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Article

Differences and Similarities in Breast and Colorectal Cancer Screening Uptake among Municipalities in Flanders, Belgium

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Abstract: Despite the recognized benefits of fecal occult blood test (FOBT) and mammography screenings, participation in breast (BC) and colorectal cancer (CRC) screening programs is still suboptimal. In this study we investigate municipal characteristics associated with their BC/CRC screening uptake profiles among women aged 55-69 years. Using data from 308 municipalities of Flanders during 2014–2017, a profile for each municipality based on its BC/CRC screening uptake compared with the median screening uptake was created. Logistic regression with generalized estimating equations was used to assess the associations between municipal characteristics and BC/CRC screening uptake profiles. The overall median uptake of cancer screening was higher for CRC (57.4%) than for BC (54.6%).

The following municipal characteristics were associated with worse performance in terms of only CRC, only BC, or both CRC and BC screening uptake respectively: non-Belgian/Dutch nationality, diabetes, 65-69 age group; non-Belgian/Dutch nationality, diabetes, disabilities; GP attendance and having children;

The following municipal characteristics were associated with better performance in terms of only CRC, only BC, or both CRC and BC screening uptake respectively: having a partner, undergoing preventive dental care, jobseeker rate, higher education, residential stability; having a partner, undergoing preventive dental care, jobseeker rate; average income and (early) retirement rate.

This study's results regarding the interrelation between the BC and CRC screening could be used to tailor interventions aimed at improving participation of the target population in both programs.

Keywords: colorectal cancer screening; breast cancer screening; BC; CRC; cancer prevention; cancer screening; FOBT; mammography; Flanders;

1. Introduction

According to the World Health Organization GLOBOCAN database, globally, breast cancer (BC) ranks first in terms of cancer incidence, with over two million cases diagnosed each year [1], and it represents the leading cause of cancer death among women. Belgium has the highest global rates of breast cancer (BC) [2], with an age-standardized rate of 105.3 per 100,000 person-years. Flanders, in particular, has the highest incidence, with an age-standardized rate of 106.2 per 100,000 person-years [3]. Colorectal cancer (CRC), the third most commonly diagnosed cancer in males and the second in females, ranks second in terms of mortality worldwide [2]. Belgium ranks 14th in terms of CRC incidence rate [4], with an age-standardized rate of CRC is of 36.1 per 100,000 person-years in males and

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25.8 per 100,000 person-years in females. In Flanders, in 2019, CRC was the second most common cancer in females and third in males [3].

Screening is an excellent preventive intervention for an early detection of cancer and can improve patient prognosis for both BC and CRC. Prior literature, in fact, has shown that BC screening mammography programs (target ages 40–70) can save approximately 1.2 lives per 1000 over a period of 12 years [5] and CRC screening programs offering annual fecal occult blood test (FOBT) (target ages 50–75) can save approximately 3 lives per 1000 over a period of 13 years [6]. In terms of relative impact, FOBT and mammography screenings result in a similar magnitude of reduction in cancer deaths: 14-32% for BC [7] and 30% for CRC [8].

Despite the recognized benefits of screening, however, in Flanders the uptake of both programs is still suboptimal with just over half of the target population participating in the organized screening program for both BC and CRC screening [9]. Understanding the determinants of screening participation in each program is therefore crucial. Nevertheless, rarely these have been investigated in a communal target population. The aim of this study is to provide an insight on municipal level determinants of screening participation in the target population for both BC and CRC screening (women aged 55-69 years). The evidence collected can be used to inform and guide more holistic interventions to effectively increase screening uptake in both the BC and CRC screening programs.

2. Methods

2.1. Study setting and data source

The present study used municipality level data of 308 Flemish municipalities in 2014–2017. Data of the Centre for Cancer Detection on organized colorectal cancer (CRC) and breast cancer (BC) screening uptake – defined as the number of people who participate in screening within 12 months after invitation, divided by the number of people invited – [10] were linked to socioeconomic, demographic and health-related municipal parameters from the Flemish provincial authorities[11]. Privacy was warranted since only aggregated data at municipality level were used and figures were not displayed for cells with less than 5 events.

In Flanders a breast cancer screening program (BCSP) has been in place since 2001 [12]. The program provides on a 2-year basis a mammographic screening test paid by the health insurance system to all eligible women aged 50–69, actively recruited through a personalized invitation letter with a fixed time and place sent by the Centre for Cancer Detection.

The organized colorectal screening program (CRCSP), offering a free of charge fecal immunochemical test (FIT) every two years to all individuals aged 50–74, actively recruited through a personalized invitation letter, has been in place since 2013[13]. Target ages have been gradually extended from 56–74 in 2013 to 50–74 in 2020.

Both programs align with the European Guidelines for Quality Assurance [14], [15].

