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Area-based comparison of risk factors and testing rates to improve sexual health care access: cross-sectional population-based study in a Dutch multicultural area

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ABSTRACT

Objectives Areas with high sexually transmitted infection (STI) testing rates may not require additional strategies to improve testing. However, it may be necessary to intervene in areas with elevated STI risk, but with low STI testing rates. We aimed to compare STI-related risk profiles and STI testing rates by geographical area to determine areas for improvement of sexual healthcare access.

Design Cross-sectional population-based study.

Setting Greater Rotterdam area, the Netherlands (2015–2019).

Participants All residents aged 15–45 years. Individual population-based register data were matched with laboratory-based STI testing data of general practitioners (GPs) and the only sexual health centre (SHC).

Outcome measures Postal code (PC) area-specific STI risk scores (based on age, migratory background, education level and urbanisation), STI testing rates and STI positivity.

Results The study area consists of approximately 500 000 residents aged 15–45 years. Strong spatial variation in STI testing, STI positivity and STI risk was observed. PC area testing rate ranged from 5.2 to 114.9 tests per 1000 residents. Three PC clusters were identified based on STI risk and testing rate: (1) high–high; (2) high–low; (3) low, independently of testing rate. Clusters 1 and 2 had comparable STI-related risk and STI positivity, but the testing rate differed greatly (75.8 vs 33.2 per 1000 residents). Multivariable logistic regression analysis with generalised estimating equation was used to compare residents in cluster 1 and cluster 2. Compared with cluster 1, residents in cluster 2 more often did not have a migratory background, lived in less urbanised areas with higher median household income, and more distant from both GP and SHC.

Conclusion The determinants associated with individuals living in areas with high STI-related risk scores and low testing rates provide leads for improvement of sexual healthcare access. Opportunities for further exploration include GP education, community-based testing and service (re)allocation.

STRENGTHS AND LIMITATIONS OF THIS STUDY

⇒ This is the first study that considers community sexually transmitted infection (STI) risk while examining determinants associated with different area-specific STI testing levels.
⇒ The study design, linking laboratory STI testing data to population microdata, has limited risk of biases and mirrors the real numbers as closely as possible, in contrast to, for example, questionnaires or sentinel databases.
⇒ The use of administrative units to distinguish areas may not differentiate social or health-related characteristics.
⇒ Individual-level STI risk may differ to community-level STI risk. Additionally, the STI risk estimate was based on a limited number of sociodemographic factors available for all residents.
⇒ The current study classified areas with 'low' and 'high' testing rates, but it remains unknown whether the 'high' testing rates are sufficient.

INTRODUCTION

Adequate access to sexually transmitted infection (STI) testing services is important as STI testing is the entry point for STI prevention and care and is critical to reduce ongoing transmission and morbidity. Due to healthcare organisation and policy in the Netherlands, general practitioners (GPs) have a pivotal role in provision of sexual healthcare and STI testing. Sexual health centres (SHCs) are important additional providers for key groups.[1–4] STI testing at an SHC is on request and free-of-charge, but only individuals considered as high risk are admitted based on triage (eg, notified for an STI, STI-related complaints, non-western migratory background, <25 years-of-age, men who have sex with men (MSM)). An STI test at the GP is performed on patient request—in principle without risk assessment—and on doctors' reasoning and advice. A consult at the GP is free-of-charge, but laboratory tests may incur costs for people who have not yet met their

financial contribution (minimum €385) to compulsory health insurance.

Although GPs are the main STI testing provider, Slurink *et al* found large nationwide differences within the Netherlands.[1] The contribution to STI testing by GPs was much lower in more urban regions, where SHCs play a more prominent role.[1] Even within a smaller area, for example, a metropolitan area, spatial differences in STI testing may occur. No studies have investigated spatial differences in STI testing on such geographical level. Previous studies focussing on spatial distribution in STI levels (operationalised as either incidence, prevalence or the absolute number of cases) showed an uneven distribution, which, among others, was associated with the population living in these areas. It is known that individuals living in an urban geographical 'STI hot spot' are more likely to have an STI.[5–8] This is partly due to the selection of sexual partners nearby one's own residential location.[9–11] In addition, sociocultural determinants of a specific area may influence spatial clustering of STIs.[12 13]

