Socio-Territorial Inequities in the French National Breast Cancer Screening Programme – A Cross-Sectional Multilevel Study

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Abstract

Background. France implemented in 2004 the French National Breast Cancer Screening Programme (FNBCSP). Despite national recommendations, this programme coexists with non-negligible opportunistic screening practices.

Aim. Analyse socio-territorial inequities in the 2013-2014 FNBCSP campaign in a large sample of the eligible population.

Method. Analyses were performed using three-level hierarchical generalized linear model. Level one was a 10% random sample of the eligible population in each département (n = 397 598). For each woman, age and travel time to the nearest accredited radiology centre were computed. These observations were nested within 22 250 IRIS, for which the European Deprivation Index (EDI) is defined. IRIS were nested within 41 départements, for which opportunistic screening rates and gross domestic product based on purchasing power parity were available, deprivation and the number of radiology centres for 100 000 eligible women were computed.

Results. Organized screening uptake increased with age (OR\(_{1SD} = 1.05 [1.04 – 1.06]\)) and decreased with travel time (OR\(_{1SD} = 0.94 [0.93 – 0.95]\)) and EDI (OR\(_{1SD} = 0.84 [0.83 – 0.85]\)). Between départements, organized screening uptake decreased with opportunistic screening rate (OR\(_{1SD} = 0.84 [0.79 – 0.87]\)) and départements deprivation (OR\(_{1SD} = 0.91 [0.88 – 0.96]\)). Association between EDI and organized screening uptake was weaker as opportunistic screening rates and as département deprivation increased. Heterogeneity in FNBCSP participation decreased between IRIS by 36% and between départements by 82%.

Conclusion. FNBCSP does not erase socio-territorial inequities. The population the most at risk of dying from BC is thus the less participating. More efforts are needed to improve equity.

1. Introduction

Worldwide, one in six deaths is due to cancer. Breast cancer (BC), despite being mostly a female disease (less than 1% occurs in men), has now surpassed lung cancer as the most frequently diagnosed cancer, with 2.3 million cases in 2020. With 685 000 deaths the same year, it ranked fifth for the most common cause of cancer death [1]. In France, after a stabilization between 2003 and 2010, incidence has increased again during 2010–2018. In contrast, mortality slowly decreased between 1990 and 2018. Therefore, in 2018, BC was the most diagnosed cancer (58 459 new cases) and ranked third in mortality (12 146 deaths) [2].

To control BC mortality [3], France has implemented in 2004 the French National Breast Cancer Screening Programme (FNBCSP). The ambition of screening is to detect the disease at an early stage to improve its prognosis via more effective treatment. This is a national population-based programme targeted towards women aged 50–74 with medium risk of BC (no familial or personal history of the disease, no genetic
disposition, and no symptoms of BC). Eligible population is invited, every two years, to perform a free of charge screening mammography and a clinical breast exam in an accredited radiology centre of her living (and sometimes bordering) département (an administrative division of France). Once performed, a double reading is insured for each negative mammogram. At the time of our study, FNBCSP territorial organization was led at the département level by screening management structures. One of many performance indicators regarding an organized screening programme is the participation-to-invitation rate, evaluated “acceptable” at 70% by the European Commission to significantly reduce mortality [4]. According to Santé Publique France, the French national public health agency in charge of evaluating the FNBCSP, participation reached a peak of 52.4% in 2011–2012, then slowly decreased to 48.6% in 2018–2019 [5].

Despite the National recommendations [6], this screening programme co-exists with opportunistic screening, where mammography realization depends on medical prescription by health-care providers (mostly general practitioners or gynaecologists). It is not recommended as it does not insure double-reading, being performed in an accredited radiology centre, is not free of charge and is not under enough monitoring to allow sufficient evaluation.