2.2. Study design and objective

The objective of the present study is to identify the factors associated with breast and colorectal cancer screening uptake in Flemish municipalities and the potential interrelationships between the two screening programs. To accomplish this objective, municipality level characteristics were linked to screening uptake among Flemish women of 55-69 years of age, representing the communal target population of both screening programs.

Because screening uptake among municipalities was not normally distributed, we compared the uptake of each municipality with the median uptake of all 308 municipalities, calculated for each year of the study period. Then, a profile for each municipality based on its BC/CRC screening uptake compared with the median screening uptake across all municipalities (4 possible profiles) was created as follows:

- Group 1: BC municipal uptake ≥ median uptake of Flemish municipalities, CRC municipal uptake ≥ median uptake of Flemish municipalities (“high BC, high CRC”)

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- Group 2: BC municipal uptake ≥ median uptake of Flemish municipalities, CRC municipal uptake < median uptake of Flemish municipalities ("high BC, low CRC")
- Group 3: BC municipal uptake < median uptake of Flemish municipalities, CRC municipal uptake ≥ median uptake of Flemish municipalities ("low BC, high CRC")
- *Group 4: BC municipal uptake < median uptake of Flemish municipalities, CRC municipal uptake < median uptake of Flemish municipalities ("low BC, low CRC")*

2.3. Determinants

Table 1 shows fourteen demographic, socioeconomic and health-related municipal parameters that were investigated as potential factors associated with BC and CRC screening uptake.

Table 1. – Potential municipal characteristics associated with BC/CRC screening uptake.

Variable	Explanation
Socioeconomic variables	
Average income	Total net taxable income / total inhabitants (EUR), per 10,000
Position in the labor market	Jobseekers: % of jobseekers / total inhabitants Wage earners: % of wage earners / total inhabitants Self-employed: % of self-employed / total inhabitants (Early) retired: % of (early) retirees / total inhabitants
Higher education	% of students in higher education / people aged 18-24 years old
Demographic variables	
Age	Age group 1: % of people aged between 55 and 59 years old Age group 2: % of people aged between 60 and 64 years old Age group 3: % of people aged between 65 and 69 years old
Average household size	Average size (n. of people) in the households (n)
Same address	% of people with same address as previous year
Having a partner	% of people having a partner
Having children	% of people having (a) child(ren)
Foreign Nationality	% of people of non-Belgian – non-Dutch nationality / inhabitants
Health-related variables	
Chronic Conditions	% of rightful claimants with at least 1 chronic condition / people with health insurance
Diabetes	% of rightful claimants with diabetes / people with health insurance
Disabilities	% of people aged 18+ registered by the Directorate General for Disabled Persons as losing at least one third of the average earning capacity or being unable to perform daily activities / inhabitants
General practitioner (GP) visits	% of people with at least 1 GP contact in last 12 months / people with health insurance
Preventive Dental visits	% of people with at least 2 preventive dental visits in last 3 years / people with health insurance

The percentages of age group were calculated for the female target population. The other listed variables were measured for the total population of a municipality and were used as a proxy for the characteristics of the female target population.

Because of the substantial similarity in language and culture (Dutch is the official Flemish language), foreigners were referred to as people without either Belgian or Dutch nationality. The percentage of residents aged 18–24 studying at a college/university

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(higher education) was used as a proxy for education level. Additional details on the included variables can be found at https://provincies.incijfers.be/databank (Accessed on 1 February 2021).

2.4. Covariates for adjustment

In order to minimize possible collider biases [16] a causal directed acyclic graph (DAG) based on prior knowledge about the Flemish organised screening programs [17], [18] was employed to identify covariates for adjustment when assessing the associations between municipal characteristics and profile of BC/CRC screening uptake. A multidisciplinary brainstorming session was organized between a medical doctor, two epidemiologists (amongst whom the program manager of the Flemish CRC screening program) and a sociologist to conceptualize the exposure – outcome relationship. DAGs have become an established framework for the analysis of causal inference in epidemiology and are used to show how associations translate into causal relations [19]. The final covariates for adjustment in multivariable analysis are presented in Table 2. The final DAG is available in Supplementary Material (Figure S1) and online at http://dagitty.net/dags.html?id=ck1-_X

Table 2. - Covariates for adjustment in multivariable analyses to estimate the association between each municipal characteristic and profile of BC/CRC screening uptake.