Recognising geographical STI clusters has potential implications, such as more efficient allocation of resources by area-specific interventions. However, in our opinion focussing solely on the spatial distribution of STI risk, without considering the spatial distribution of STI testing, could limit the effectiveness of area-specific strategies aimed to improve testing. Areas with high STI risk together with high STI testing rates may not require additional strategies to improve testing; it might be more effective to intervene in areas with high STI risk but with low STI testing rates. Our study focuses on the greater Rotterdam area which in several respects has a very diverse population. We hypothesised that STI testing rates differ greatly within this area. This study aimed to compare STI-related risk profiles and STI testing rates geographically to determine areas for improvement of access to sexual healthcare. We based STI risk on residents' characteristics and STI testing is defined as the number of residents tested for STI per capita. The study combined population register data with sexual health provider data.

METHODS

Study area

This cross-sectional study included Netherlands' second largest city, Rotterdam, and 14 neighbouring municipalities (greater Rotterdam area), with approximately 1.3 million residents.[14] The area had 179 residential administrative postal code (PC) areas ranging in population from 10 to 22 780 (mean 7200 residents).[14] The population was relatively stable across the study period (2015–2019), and the sociodemographic composition between PC areas was heterogeneous.[14] The area harboured 367 general practices and one central SHC.[15] The number of general practices and SHC staffing were stable over the studied years.

Data sources and determinants

Population data

Non-public population data, with one record per person per year (aged 15–45 years; 2015–2019), was accessed via the Statistics Netherlands. The population database captures the following individual-level determinants: sex, date of birth (age), migratory background based on individual's and parents' country of birth, migrants' generation, education level, distance to the nearest GP practice. Migratory background was encoded according to the Statistics Netherlands' coding scheme. The code was Western if at least one parent was born in another country in Europe (excluding Turkey), North America, Oceania, Indonesia or Japan. The code was non-Western when at least one parent was born in a country in Africa, Latin America or Asia (excluding Indonesia and Japan) or Turkey.[16] Because level of education was missing for 14% of the records, multiple imputation by chained equations was used to handle missing data. The imputed data sets (n=5 with each 10 iterations) were examined for reasonable imputation by checking whether the SD of the imputed data sets was comparable. The International Standard Classification of Education was used to categorise education level (low, middle, high). At four-digit PC level of residential location, the database also included the determinants: degree of urbanisation (very high: ≥2500 addresses/km^2, high: 1500–2500, moderate: 1000–1500, low: 500–1000 and very low: <500), and median income per household as indicator for area socioeconomic status (highest: >€36 000, upper middle: €28 400–€36 600, middle: €22 200–€28 400, lower middle: €16 800–€22 200, lowest: <€16 800). For each resident also straight-line distance from PC centroid to the SHC in Rotterdam was calculated with ArcGis V.9.3 GIS software (ESRI, Redlands, California).[17]

STI testing data

GP and SHC testing data for *Chlamydia trachomatis* (CT) and *Neisseria gonorrhoea* (NG) for the years 2015 to 2019 were used. GP testing data were obtained from one laboratory. Depending on the municipality (n=15), this laboratory performed diagnostics for 12%–100% of all general practices in the study area ('GP data coverage'). The median GP data coverage was 88% (IQR 60%–100%). SHC data were obtained from the only SHC in the study area. Both in the GP and SHC testing file, one record per person per study year was created. This record stated dichotomously whether the person was tested at least once for CT and/or NG and tested at least once positive per study year. We included all tests, independently of anatomical location.

Outcomes

Individuals tested in the population

For each study year, the population and STI testing data were linked using a unique pseudonymised personal identifier to define whether someone was tested (including test result). This identifier was based on the citizen service

number for GP clients. For SHC clients, the identifier was based on a combination of sex, birth data and PC at the time of testing, because no citizen service number is registered at the SHC. In total, 98% of GP clients and 88% of SHC clients could be linked to the population database. As a result of the annual population and STI testing data match, the population records stated whether someone was tested and was tested positive for CT/NG (overall and provider specific) in that year. Population records without GP and/or SHC match were assumed not to have been tested.

Testing rates and positivity by PC area

To provide a stable measure over time and geography, the number of (positive) tests and residents was based on a 5-year cumulative sum (2015–2019). These 5-year cumulatives were also used to calculate STI testing rates and STI positivity percentages (hereafter referred to as STI positivity). STI testing rates—the number of residents CT/NG tested per 1000 residents—were calculated per PC area. To account for incomplete data, we corrected the number of GP tested residents with 100 divided by the municipality-specific GP data coverage. The number of SHC tested residents was corrected with 100/88, considering the 88% match between SHC and population data. STI positivity—the number of residents with a positive test divided by the number of residents tested × 100%—was calculated based on the raw numbers. The number of residents, testing rates and positivity shown hereafter in the main text, tables and figure are based on 5-year cumulative data.