Beyond participation, another aim of the FNBCSP is to ensure equity of access to screening [7]. Multiple publications have shown that this goal was not reached, with individual factors associated with lower participation, such as poor socioeconomic status [8–12], poor health [11, 13] or healthcare system barriers [10–12, 14]. Territorial inequities have also been reported, with lower screening rates among eligible women living further from the accredited radiology centres [15, 16]. In recent years, attention has also increased in the association between area-based deprivation and participation. Higher deprivation was associated with lower participation in the FNBCSP in the départements of Calvados [17] and Orne [15], and in a representative sample of the eligible population covered by the three main health insurance schemes in thirteen départements [16]. In metropolitan France (95 départements), an ecological study found a more complex relation between participation and deprivation, described as an “inverse U-curve” [18], but lacked individual data and used population estimates for outcome assessment.

In this context, we aimed to evaluate socio-territorial inequities in the FNBCSP 2013–2014 campaign by studying individual and contextual factors in a single model, in a large sample of the eligible population residing in 41 départements of metropolitan France.

2. Material And Method

Redaction of this article follows the Strengthening the Reporting of Observational Studies in Epidemiology guidelines [19] (Supplementary S4).

2.1 Population and sample:

Screening management structures were invited to send their data regarding the 2013-2014 invitation campaign. These data corresponded to the follow-up of the FNBCSP and included eligible women's
addresses of residence, dates of birth, dates of invitation (from which we computed age at invitation), and whether they performed a mammography screening through the FNBCSP in the two years following invitation. We received 4 236 066 observations nested in 41 départements. Data management was performed by suppressing duplicated individuals, observations out of the study period for invitation or mammography realisation and when women invited were living in another département. 4 001 225 (94%) unique eligible women were identified. Before geolocalisation, we performed a stratified random sampling by drawing 10% of the eligible population in each département (n = 400 125). Comparisons between samples and départements' populations (data not shown) showed no important differences in participation rates (from 0 to 1.6% difference) and age (no differences exceeded ¼ years in mean age). During geolocalisation, some residential addresses had not reached the required quality criterion, they were excluded (n = 1921 – 0.5%). We also identified and excluded additional women living in another département (n = 606 – 0.2%). Final sample consisted of 397 598 women. Flow chart of the population is available in Figure 1.

2.2 Variables

Level 1 - Individual level (n = 397 598)

- Age at invitation
- Travel time to the nearest accredited radiology centre

We asked screening management structures which centres were active on the period. All these centres have been geocoded. The travel time to the nearest accredited radiology centre (NARC) was computed for all individuals using Navstreets© V14.0 data, provided by ESRI France and HERE, using the Network Analyst extension of ArcGIS© PRO software.

Level 2 - IRIS level (n = 22 250)

- French version of the European Deprivation Index (EDI)

Thanks to geolocalisation, each woman was allocated to her residential IRIS (Îlots Regroupés pour l'Information Statistique), the smallest geographical unit for which census data is available. They are either neighbourhood proxies in all municipalities with more than 10 000 inhabitants and in most municipalities with more than 5000, and to the municipalities themselves in other cases. Each of these IRIS correspond to an EDI score [20], computed with the 2011 census data. Briefly, this ecological index is based on fundamental needs associated with both objective and subjective poverty, a higher EDI score reflecting higher deprivation in the area.

Level 3 - Département level (n = 41)

- Opportunistic screening
Opportunistic screening practices are not routinely collected at the individual level. We used the estimations from *Santé Publique France* [21], computed using the national health data system for the population of women aged 50-75 in 2013-2014. They defined these data as a “crude indicator”, because of the impossibility to differentiate opportunistic screening from mammography following clinical anomalies, or a follow-up mammogram for high-risk women. Numeric values might suffer from imprecisions, it should be interpreted as a proxy for the propensity of the population to resort to opportunistic screening procedures.

- **Care offer**

The number of accredited radiology centres for 100 000 eligible women was calculated for each *département*.

- **Département** socioeconomic level

Two indicators have been used in this study. The first one, income-based, was the gross domestic product per capita based on purchasing power parity (GDP-PPP) in 2015 according to the OECD statistics [22]. The second, deprivation-based, was to use the population mean of the EDI by *département*, entitled “*département* deprivation” for the rest of the document.

### 2.3 Statistics

**Centring and standardization**

All variables have been centred for interpretational reasons and standardized for computational reasons. For the rest of the document, a reference individual will be an individual for which all variables are equal to their mean, and the variable’s effect size for an increase of one standard deviation.