Municipal Characteristics	Covariates for adjustment
Socioeconomic variables	
Average income	Chronic Condition, Age group, Disabilities, With a partner, Foreign Nationality, Position in Labor Market, Higher Education
Position in Labor Market	Age group, Disabilities, Foreign Nationality, Higher Education
Higher education*	Chronic Condition, Age group, Dental Visits, Diabetes, Disabilities, GP visits, With a partner, Foreign Nationality, Position in the Labor Market
Demographic variables	
Age	No adjustment
Average household size	With a partner, With children, Foreign Nationality
Same address	Disabilities
Having a partner	Age group
Having children	Age group, With a partner
Foreign Nationality	No adjustment
Health-related variables	
Chronic Conditions	Age group, Disabilities, Foreign Nationality, Higher Education
Diabetes	No adjustment
Disabilities	No adjustment
General practitioner (GP) visits	Chronic Condition, Age group, Dental Visits, Diabetes, Disabilities, With a partner, Foreign Nationality, Position in the Labor Market, Higher Education
Preventive Dental visits	Chronic Condition, Age group, Nationality, Position in the Labor Market, Average Income, Higher Education
* Adjustment set for the direct effect only	

2.4. Statistical analysis

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At least 10 events per variable are required for accurate coefficient estimation in multinomial logistic regression models [20]. In this study, we included 17 determinants and 308 municipalities carrying independent data on screening uptake to provide sample size with sufficient statistical power. Not normally distributed continuous variables were calculated using median values.

Each municipality was assigned a screening uptake profile (study outcome), with group 1 as reference group in all analyses (Group 1: high BC, high CRC; Group 2: high BC, low CRC; Group 3: low BC, high CRC, Group 4: low BC, low CRC).

With multinomial logistic regression analysis using generalized estimating equation (GEE) we evaluated the associations between considered determinants and BC/CRC screening uptake profiles. In the GEE model, the dependent variable was the municipal profile of BC/CRC screening uptake and the independent variables were the municipal characteristics, as given in Table 1. Crude and adjusted odds ratios (ORs) were reported with 95% confidence intervals (95% CIs). Multicollinearity in multivariate models was checked using variance inflation factors (VIFs). P-values < 0.05 (two-sided) were considered statistically significant. All analyses were performed with R (version 4.0.3) [21].

3. Results

3.1. Municipal Characteristics

Data of all 308 municipalities of Flanders for the period 2014–2017 was included.

Considering women only, the overall median uptake of all years and municipalities was 54.6% for BC screening uptake and 57.4% for CRC screening uptake. In particular, uptake rates were, for BC and CRC screening respectively, 52% and 56.6% in 2014, 54.5% and 56.5% in 2015, 55.2% and 59% in 2016 and 56.9% and 57.9% in 2017.

Median values of the included municipal characteristics grouped, for each year, by BC/CRC screening uptake municipality profiles (Group 1: high BC, high CRC; Group 2: high BC, low CRC; Group 3: low BC, high CRC, Group 4: low BC, low CRC) are shown in Table 3.

Figure 1 displays a map of Flanders showing the assigned municipality uptake profile based on the mode across all years. Municipalities for which it was not possible to find a mode are represented in white. Additional maps showing the mode for each year can be found in the Supplementary Material (Figures S2)

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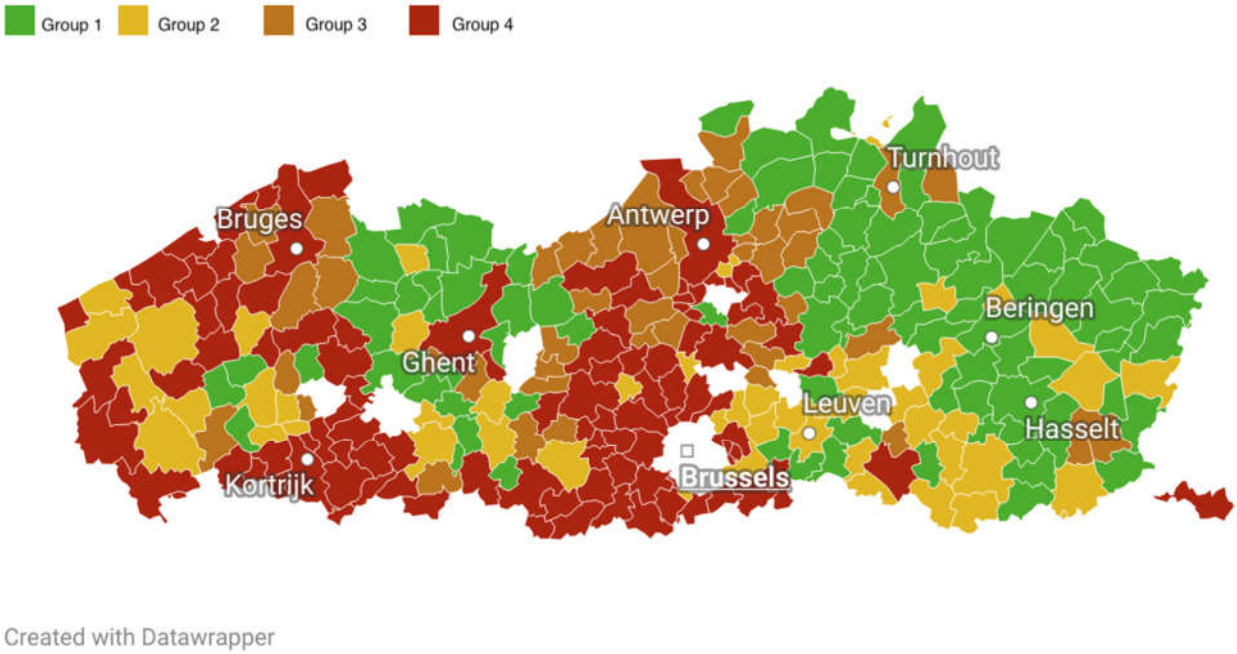

Group 1 (reference group): high BC, high CRC; Group 2: high BC, low CRC; Group 3: low BC, high CRC: Group 4: low BC, low CRC.