Community STI risk by PC area

We assigned a community STI risk score to PC areas. First, a risk score was calculated for each individual in the population database by summing up the scores for separate factors:

- 15–19 years: 1 point; otherwise: 0 points.
- Very highly urbanised: 3 points; moderately/highly urbanised: 2 points; otherwise: 0 points.
- Low/middle level of education: 2 points; otherwise: 0 points.
- Surinam or Antillean migratory background (former Dutch colonies): 2 points; other non-Western: 1 point; otherwise: 0 points.

The maximum score for an individual was eight points. The scoring was derived from a scoring system previously developed to select individuals with elevated CT risk for CT screening in the Netherlands.[18 19] With this method, the risk is not only based on those who are tested, as is the case for STI positivity. Subsequently, the individual risk score was converted into a community STI risk score for each PC area by adding up the individual risk scores per PC divided by the number of residents in that PC area.

Statistical analysis

PC area-specific testing rates, STI positivity and community STI risk scores were calculated and plotted geographically. We plotted STI risk score against testing rates at the PC level and identified clusters with two-stepped cluster analysis. Three clusters were automatically identified based on the Schwartz's Bayesians inference criterion (figure 1D): (1) high risk score with high testing rate (high R-high TR); (2) high risk score with low testing rate (high R-low TR); (3) low risk score, independently of testing rate (low). Multivariable logistic regression with generalised estimating equations (GEE) was performed to compare characteristics of individuals residing in PC areas assigned to cluster 1 (high R-high TR) with individuals from cluster 2 (high R-low TR) and presented in odds ratio (OR) and 95% confidence interval (CI). In the main analyses, STI positivity was not included. We conducted a sensitivity analysis with STI positivity in quartiles (Q1: 0.0%–15.4%, Q2: 15.4%–17.6%, Q3: 17.6%–19.2% and Q4: 19.2%–30.4%) as an extra determinant. The municipality with GP data coverage of 12% was excluded from all analyses to avoid unreliable estimates. This exclusion involved seven PC areas and 5.1% of all residents. Cluster analysis was performed with SPSS V.25.0, GEE analysis with STATA V.16.1, and all other statistical analyses and geographical plots with R V.3.6.2. Statistical significance level was set at a p value <0.05. Areas and population subgroups with less than 10 residents, tests and/or positive cases were not geographically plotted or presented for privacy reasons.

RESULTS

Characteristics of residents

Approximately 500 000 people aged 15–45 years were resident annually in the 14 included municipalities, yielding a total population of 2 508 300 person-years over the 5-year study period. Table 1 is an overview of the residents' characteristics. Over 50% of the residents lived in very highly urbanised areas and over 40% lived in lower income household areas. Most people lived close to a GP (ie, 77.9% within 1 km) and two-fifths lived within 5 km of the central SHC. The city of Rotterdam, of which 80% is very highly urbanised, harboured almost 60% of the residents. About one-third of the residents in the study area had a non-Western migratory background. Among the people with a non-Western migratory background, about half were first-generation migrants. The age and sex structure were relatively evenly distributed.

Area-specific testing rates, positivity and risk

During the 5-year study period, the median number of tests per PC area was 548 (IQR: 179–1062). The area-specific number of tests per 1000 residents ranged from 5.2 to 114.9. Figure 1A–C shows the spatial variation of STI testing, STI positivity and STI risk scores in the study area. The highest testing rates were clustered in the very highly urbanised inner city of Rotterdam (figure 1A). This was not found for STI positivity (figure 1B). Overall, the positivity was 17.5% (table 1). The positivity at the GP (14.5%) was lower than at the SHC (24.6%). The lowest STI risk score was 1.4 and the highest was 5.5. Low-risk