**Model building**

Eligible women were nested in the IRIS, themselves nested in the *départements*. To get an accurate modelling of the probability of FNBCS participation according to individuals and area characteristics, multivariate hierarchical generalized linear model was used. The statistical models were built level by level, by increasing complexity. The first model presented (Model 0) is the “null model”, a model without any explanatory variable, only composed of fixed and random intercepts. Second model (Model 1) was built by adding level 1 variables’ fixed effects and testing random slopes at higher levels. Third (Model 2) and final (Model 3) models were built on the same logical steps, with the addition of testing for cross-level interactions. Model selection was done by comparing deviance using ANOVA and variance confidence intervals were computed using bootstrap.

**Additional measures**

To give an easier interpretation of the random intercepts variance, we computed the *variance partition coefficient* (VPC) [23] using the threshold latent variable hypothesis [24] and the *proportional change of...*
3. Results

Population

Description of the population is available in Table 1 and list of participating départements, sample sizes and participation rates are available in Supplementary S1. Overall participation was 55%, with marked disparities between départements (from 40.8% in Essonne and Seine-Saint-Denis to 68.3% in Indre-et-Loire). We illustrated univariate analyses of the relation between FNBCSP participation, EDI and travel time by département (Supplementary S2 and S3). Briefly, participation by population’s quintiles of the EDI followed a strong pattern, with lower participation as deprivation increased in almost all départements. Participation by travel time was less straightforward. It was lower among the very close population than for those who live a little further away. Then, participation seemed to decrease as distance increased.

All model results are described in Table 2.

- Model 0: There was heterogeneity in FNBCSP participation (i.e. random intercepts variance) around the fixed intercept (OR = 1.32 \([1.22 – 1.45]\)) at both IRIS (\(\sigma^2 = 0.055, VPC = 1.6\%\)) and département levels (\(\sigma^2 = 0.082, VPC = 2.4\%\)). Shrunken residuals used to estimate these variances are illustrated in Figure 2a and 2b (Model 0).

- Model 1: Overall, FNBCSP participation increased with age (OR = 1.05 \([1.03 – 1.07]\)) and decreased with travel time (OR = 0.98 \([0.96 – 0.99]\)). As shown by the random slopes, and illustrated in Figure 2c and 2d (Model 1), strength of these effects varied across départements, in such a way that the relation was insignificant or reversed in some cases. Random effects correlations showed that départements with higher intercepts tended to have a stronger effect for travel time and a weaker effect for age. It led to higher heterogeneity between départements for younger women and those closest to and furthest from the NARC (Figure 3a and Figure 3b (Model 1)). There was an interaction between age and travel time (OR = 0.99 \([0.98 – 1.00]\)), illustrated in Figure 4a.

- Model 2: Overall, an increase in EDI was associated with lower probability of FNBCS participation (OR = 0.84 \([0.82 – 0.86]\)). Accounting for EDI reduced travel time effect heterogeneity (Figure 3b (Model 2)). As shown by the random slope and illustrated in Figure 2e, strength of the association between EDI and FNBCSP participation varied across départements, but few had a weak relationship. Random effects correlations showed that départements with higher random intercepts tended to have a stronger effect of EDI. It led to more heterogeneity in FNBCSP participation among the wealthiest women, and, to a lesser extent, the most deprived (Figure 3c (Model 2)). Accounting for
EDI also reduced random intercepts variances at IRIS and département levels by 34% (Figure 2a (Model 2) and 12.2%.

- Model 3: FNBCSP participation was lower as départements’ opportunistic screening rates (OR = 0.84 [0.79–0.87]) and départements’ deprivation (OR = 0.91 [0.88–0.96]) increased. There were cross-level interactions between opportunistic screening rates and both age (OR = 1.02 [1.01–1.04]) and EDI (OR = 1.04 [1.03–1.06]). As illustrated in Figure 4b and 4c, FNBCSP participation in départements with high opportunistic screening rates was lower for younger and wealthy women. There was a cross-level interaction between départements’ deprivation and EDI (OR = 1.02 [1.00–1.03]), here again with lower participation among the wealthiest (Figure 4d). These effects reduced the remaining variance across départements by 79.2% (Figure 2b (Model 3)). They also strongly reduced heterogeneities between départements in the strength of the effects of age, travel time and EDI (Figure 2c, 2d and 2e (Model 3)). In addition, random effects correlations were reduced to statistical insignificance. Unexplained remaining variances between départements were thus independent of the lower-level variables. (Figures 3a, 3b and 3c (Model 3)). GDP-PPP and the number of radiology centres per 100 000 eligible women were not associated with FNBCSP participation.