Figure 1. – Map of Flanders municipalities (division before 2019) displaying municipality screening uptake profiles based on the mode across all years.

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Table 3 – Municipal characteristics of Flanders municipalities grouped by BC/CRC screening uptake municipality profiles, 2014–2017 (median)

		2014				2015				2016				2017			
		Group 1	Group 2	Group 3	Group 4	Group 1	Group 2	Group 3	Group 4	Group 1	Group 2	Group 3	Group 4	Group 1	Group 2	Group 3	Group 4
Socioeconomic variables	Average income (EUR)	18542.5	19195.5	19982.5	20623.0	18473.0	19284.0	19611.0	18641.5	18858.0	18441.5	19704.5	18970.5	19201.0	20129.0	20266.0	19295.0
	Jobseeker rate (%)	2.20	1.80	1.70	1.80	2.10	1.70	1.70	1.80	1.80	1.70	1.60	1.70	1.70	1.40	1.50	1.60
	Wage earners (%)	36.75	36.25	37.10	36.10	36.30	36.90	37.40	35.95	36.65	36.65	36.85	36.25	36.8	36.7	37	36.6
	Self-employed (%)	7.80	8.70	7.50	7.80	7.80	7.90	7.80	8.30	80.00	8.20	8.10	7.80	8.10	7.80	8.35	80.00
	(Early) retired (%)	18.85	20.35	19.25	19.85	19.10	19.45	20.10	20.35	19.75	19.95	20.35	19.85	19.90	19.80	20.60	20.20
	Higher education (%)	44.25	41.15	45.40	44.45	45.10	43.55	46.20	41.15	44.25	41.75	46.85	44.95	45.60	46.70	49.00	42.90
Demographic variables	Age group 1 (%)	37.96	36.94	37.30	37.10	37.42	37.40	37.12	37.13	37.59	37.64	37.13	37.69	37.23	37.66	37.62	37.26
	Age group 2 (%)	32.92	32.48	32.72	32.56	33.20	32.71	32.80	32.60	32.91	33.18	33.11	33.07	33.07	33.55	33.17	33.27
	Age group 3 (%)	29.17	30.84	29.14	30.54	29.19	29.62	29.79	30.43	29.35	29.31	29.73	29.56	29.24	29.00	29.20	29.54
	Average household size	2.44	2.41	2.45	2.41	2.42	2.44	2.42	2.39	2.41	2.41	2.41	2.41	2.42	2.44	2.39	2.39
	Same address (%)	92.95	92.55	92.70	91.75	92.70	92.15	92.40	91.60	92.95	92.50	92.65	91.90	92.80	92.30	92.25	91.60
	Having a partner (%)	53.40	51.70	53.30	51.30	53.50	51.85	53.40	51.25	53.40	51.80	53.30	51.10	53.45	51.60	53.20	51.10
	Having children (%)	29.85	29.25	29.60	28.95	29.40	29.40	29.00	28.65	29.10	28.80	28.80	28.60	29.05	28.80	28.40	28.30
	Foreign Nationality (%)	2.45	2.35	2.10	3.45	2.50	3.45	1.90	3.45	2.60	3.05	2.40	3.90	2.70	3.60	2.95	3.90
Health-related variables	Chronic Conditions (%)	9.10	10.10	8.80	8.70	9.70	9.90	9.40	9.90	10.50	11.20	10.20	10.00	11.05	11.20	10.80	11.10
	Diabetes (%)	5.10	5.90	5.30	5.50	5.10	5.65	5.30	5.90	5.30	5.80	5.60	5.75	5.10	5.70	5.20	5.70
	Disabilities (%)	6.25	8.21	6.04	5.79	6.36	6.92	5.68	6.94	6.58	7.66	6.15	6.01	6.51	6.73	5.79	6.86
	General practitioner (GP) visits (%)	84.80	84.00	82.45	81.25	85.30	84.60	84.40	82.80	86.30	85.40	84.85	82.85	86.05	84.10	84.10	83.30

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Preventive Dental visits (%)	32.70	30.70	32.15	30.90	36.50	33.50	34.60	32.40	38.45	36.50	37.65	35.80	41.95	39.60	41.20	37.10

Group 1 (reference group): high BC, high CRC; Group 2: high BC, low CRC; Group 3: low BC, high CRC: Group 4: low BC, low CRC.