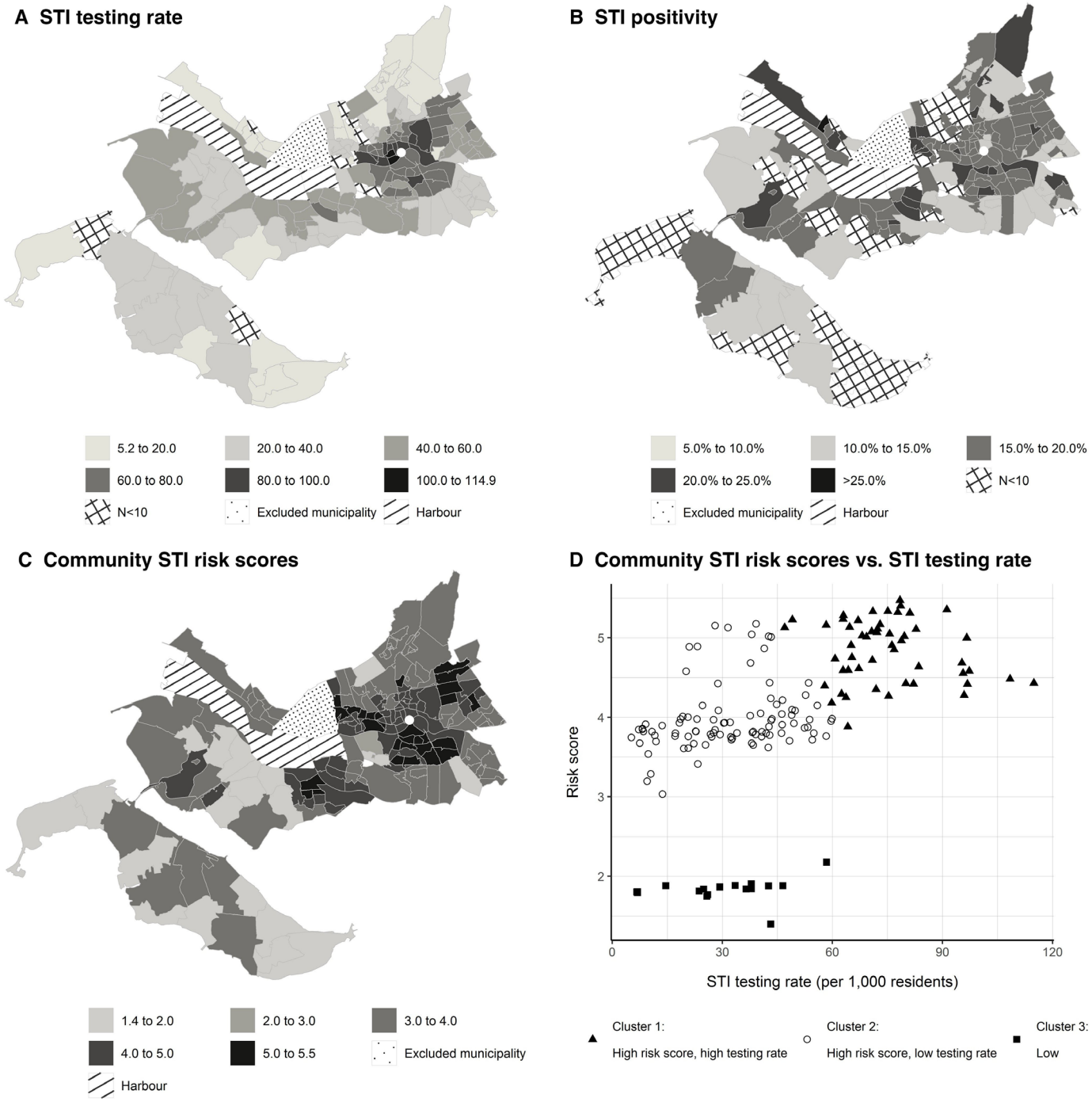

Figure 1 Plots per postal code area, the greater Rotterdam area, the Netherlands (2015–2019). White dot in the geographical plots represents the central sexual health centre. (A)STI testing rate (per 1000 residents). (B)STI positivity (%): residents with a positive test out of number of residents tested. (C)Mean community STI risk scores based on age, migratory background, education level and urbanisation. (D)Mean community STI risk score versus STI testing rate classified in three clusters. The maps were generated using ggplot in R (version 3.6.2). STI, sexually transmitted infection.

scores were mainly confined to suburban areas, while the highest risk scores were in highly urbanised areas (figure 1C).