4. Discussion

In this large sample of eligible women for the 2013-2014 screening campaign, our results strengthen the converging findings that the FNBCSP produces both territorial and social inequities in participation. Our findings about the effect of travel time are coherent with other studies [15, 16]. Its strength varied across départements, but accounting for deprivation and opportunistic screening rate patterns reduced this heterogeneity. The effect of travel time was stronger as age increased. We found no other publication studying this effect, further work is needed to appreciate its robustness. The number of radiology centres for 100 000 eligible women by département was not associated with screening uptake, in accordance with previous results [17]. Measure of specific care accessibility through this density may not be sufficient. More complete measure of accessibility (including social isolation, public transport availability, women's travel possibilities or radiology centres characteristics) might be more informative. Our findings about EDI are in line with other studies using this index [15, 16], Townsend index [17], or individual socioeconomic status [8-12]. We did not find the “inverse U-curve” reported on the same screening campaign [18]. Multiple factors could explain this difference: the indexes used (FDEP [27] and EDI), their level of measure (municipalities and IRIS), the level of outcome assessment (municipality and individual) or differences in population (estimated and eligible – 95 and 41 départements). However, we made the same observation that strength of social inequities varied across départements. Whereas participation among the most deprived was lower, but more comparable between départements, participation among the wealthiest was higher but more heterogeneous. We identified two factors explaining this heterogeneity. Firstly, participation to the FNBCSP was lower in départements with high opportunistic screening rates, mostly for the wealthiest. It has been reported that wealthiest populations tend to participate more to opportunistic screening [28-30]. Moreover, it is most often a screening prescription by the general practitioner or gynaecologist [10, 29], and France displays high
income inequities in visiting both [8]. Finally, studies have shown that opportunistic screening is more unequal than organized screening [31, 32]. Opportunistic screening, by competing with the FNBCSP, is thus one of the factors explaining low participation, and could hide a stronger deprivation gap in eligible population coverage. Secondly, participation was lower as départements’ deprivation increased, here again with a stronger effect among the wealthiest. Although interesting, these results should be taken with caution as this is the first time that this measure was used – further work is needed in understanding deprivation patterns as well as robustness of these findings. The GDP-PPP was not associated with participation – this income-based socioeconomic status may not carry sufficient information to identify social inequities in FNBCSP participation. On note, neither social nor territorial inequities were found in a population having the possibility to choose between radiology centres and mobile mammography units [15]. In agreement with other publications [15, 16, 28, 29, 33], overall participation to the FNBCSP increased with age. Strength of this association varied across départements, with lower rates of screening uptake among the youngest in départements with higher opportunistic screening rates. This is consistent with other studies, showing that individual screening is mostly used by younger women [28, 34], often starting before the recommended age range [33]. Lack of data on opportunistic screening leads to underestimate the true screening coverage, more importantly among the youngest. In the final model, the unexplained differences in FNBCSP participation between areas were reduced, mostly between départements (-82%) and to a lower extent between IRIS (-36%). We also explained most of the heterogeneities in the effects of age, travel time and EDI. Other studies are needed to find the factors influencing these remaining disparities. It should be noted that most of the heterogeneity in participation resided between individuals, with a total variance partition coefficient of 4% inside our levels (using the latent variable hypothesis).

This study has multiple strengths. First, this is the largest study about screening uptake using individual data led in France. In addition, collaboration with screening management structures allowed great accuracy in the study population. Even if, by default, homeless populations and women who recently moved are excluded, it can still be assumed that the invited population represents most of the eligible population. Additionally, départements’ samples and populations did not differ greatly in age and participation to the FNBCSP. Although it does not guarantee representativeness, any major systematic differences would be unfortunate. High precision geocoding for both women and radiology centres allowed to enrich screening database by adding travel time to the nearest accredited radiology centre and area-based deprivation measures. Finally, we tried to get the most out of multilevel models – which are particularly appropriate for nested data and contextual measures.