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Table 4. - Multivariable associations between municipal characteristics and BC/CRC screening uptake municipality profiles.

		Group 2 vs. 1				Group 3 vs. 1				Group 4 vs. 1			
		OR	95%CI L	95%CI H	p value	OR	95%CI L	95%CI H	p value	OR	95%CI L	95%CI H	p value
Socioeconomic variables	Average income	2.27	0.64	7.99	0.20	3.49	0.81	15.05	0.09	0.03	0.005	0.19	<0.001*
	Jobseeker rate	0.39	0.22	0.70	0.002*	0.31	0.18	0.54	<0.001*	1.37	0.78	2.41	0.27
	Wage earners	1.04	0.96	1.14	0.32	1.01	0.91	1.11	0.87	0.95	0.89	1.02	0.19
	Self-employed	1.04	0.92	1.17	0.51	1.07	0.95	1.21	0.24	0.91	0.81	1.03	0.13
	(Early) retired	1.12	0.99	1.28	0.07	1.08	0.92	1.26	0.34	0.83	0.73	0.96	0.010*
	Higher education	0.94	0.90	0.98	0.005*	0.98	0.94	1.03	0.46	1.00	0.96	1.04	0.85
Demographic variables	Age group 1	0.93	0.86	1.01	0.09	0.97	0.88	1.07	0.55	1.04	0.97	1.11	0.30
	Age group 2	0.97	0.85	1.11	0.65	1.03	0.89	1.18	0.72	1.03	0.91	1.17	0.61
	Age group 3	1.11	1.01	1.21	0.025*	1.03	0.94	1.14	0.51	0.95	0.87	1.05	0.32
	Average household size	0.16	0.01	3.22	0.23	0.08	0.002	3.20	0.18	0.13	0.00	5.81	0.30
	Same address	0.68	0.58	0.80	<0.001*	0.83	0.68	1.01	0.07	1.13	0.99	1.30	0.08
	Having a partner	0.60	0.53	0.69	<0.001*	0.68	0.60	0.77	<0.001*	1.03	0.92	1.17	0.58
	Having children	0.94	0.79	1.12	0.49	1.07	0.88	1.31	0.50	1.31	1.08	1.58	0.005*
	Foreign Nationality	1.49	1.28	1.73	<0.001*	1.43	1.23	1.65	<0.001*	1.10	0.95	1.27	0.21
Health-related variables	Chronic Conditions	1.10	0.91	1.32	0.32	1.20	0.98	1.46	0.07	1.17	0.99	1.38	0.06
	Diabetes	2.07	1.45	2.97	<0.001*	2.06	1.44	2.94	<0.001*	0.82	0.59	1.16	0.27
	Disabilities	1.06	0.94	1.20	0.36	1.24	1.09	1.41	<0.001*	1.09	0.98	1.20	0.12
	General practitioner (GP) visits	0.96	0.84	1.09	0.51	1.11	0.96	1.27	0.15	1.32	1.13	1.55	<0.001*
	Preventive Dental visits	0.94	0.90	0.98	0.006*	0.91	0.87	0.96	0.001*	1.02	0.98	1.06	0.39

* = significant p values; Group 1 (reference group): high BC, high CRC; Group 2: high BC, low CRC; Group 3: low BC, high CRC: Group 4: low BC, low CRC.

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3.2. Factors Associated with BC/CRC screening uptake

Results from the univariable analysis are shown in Table 4. Multicollinearity in multivariate models was low (VIFs <5). Results after covariate adjustment are presented in Table 4 and are graphically summarized in Figure 2.

As mentioned above, each municipality was assigned a screening uptake profile and Group 1 ("high BC, high CRC") was used as the reference group in all analyses.

As a consequence, municipalities with characteristics that are negatively associated (OR < 1) with Group 2 ("high BC, low CRC"), Group 3 ("low BC, high CRC") or Group 4 ("low BC, low CRC") are more likely, in comparison to the median uptake of all Flemish municipalities, to have a better performance in terms of screening uptake (more likely to be in Group 1, our reference group). By contrast, municipalities with characteristics that are positively associated (OR > 1) with Group 2 ("high BC, low CRC") or Group 3 ("low BC, high CRC"), are more likely to perform, in comparison to the median uptake of all Flemish municipalities, better with regards to one screening, worse with regards to the other. Accordingly, municipalities with characteristics that are positively associated (OR > 1) with Group 4 ("low BC, low CRC") are more likely, in comparison to the median uptake of Flemish municipalities, to have worse performance in terms of screening uptake for both BC and CRC.