Characteristics of clusters and associated determinants

The characteristics of residents in the three identified clusters are shown in table 1 and a cluster plot is shown in figure 1D. Areas belonging to cluster 3 (low) were excluded for further analysis (overall risk score of 1.8 and STI positivity of 13.9%), leaving 151 PC areas with a 5-year total of 2 446 120 residents for analysis. Cluster 1 (high R-high TR) consisted of 51 PC areas with 48.5% of these residents. The overall risk score (4.9) and STI positivity (17.8%) in cluster 1 were comparable to cluster 2 (4.0 and 16.9%), but the testing rate was more than two

Table 1 Characteristics of the population 15–45 years and stratified by cluster,* the greater Rotterdam area, the Netherlands (2015–2019)

	General population	Cluster 1 (high R-high TR)	Cluster 2 (high R-low TR)	Cluster 3 (low)
	n=2 508 300	n=1 187 499	n=1 258 621	n=62 180
Individual				
Sex				
Male	1 248 716 (49.8%)	593 053 (49.9%)	623 913 (49.6%)	31 750 (51.1%)
Female	1 259 584 (50.2%)	594 446 (50.1%)	634 708 (50.4%)	30 430 (48.9%)
Age (years)				
15–19	350 154 (14.0%)	141 649 (11.9%)	197 269 (15.7%)	11 236 (18.1%)
20–24	407 977 (16.3%)	217 830 (18.3%)	180 888 (14.4%)	9259 (14.9%)
25–29	445 054 (17.7%)	244 825 (20.6%)	191 273 (15.2%)	8956 (14.4%)
30–34	423 086 (16.9%)	213 283 (18.0%)	200 833 (16.0%)	8970 (14.4%)
35–39	396 052 (15.8%)	176 453 (14.9%)	210 089 (16.7%)	9510 (15.3%)
40 and older	485 977 (19.4%)	193 459 (16.3%)	278 269 (22.1%)	14 249 (22.9%)
Migratory background†				
Western				
Native Dutch	1 342 049 (53.5%)	437 294 (36.8%)	848 917 (67.4%)	55 838 (89.8%)
Middle and Eastern European	129 766 (5.2%)	79 415 (6.7%)	49 104 (3.9%)	1247 (2.0%)
Other Western	179 235 (7.1%)	99 006 (8.3%)	78 036 (6.2%)	2193 (3.5%)
Non-Western				
Dutch Antillean	94 700 (3.8%)	63 810 (5.4%)	30 390 (2.4%)	500 (0.8%)
Surinamese	175 116 (7.0%)	114 459 (9.6%)	60 237 (4.8%)	420 (0.7%)
Turkish	177 841 (7.1%)	119 541 (10.1%)	58 012 (4.6%)	288 (0.5%)
Moroccan	134 214 (5.4%)	96 628 (8.1%)	37 382 (3.0%)	204 (0.3%)
Other non-Western	186 370 (7.4%)	115 138 (9.7%)	70 136 (5.6%)	1096 (1.8%)
Sub-Saharan African‡	43 537 (1.7%)	28 844 (2.4%)	14 381 (1.1%)	312 (0.5%)
Cape Verdean	45 472 (1.8%)	33 364 (2.8%)	12 026 (1.0%)	82 (0.1%)
Migratory background† by generation				
Western (without native Dutch)				
First generation	190 026 (61.5%)	123 842 (69.4%)	64 605 (50.8%)	1579 (46.0%)
Second generation	118 975 (38.5%)	54 579 (30.6%)	62 535 (49.2%)	1861 (54.0%)
Non-Western				
First generation	416 557 (48.6%)	280 015 (49.0%)	134 900 (47.7%)	1642 (56.6%)
Second generation	440 693 (51.4%)	291 769 (51.0%)	147 664 (52.3%)	1260 (43.4%)
Migratory background† by age				
Western (without native Dutch)				
<25 years	75 244 (24.4%)	46 476 (26.0%)	28 012 (22.0%)	756 (22.0%)
≥25 years	233 757 (75.6%)	131 945 (74.0%)	99 128 (78.0%)	2684 (78.0%)
Non-Western				
<25 years	268 166 (31.3%)	180 395 (31.5%)	86 865 (30.7%)	906 (31.2%)
≥25 years	589 084 (68.7%)	391 389 (68.5%)	195 699 (69.3%)	1996 (68.8%)
Education level§				
Low	667 506 (26.6%)	328 206 (27.6%)	323 625 (25.7%)	15 675 (25.2%)
Middle	914 301 (36.5%)	430 934 (36.3%)	459 146 (36.5%)	24 221 (39.0%)
High	578 381 (23.1%)	285 120 (24.0%)	283 639 (22.5%)	9622 (15.5%)
Missing	348 112 (13.9%)	143 239 (12.1%)	192 211 (15.3%)	12 662 (20.4%)
Education level (imputed)§¶				
Low	786 550 (31.4%)	381 717 (32.1%)	385 179 (30.6%)	19 654 (31.6%)