Some limitations also need to be addressed. By combining our 10% sample design and the unbalanced populations defined by the administrative boundaries of the IRIS, half of the IRIS had a population of less than 10 eligible women. Although it has been argued that the most important factor in multilevel analyses is the number of higher-level units [35], this could be of importance in estimating the model parameters. We excluded radiology centres from bordering départements because of poor data quality and did not account for opening and closing dates because of insufficient data. Radiology centres database needs to be created and updated by the public health authorities. We chose travel time from
home to the nearest accredited radiology centre, but it is unknown whether it is the one chosen by eligible women, especially when accounting that a part of them is professionally active. The use of area-based deprivation index is known to raise the question of whether they act as a proxy for the individual status (e.g. people with high deprivation in these areas have their decision shifted towards no) and/or as contextual factors (e.g. living in an area with high deprivation shifts the decision of all its population towards no). It has been argued that adjusting for individual characteristics would help detangle these effects [36], but these data are not routinely collected. Finally, area-based deprivation is defined based on all population in these areas, while our population is age-gender-specific.

This work includes 41 départements, our results may not be generalizable for all metropolitan France. However, it shows that it is logistically doable to develop a methodology which could be replicated to the whole metropolitan country. These results are also not generalizable to overseas départements for which the global context is quite different, and EDI might be inappropriate. Finally, this study evaluates only one screening campaign, and it is impossible to assert that every campaign suffers from the same pitfalls. However, our findings are in line with studies on other campaigns, and little has been done in targeting inequities in the FNBCSP. It is thus probable that inequities accumulate all along screening life – which could lead to a high loss of opportunities for some populations. In 2017, nearly all EU members had population-based BC screening programmes [37]. In a lot of them, coverage and participation remained low, and social inequities have often been reported, whether individual [38] or contextual [39]. Unfortunately, comparisons between these results and our findings are difficult because of the wild heterogeneity across measures and methodologies. EDI has been developed to be computable and comparable across all European countries and has already been developed in Spain, Portugal, Italy, Slovenia, and Lithuania. Our methodology is thus hypothetically replicable at the European level. The same approach could also be used in studying screening patterns for other cancer localisations.

5. Conclusion

BC is a particular disease in terms of social inequities – in Europe, its incidence (particularly for in situ cancers) is higher among the wealthiest populations [40]. However, case fatality patterns follow the classical socioeconomic burden, with higher case fatality among the more unfavourable socioeconomic populations [41]. The populations that would benefit the most from a mortality reduction through screening is thus the most at risk of non-participation. This is in contradiction with two main goals of an organized screening programme: reducing mortality and ensuring equitable access. Additionally, the impact of the coexistence with opportunistic screening, beyond any control and evaluation, is adding more risks (over diagnosis, overtreatment) [42], mainly in the youngest and wealthiest populations. Deeper evaluations are needed to evaluate the full implications of these results. The proportion of cancer found and missed, the stage at diagnosis, the follow-up to treatment, the effect on mortality, quality of life and the costs engendered and avoided by all these indicators needs to be appreciated to allow an exhaustive evaluation. Research of immense value could be led with efficient linkage between cancer registries and screening databases. Some controversies about the benefit-risk balance of BC organized screenings have been widely discussed through the scientific community [43] and beyond [44]. They
cannot be resolved without a better understanding of all consequences. A recent study at European level [45] estimated that yearly, 21,680 BC deaths were prevented due to mammography screening, and, with a hypothetic full coverage of 100%, 12,343 additional deaths could be prevented. Although this hypothetic coverage is not doable, the FNBCSP programme needs to evolve to be more efficient in both coverage of the population and reduction of the unfair gaps in participation.

**Declarations**

Ethics approval and consent to participate: The study protocol was approved by the *Commission Nationale de l’Informatique et des Libertés* (authorization no. 917208).

Consent for publication: Not applicable.

Availability of data and materials: Access to the data that support the findings of this study is restricted. These data are not publicly available.