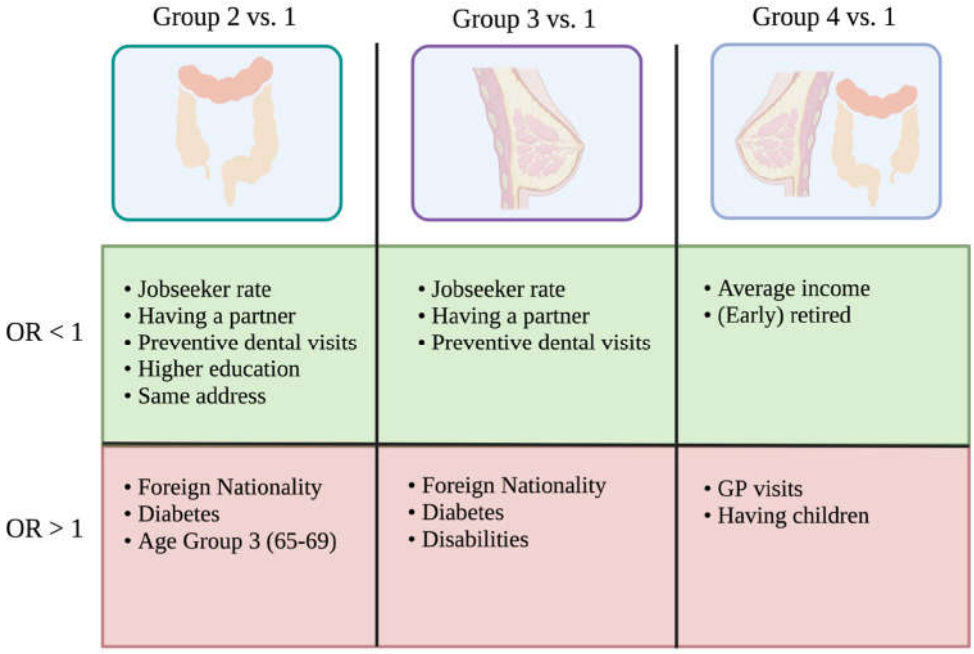

Figure 2. – Positive/negative association between municipal characteristics and BC/CRC screening uptake municipal profile – The picture was created in www.biorender.com .

3.2.1. Factors associated with higher BC/CRC screening uptake

Municipalities with a higher percentage of jobseekers, people with a partner and people with at least 2 preventive dental visits in 3 years were less likely to be in Group 2 ("high BC, low CRC") [OR 0.39 (95%CI 0.22-0.70), OR 0.60 (95%CI 0.53-0.69), and OR 0.94 (95%CI 0.90-0.98, respectively] or Group 3 ("low BC, high CRC") [OR 0.31 (95%CI 0.18-0.54), OR 0.68 (95%CI 0.60-0.77), and OR 0.91 (95%CI 0.87-0.96), respectively], compared to Group 1. In other words, these municipalities were more likely to have "high BC, high CRC" compared to "high BC, low CRC" or "low BC, high CRC". Moreover, municipalities with a higher percentage of people in higher education [OR 0.94 (95%CI 0.90-0.98)] and people living at the same address as previous year [OR 0.68 (95%CI 0.58-0.80)] were

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also less likely to be in Group 2 vs Group 1, meaning that these municipalities were more likely to have "high BC, high CRC" compared to "high BC, low CRC".

Finally, municipalities with higher average income [OR 0.03 (95%CI 0.005-0.19)] and a higher percentage of (early) retired [OR 0.83 (95%CI 0.73-0.96)] were less likely to be in Group 4 ("low BC, low CRC") compared to Group 1. In other words, these municipalities were more likely to have "high BC, high CRC" compared to "low BC, low CRC".

3.2.2. Factors associated with lower BC/CRC screening uptake

Municipalities with a higher percentage of people of foreign nationality and people with diabetes were more likely to be in either Group 2 ("high BC, low CRC") [OR 1.49 (95%CI 1.28-1.73) and 2.07 (95%CI 1.45-2.97), respectively] or Group 3 ("low BC, high CRC") [OR 1.43 (95%CI 1.23-1.65) and 2.06 (95%CI 1.44-2.94), respectively] compared to Group 1. Moreover, municipalities with a higher percentage of people aged 65-69 years [OR 1.11 (95%CI 1.01-1.21)] were more likely to be in Group 2 ("high BC, low CRC") compared to Group 1 and municipalities with a higher percentage of people with disabilities [OR 1.24 (95%CI 1.09-1.41)] were more likely to be in Group 3 ("low BC, high CRC") compared to Group 1.

Lastly, municipalities with a higher percentage of people with at least 1 GP contact in last 12 months [OR 1.32 (95%CI 1.13-1.55)] and people with child(ren) [OR 1.31 (95%CI 1.08-1.58)] were more likely to be in Group 4 ("low BC, low CRC") compared to Group 1.

