords and real estate agencies frequently refuse to rent to immigrants or low-income families (Musterd, 2005). Over time, these processes become self-reinforcing: social networks develop within immigrant-dense areas, majority residents move elsewhere, and local housing policies and uneven distribution of public services entrench existing spatial divisions (Logan et al., 2002). As a result, neighbourhoods with high immigrant concentrations tend to be among the most socioeconomically deprived (Arcaya et al., 2016). In this way, segregation functions as more than a demographic pattern in that it becomes a spatial mechanism that organises access to resources, exposure to risk, and ultimately, opportunities for good health.

Segregated neighbourhoods often combine socioeconomic deprivation, environmental stressors such as pollution and noise, and limited access to green space and public services, all of which contribute to elevated risks of chronic disease and poorer mental health (Dzhambov et al., 2018; Freedman et al., 2011). Long-term exposure to air pollution, for example, has been linked to the development of severe respiratory illnesses, and limited access to green space or walkable environments limits opportunities for physical activity, and has thus been linked to obesity, diabetes and hypertension (Alves et al., 2013; Freedman et al., 2011; Mitchell & Popham, 2008). Segregation furthermore reinforces psychosocial stress through experiences of stigma, discrimination, and reduced institutional trust, which have been linked to worse self-rated health and wellbeing (Bécares et al., 2012). Moreover, the concentration of disadvantage often coincides with under-resourced health and social infrastructure, meaning that segregated communities are doubly burdened, by higher exposure to health risks and lower access to mitigating services (Hussein et al., 2016).

Building on this broader evidence, a growing body of research has begun to examine how neighbourhood environments influence cancer incidence, stage at diagnosis, and survival (Abdelhadi et al., 2025; Gomez et al., 2015; Landrine et al., 2017). Neighbourhood exposure to environmental hazards and air pollution has long been linked to higher cancer incidence and mortality (Jackson, 2003) while social characteristics such as concentrated poverty and social isolation have been associated with later-stage diagnoses and poorer survival outcomes(Gomez et al., 2015). In the

United States, studies of racial residential segregation show that individuals living in highly segregated areas are more likely to be diagnosed with cancer at advanced stages and have lower survival rates, even after adjusting for individual socioeconomic status (Abdelhadi et al., 2025; Krieger et al., 2016; Landrine et al., 2017). However, much less is known about how residential segregation affects earlier points in the cancer care continuum, particularly participation in cancer screening, and almost no research has explored this in the European context or among immigrant populations (Gomez et al., 2015). If residential segregation constrains both the conditions that determine cancer and the ability access preventive care, then its full contribution to inequalities in cancer outcomes is likely underestimated.

The present study

We aim to conduct a multi-city analysis of neighbourhood segregation and its association with timely uptake of breast, cervical, and colorectal cancer screening in Belgium. This study employs an individual-level linked longitudinal administrative dataset combining population register data with the Belgian Cancer Registry, allowing the integration of detailed demographic, socioeconomic, and healthcare uptake information within a single analytic framework. We focus on cancer screening uptake for three main reasons. First, ethnoracial and socioeconomic inequities in screening participation are well-documented in Belgium (Derveeuw et al., 2025; Hoeck & Kellen, 2017), yet the role of neighbourhood segregation in these disparities remains unexplored. Second, in contrast to neighbourhood effects on cancer incidence, which require long-term longitudinal observation over an etiological period, screening participation is more directly influenced by current neighbourhood conditions, such as access to health information, and local service availability. Third, cancer registries in Belgium adhere to rigorous data collection protocols for population-based screening, ensuring reliable and standardised measures of screening participation.

We propose that neighbourhood contexts shape migrant-origin inequalities in cancer screening uptake through intertwined social and institutional mechanisms. In many European cities, immigrants are overrepresented in precarious or unstable housing, where frequent moving and barriers to registration create a form of institutional invisibility. Screening invitations may not be received, follow-up at the health system level is hindered, and access to preventive services often depends on stable residence. These dynamics reflect broader patterns of state neglect and structural violence, in which public health systems are organised around assumptions of stability and citizenship that exclude those living at the urban margins (Krieger et al., 2020). At the same time, neighbourhoods with high ethnic density may also result in closer ties within the same ethnic or social group which can promote mutual tust and support, otherwise known as *bonding social capital*. While such networks can enhance collective efficacy and provide informal routes for sharing information about screening, they may also inadvertently reinforce collective uncertainty or scepticism toward preventive care, often in contexts where institutional trust and access to health information are limited. By contrast, *bridging social capital*, the connections that extend across ethnic or social boundaries, are more common in less segregated neighbourhoods and therefore facilitate greater access to reliable health information and stronger links to formal healthcare systems (Kawachi et al., 2008).

This brings us to out three main hypotheses:

H1: Individuals living in neighbourhoods with higher levels of immigrant residential segregation will have lower odds of timely participation in breast, cervical, and colorectal cancer screening, net of individual socioeconomic and demographic characteristics.