Competing interests: The authors declare that they have no competing interests.

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Authors’ contributions: GL and EG conceived this project, All authors designed it, LL ensured data geolocalisation, QR ensured data analysis, All authors interpreted results, QR drafted the work, All authors revised it and approved the submitted version.

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Contributions to the literature:

- The design of this study allowed to evaluate precisely the French National Breast Cancer Screening Programme on a large sample of eligible women
- By using multilevel modelling, we studied both individual and contextual predictors of screening uptake in a single model
- The French National Breast Cancer Screening Programme does not erase socio-territorial inequities in participation, and the populations the most at risk of dying from breast cancer are the most at risk for non-participation - it could drastically impact the programme effectiveness
- Uncontrolled opportunistic screening prevents knowledge of population coverage and may increase the deleterious effects of screening
- The design of this study in theoretically replicable across all European countries with a cancer screening programme
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Table 1. Characteristics of the population
| Individual level | Mean | Standard deviation | Minimum | Maximum |
|------------------|------|--------------------|---------|---------|
| Travel time (minutes) | 8.70 | 7.47 | 0.00 | 132.48 |
| Age (years) | 60.73 | 7.11 | 50 | 74 |
| FNBCSP\textsuperscript{a} participation (%) | 55.06 | / | / | / |

**Level 1 – IRIS\textsuperscript{b}**

| | Mean | Standard deviation | Minimum | Maximum |
|------------------|------|--------------------|---------|---------|
| EDI\textsuperscript{c,d} (dimensionless) | 0.97 | 5.12 | -11.08 | 35.96 |

**Level 2 - Départements**

| | Mean | Standard deviation | Minimum | Maximum |
|------------------|------|--------------------|---------|---------|
| Opportunistic screening rates (%) | 8.91 | 6.06 | 2.30 | 28.00 |
| Mean of EDI\textsuperscript{c,d} (dimensionless) | 0.97 | 2.29 | -1.67 | 9.63 |
| GDP (PPP)\textsuperscript{e} per capita (US$) | 20,638 | 6,134 | 17,310 | 23,360 |
| Number of accredited radiology centres/100,000 eligible women | 21.88 | 8.55 | 7.69 | 59.06 |

\textsuperscript{a} French national breast cancer screening programme

\textsuperscript{b} Îlots regroupés pour l’information statistique

\textsuperscript{c} European Deprivation Index

\textsuperscript{d} Population weighted

\textsuperscript{e} Gross-domestic product based on purchasing power parity

Table 2. Individual and contextual factors associated with French National Breast Cancer Screening Programme participation
|                          | Model 0: Empty model | Model 1: Level 1 variables | Model 2: Level 2 variable | Model 3: Level 3 variables |
|--------------------------|----------------------|----------------------------|---------------------------|---------------------------|
| **Level 1 - Individuals**|                      |                            |                           |                           |
| Intercept                | 1.32 [1.22 – 1.45]   | 1.35 [1.24 – 1.47]         | 1.32 [1.22 – 1.43]        | 1.32 [1.27 – 1.37]        |
| Age                      | /                    | 1.05 [1.03 – 1.07]         | 1.05 [1.04 – 1.06]        | 1.05 [1.04 – 1.06]        |
| Travel time              | /                    | 0.98 [0.96 – 0.99]         | 0.95 [0.93 – 0.96]        | 0.94 [0.93 – 0.95]        |
| Age * travel time        | /                    | 0.99 [0.98 – 1.00]         | 0.99 [0.98 – 1.00]        | 0.99 [0.98 – 1.00]        |
| **Level 2 - IRIS**       |                      |                            |                           |                           |
| Fixed effects            |                      |                            |                           |                           |
| EDI                      | /                    | /                          | 0.84 [0.82 – 0.86]        | 0.84 [0.83 – 0.85]        |
| **Random effects**       |                      |                            |                           |                           |
| Random intercept         | 0.055 [0.048 – 0.058]| 0.053 [0.048 – 0.058]      | 0.035 [0.030 – 0.039]     | 0.035 [0.031 – 0.039]     |
| VCP                      | 1.60%                | 1.55%                      | 1.03%                     | 1.05%                     |
| PCV (compared with empty model) | /                  | -3.64%                     | -36.36%                   | -36.36%                   |
| **Level 3 - Départements** |                   |                            |                           |                           |
| Fixed effects            |                      |                            |                           |                           |
| Individual screening rates | /                       | /                          | /                         | 0.84 [0.79 – 0.87]        |
| Deprivation              | /                    | /                          | /                         | 0.91 [0.88 – 0.96]        |
| **Cross-level interactions** |          |                            |                           |                           |
| Individual screening rates * Age | /                      | /                          | /                         | 1.02 [1.01 – 1.04]        |
| Individual screening rates * | /                      | /                          | /                         | 1.04 [1.03 – 1.06]        |
## EDI