4. Discussion

In this study we found that, considering women only, the overall median uptake of cancer screening during the study period was 57.4% for CRC and 54.6% for BC. The median uptake rate of both screening programs is within the range of uptake levels of European countries (respectively 48.2% (range: 19.4–88.9%) for BC [22] and 45.4% (range: 19.9-68.2%) for CRC in both sex [23]).

Demographic, socio-economic and health-related characteristics were significantly associated to the BC/CRC screening uptake profiles.

We found that percentages of people with non-Belgian/Dutch nationality and diabetes are associated with a lower probability of screening for CRC (more chances of being in Group 2 vs. Group 1) and BC (more chances of being in Group 3 vs. Group 1). With regards to foreign nationality, these findings are consistent with previous observations at both municipal and individual level [17], [24], [25] and can be explained by the reported perceived language barriers and embarrassment when talking about screening [26]. Moreover, migrants are a high-risk group for limited health literacy and may experience higher difficulties, compared to non-immigrant individuals, in processing health information and translating them it into healthy behaviors [27].

With regards to diabetes, a prioritization of disease-related care over routine preventive care may explain the reduction in screening utilization. Previous evidence has shown that screening rates are about 17% and 14% lower for, respectively, BC and CRC screening in women with diabetes, which is particularly alarming when we consider that adults with type 2 diabetes have an increased risk of cancer mortality [28].

Other health priorities may as well be a reason for the association between disabilities and a lower BC screening uptake (more chances of being in Group 3 vs. Group 1). Participation in the BC and CRC screening programs, in fact, has been shown to be about 10% less in persons with disabilities in comparison with the Flemish average [29]. This may be due to the existence of physical barriers (transport, accessibility of mammography and examination tools).

With regards to the age groups considered, a higher percentage of people aged 65-69 was associated with lower CRC screening uptake (more chances of being in Group 2 vs. Group 1). Although, in this study, we could not assess the oldest age group participating in CRC screening (ages 70-74) because it is not included in the BC screening target population, previous studies have found a negative association with ages 70-74 and FOBT

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screening in Flanders [17] and other European countries [30]. It is plausible that people from the two age groups, both including elderly individuals, act in a similar manner: older people tend to suffer from multiple health issues that may need prioritization. Moreover, they have a lower perceived life expectancy, which is associated to worse screening participation [31]. It should be kept in mind that age is a major risk factor for sporadic CRC and age-specific incidence rates increase in each succeeding decade after ages 40-50 [32]. Interestingly, a higher percentage of people with at least 1 general practitioner (GP) visit in last 12 months and people with children have been shown to be associated with lower uptake of both CRC and BC screening (more chances of being in Group 4 vs. Group 1). With regards to GP visits, these results are in contrast with those of a previous study that found that GP visits are positively associated with CRC screening coverage [17]. In this study, however, the association of GP visits and non-organized screening was more pronounced than the association with organized screening. Our hypothesis is that people who visit the GP at least once a year may have higher chances to be recommended with seeing a specialist or take exams outside of the screening program (opportunistic screening). Moreover, people who see their GP more regularly may overestimate their health status, feel "safer" and not feel the need to participate in screening. Nevertheless, literature shows that suggestions by one's GP may play an important role in positively influencing screening participation [33].

With respect to the percentage of people with children, our results run counter to what prior evidence, identifying parents as more likely to undergo screening and maintain a healthy lifestyle in order to provide for their children needs [34], has suggested. Further research is needed to expand on these findings. We found a marked association between average income and uptake of both BC and CRC screening (less chances of being in Group 2 vs. Group 1). It is interesting to compare our findings with results of previous studies which have found that, with regards to both BC and CRC screening, a higher average income is related to lower screening coverages for the organized screening, but to higher screening coverages for the non-organized (opportunistic) screening[17], [25]. Nevertheless, it should be kept in mind that, compared to this one, these studies investigated a different outcome (screening uptake vs. screening coverage). In general, it is plausible that women with a higher socio-economic status (SES) (average income as an indicator of SES), may have a higher health literacy and perceive, particularly with regards to FOBT screening, fewer psychological barriers. They may also have, with regards to mammography screening, fewer financial barriers associated with costs of transportation, lost days of work and childcare.

Regarding position in the labor market, a higher percentage of jobseeker was associated with a higher probability of screening of CRC (less chances of being in Group 2 vs. Group 1) and BC (less chances of being in Group 3 vs. Group 1) screening, and a higher percentage of (early) retired was associated with higher probability of both CRC and BC screening (less chance of being in Group 4 vs. Group 1). These findings confirm previous results on CRC screening that have shown that, in comparison with employees/entrepreneurs, jobseekers [17] and (early) retired [24] are more likely to participate. It is plausible that individuals from both groups may have more free time to participate in screening and, because screening is completely free of charge, there are no financial barriers to participate.