H2: Low-segregated areas where connections with the majority group are higher (higher bridging social capital) will be associated with *higher* screening uptake through greater opportunities for information flow.

H3: The negative association between residential segregation and cancer screening uptake will be *stronger among immigrant-origin populations* than among the native-born population.

METHODS

Study population

We will use longitudinal linked administrative and cancer registry data for all women residing and registered in Belgium from 2013 – 2021, who are between the ages of 25 and 76 and live in the ten largest urban areas(Brussels, Antwerp, Ghent, Charleroi, Liège, Bruges, Namur, Leuven, Mons, and Oostende). The analytic dataset has been constructed by combining sociodemographic information from the Belgian Statistics Office (Statbel) and cancer screening data from the Belgian Cancer Registry (BCR). Separate analytic populations will be created for each screening outcome, restricted to women eligible for the corresponding national or regional cancer screening programme during the observation period. Eligibility will be defined as being aged 50–69 years for breast cancer screening, 55–74 years for colorectal cancer screening, and 25–64 years for cervical cancer screening. Individuals not registered in the population registry, such as asylum seekers and undocumented migrants, are therefore not captured in our analysis.

Dependent variable: timely cancer screening

Adherence to screening guidelines will be defined as completion of the relevant screening test within the recommended interval for each programme: every two years for breast and colorectal cancer, and every three years for cervical cancer. For each cancer site, the outcome variable will be binary, taking the value 1 for timely screening (adherent) and 0 for non-adherent.

Individual-level variables

At the individual level (Level 1), Migration origin will be the primary exposure of interest, determined using information on country of birth and first nationality at birth. Individuals born with Belgian nationality and with both parents also holding Belgian nationality at birth will be classified as majority native Belgians. Individuals born outside Belgium without Belgian nationality at birth with be considered first generation migrants, while those born in Belgium with at least one parent who did not hold Belgian nationality at birth will be classified as second-generation descendants. We will further distinguish between regions of origin, defined by the respondent's own nationality at birth for first-generation migrants and by parental country of birth for the second generation, using the following regional categories: countries bordering Belgium; Southern EU countries (Spain, Italy, Portugal, Greece); other Southern, Northern, or Eastern EU countries; other European countries; Turkey; Middle Eastern countries; other Asian countries; Morocco; Central and other North African countries; Sub-Saharan African countries; other Western countries (including North America and Oceania); and Central or South America.

We will further control for age, education, household income, and household composition

Neighbourhood-level variables

Neighbourhoods will be defined using statistical sectors, the smallest administrative spatial units in Belgium, typically containing between 200 and 8,000 residents. Neighbourhood racial and socioeconomic segregation will be characterised using the following measures:

1. Co-ethnic density: The proportion of residents of non-Belgian origin within each statistical sector, capturing local co-ethnic concentration and potential social network effects.
2. Localized isolation and exposure indices: These indices quantify the probability of interaction within and between population groups.
3. Location Quotient (LQ): Measures the relative concentration of residents of non-Belgian origin in each neighbourhood compared with their share in the larger urban population. Higher values indicate overrepresentation or spatial compactness of the group.
4. Socioeconomic deprivation: Belgian index of multiple deprivation (Otavova et al., 2023)

Statistical analysis

We will estimate multilevel logistic regression models, with individuals (Level 1) nested within statistical sectors (Level 2). This multilevel structure will account for clustering of individuals within neighbourhoods and enable estimation of both individual- and contextual-level effects.

Five models will be estimated for each cancer site:

- Model 0 will include only a random intercept to estimate the ICC.
- Model 1 will add individual-level covariates (migrant origin, age, education, household income, household composition).
- Model 2 will extend Model 1 by adding one neighbourhood variable to assess contextual influence and possible attenuation of migration-related inequalities.
- Model 3 will include city, year, and region fixed effects to adjust for broader contextual and policy differences.
- Model 4 will further incorporate a cross-level interaction term between migration background and the neighbourhood measure to evaluate potential effect modification.

Longitudinal extension: event-history analysis

In a second step, we will estimate event-history models to examine the timing and recurrence of cancer screening participation over the 2013–2023 period. Because screening eligibility recurs at regular intervals of every two years for breast and colorectal cancer and every three years for cervical cancer, individuals will be considered repeatedly at risk of the event of interest (timely screening). We will model screening as a recurrent event process, employing Cox proportional hazards models (Andersen & Gill, 1982). This longitudinal framework will allow us to assess not only whether but also when screening occurs within each eligibility window, thereby incorporating the temporal dimension of adherence. Socioeconomic and neighbourhood variables will be treated as time-varying covariates, enabling us to capture dynamic changes in individual and contextual conditions. The recurrent-event structure will also allow us to partially address selection into neighbourhoods, as we will observe limited residential mobility across the 11-year period and can estimate how changes in neighbourhood context relate to changes in screening behaviour. City, region, and year fixed effects will be included to control for unobserved time-invariant differences in healthcare infrastructure and programme implementation. Results from the event-history analyses will be compared with those from the multilevel logistic models to assess robustness and temporal consistency of the observed associations.

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