|                           |        |        |        |        |
|---------------------------|--------|--------|--------|--------|
| **Mean of EDI * EDI**     | /      | /      | /      | 1.02 [1.00 – 1.03] |

### Random effects

|                           |        |        |        |        |
|---------------------------|--------|--------|--------|--------|
| **Random intercept**      | 0.082  | 0.082 [0.048 – 0.123] | 0.072 [0.044 – 0.108] | 0.015 [0.007 – 0.021] |
| (σ²₀D)                    | 0.082 [0.053 – 0.130] |        |        |        |
| **VPC**                   | 2.39%  | 2.39%  | 2.12%  | 0.45%  |
| **PCV (compared with empty** |        |        |        |        |
|  model)**                 |        |        |        |        |
| **Age random slope**      | /      | 2.3x10⁻³ [1.2x10⁻³ – 3.7x10⁻³] | 2.3x10⁻³ [1.2x10⁻³ – 3.6x10⁻³] | 1.4x10⁻³ [5.3x10⁻⁴ – 2.2x10⁻³] |
| (σ²₁D)                    | /      | 2.3x10⁻³ [1.2x10⁻³ – 3.7x10⁻³] | 2.3x10⁻³ [1.2x10⁻³ – 3.6x10⁻³] | 1.4x10⁻³ [5.3x10⁻⁴ – 2.2x10⁻³] |
| **Travel time random slope** | /      |        |        |        |
| (σ²₂D)                    | /      | 2.1x10⁻³ [1.0x10⁻³ – 3.4x10⁻³] | 1.4x10⁻³ [5.3x10⁻⁴ – 2.3x10⁻³] | 1.2x10⁻³ [4.0x10⁻⁴ – 2.2x10⁻³] |
| **EDI random slope**      | /      | /      | /      | 1.1x10⁻³ [1.0x10⁻³ – 1.8x10⁻³] |
| (σ²₃D)                    | /      | /      | /      | 1.1x10⁻³ [1.0x10⁻³ – 1.8x10⁻³] |

### Random effects correlation

|                           |        |        |        |        |
|---------------------------|--------|--------|--------|--------|
| **σ²₀D, σ²₁D**            | /      | -0.55 [-0.77, -0.19] | -0.55 [-0.78, -0.23] | -0.18 [-0.57, 0.23] |
| **σ²₀D, σ²₂D**            | /      | -0.60 [-0.83, -0.31] | -0.71 [-0.94, -0.42] | -0.32 [-0.67, 0.13] |
| **σ²₀D, σ²₃D**            | /      | /      | -0.76 [-0.91, -0.54] | -0.03 [-0.65, 0.59] |
| **σ²₁D, σ²₂D**            | /      | 0.49 [0.12, 0.82] | 0.68 [0.34, 0.95] | 0.55 [0.10, 0.93] |
| **σ²₁D, σ²₃D**            | /      | /      | 0.43 [0.08, 0.75] | -0.04 [-0.72, 0.70] |
| **σ²₂D, σ²₃D**            | /      | /      | 0.60 [0.17, 0.89] | -0.09 [-0.87, 0.52] |

### Deviance

|        | 536 474 | 535 848 | 534 615 | 534 549 |
|--------|---------|---------|---------|---------|

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Figures

Figure 1

Flow chart of the population
Figure 2

Illustrations of the random effects
Figure 3

Variance between départements according to lower-level variables

Figure 4

Interactions in the final model

Supplementary Files

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