In accordance with other studies [35], [36], our results show a positive association between percentage of people with a partner and BC (less chances of being in Group 3 vs. Group 1) or CRC (less chances of being in Group 2 vs. Group 1) screening uptake. Marital status has in fact been suggested as a proxy for social support [37] and several studies have shown that married individuals are more likely to adopt preventive and healthy lifestyles or that spouses can influence their partner's awareness and engagement in health-seeking behaviors [38].

Consistently with a previous study [18] , we found that preventive dental care was associated with higher BC (less chances of being in Group 3 vs. Group 1) or CRC (less chances of being in Group 2 vs. Group 1) screening uptake. Considering that dental visits

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are not fully covered by the health insurance system in Flanders, a higher dental care may be a strong indicator of predisposition towards preventive health behaviors.
Finally, we found percentage of people in higher education and people living at the same address as previous year to be associated with higher uptake of CRC screening (less chances of being in Group 2 vs. Group 1). Higher education (as a proxy for education level and health literacy) may facilitate comprehension of screening information and therefore adhesion to preventive behaviors [27]. Moreover, with regards to FOBT screening, a higher health literacy may help overcome psychological barriers related to stool collection [17], [33]. Residential stability (same address), on the other hand, guarantees that invitation letters arrive at the right address.

Flanders offers an interesting scenario in which to study screening participation patterns. In Figure 2 we can observe a noticeable difference, in term of BC/CRC screening uptake profiles, between the areas closer the French-speaking southern part (Wallonia) and the north-eastern part of Flanders, closer to the border with the Netherlands. The two areas tend to perform worst (more chances of being in Group 4 vs. 1) and best (less chances of being in Group 4 vs. 1), respectively. In Flanders each municipality has relative autonomy in health promotion and disease prevention actions which, along with socio-demographic (e.g. SES, number of immigrants, spoken languages) and cultural differences among these communities may be an explanation of variations in uptake. In particular, inhabitants closer to the border with Wallonia may have developed a higher affinity with the healthcare services of the region, where most are screened outside the organized program following consultations with their GPs or gynecologists [39]. It is also possible that a number of these women have moved from Wallonia to Flanders and carried on the habit of opportunistic screening. Additional analyses, not yet published, indicate that municipalities in these areas have a high BC outside screening coverage (but a low CRC outside screening coverage). While this data may partially support the hypothesis of a tendency towards opportunistic screening, more in-depth analyses of screening patterns in these areas are needed.

Some limitations need to be acknowledged. First, in this study we employed data aggregated at a municipal level which, with regards to screening uptake, was subcategorized in four different municipal profiles for BC/CRC screening. This may lead to ecological fallacy which means incorrect assumptions about individuals based on data for a group to which those individuals belong [40]. Second, with the exception of age, the other independent variables were measured for the complete municipality population and used as a proxy for the communal target population. Despite the limitations, our results substantiate previous findings at both municipal [17], [18], [24], [25], [29] and individual [26] level.

A key strength of this study is that the use of administrative data minimizes possible recall biases associated with self-reported data. In addition, the use of DAG to identify covariates for adjustment allowed us to avoid collider biases (see Method section).

5. Conclusions

The present study was the first to compare CRC and BC screening uptake in a target population for both screenings in Flanders and allowed us to explore not only the existing interrelationships between the two programs, but also geographical differences in screening participation patterns. Retrieved data should be used to tailor interventions with the intent of improving knowledge about the importance of early detection of both BC and CRC and increase screening uptake, particularly among women presenting with the characteristics which are common within municipalities that perform worse in terms of BC and CRC screening uptake. For example, seen as foreign nationality has been found to be associated with lower screening uptake, it is important for us to be mindful of the possible cultural and language barriers which may exist within our target population and therefore attempt to tailor invitation letters and informative content to these needs.

In addition, it is important for us to actively ensure that the presence of any pre-existing condition (older age, having diabetes, having a disability) does not overshadow the importance of preventative screening. Providers, in particular GPs, should remain up to date regarding the need for cancer screening and should be given the tools with which to promote screening adherence among their patients.

Supplementary Materials: Figure S1: Causal directed acyclic graph (DAG) built to identify covariates for adjustment in multivariable analyses.; Figures S2: Maps of Flanders municipalities (division before 2019) displaying municipality uptake profiles (2014-2017). Table S1: Univariable associations between municipal characteristics and BC/CRC screening uptake municipality profiles.
Causal directed acyclic graph (DAG) is also available online at: http://dagitty.net/dags.html?id=ck1-_X

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Data Availability Statement: Data on screening uptake, gender and age-specific proportions of the target screening population can be requested by contacting the Centre for Cancer Detection in Flanders at https://www.bevolkingsonderzoek.be/ (accessed 2022-01-02). Data on demographic, socio-economic and health-related variables are publicly available on the https://provincies.incijfers.be/databank (accessed 2022-01-02) website.

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