Continued

Table 1 Continued

	General population	Cluster 1 (high R-high TR)	Cluster 2 (high R-low TR)	Cluster 3 (low)
	n=2 508 300	n=1 187 499	n=1 258 621	n=62 180
Middle	1 052 806 (42.0%)	483 382 (40.7%)	539 356 (42.9%)	30 068 (48.4%)
High	668 944 (26.7%)	322 400 (27.1%)	334 086 (26.5%)	12 458 (20.0%)
Area				
Degree of urbanisation				
Very high (≥2500 addresses/km^2)	1 334 805 (53.2%)	1 082 155 (91.1%)	252 650 (20.1%)	0 (0.0%)
Other (<2500 addresses/km^2)	1 172 938 (46.8%)	105 344 (8.9%)	1 005 971 (79.9%)	61 623 (99.1%)
Missing	557 (0.0%)	0 (0.0%)	0 (0.0%)	557 (0.9%)
Median household income				
Other (≥€22 200)	1 438 463 (57.3%)	289 269 (24.4%)	1 090 417 (86.6%)	58 777 (94.5%)
Lowest/lower middle (<€22 200)	1 069 117 (42.6%)	898 230 (75.6%)	168 124 (13.4%)	2763 (4.4%)
Missing	720 (0.0%)	0 (0.0%)	80 (0.0%)	640 (1.0%)
Distance to closest general practice (in km)**				
<1	1 953 146 (77.9%)	1 074 116 (90.5%)	847 020 (67.3%)	32 010 (51.5%)
1–3	529 872 (21.1%)	107 365 (9.0%)	404 685 (32.2%)	17 822 (28.7%)
>3	16 209 (0.6%)	62 (0.0%)	4562 (0.4%)	11 585 (18.6%)
Missing	9073 (0.4%)	5956 (0.5%)	2354 (0.2%)	763 (1.2%)
Distance to SHC (in km)				
<5	1 077 986 (43.0%)	883 470 (74.4%)	191 776 (15.2%)	2740 (4.4%)
5–10	870 146 (34.7%)	262 175 (22.1%)	602 803 (47.9%)	5168 (8.3%)
10	559 611 (22.3%)	41 854 (3.5%)	464 042 (36.9%)	53 715 (86.4%)
Missing	557 (0.0%)	0 (0.0%)	0 (0.0%)	557 (0.9%)
Other				
No. of PC areas	172	51	100	21
Mean risk score	4.4	4.9	4.0	1.8
No. STI tests per 1000 residents††	53.1	75.8	33.2	22.6
% STI positive‡‡	17.5%	17.8%	16.9%	13.9%
% STI positive at GP‡‡	14.5%	14.7%	14.2%	12.7%
% STI positive at SHC‡‡	24.6%	24.7%	24.4%	19.4%

Data presented as No. and column percentages, unless otherwise indicated.
*Clusters are identified with two-step cluster analysis.
†Migratory background was encoded according to the Statistics Netherlands' coding scheme. Western if at least one parent was born in another country in Europe (excluding Turkey), North America, Oceania, Indonesia or Japan. Non-Western when at least one parent was born in a country in Africa, Latin America or Asia (excluding Indonesia and Japan) or Turkey.
‡Without Cape Verdean.
§The International Standard Classification of Education was used as basis. Low: no education, elementary school, pre-vocational secondary education, senior general secondary education (first 3 out of 5 years), pre-university education (first 3 out of 6 years), secondary vocational education level 1. Middle: senior general secondary education (last 2 out of 5 years), pre-university education (last 3 out of 6 years), secondary vocational education level 2 to 4. High: university of applied sciences, university.
¶Multiple imputation via chained equations (MICE) using ten iterations of five multiple imputations.
**Based on address of residential location. Other area characteristics are based on the four-digit postal code of residential location.
††No. of STI tests corrected for data coverage.
‡‡Percentage STI positive is based on the performed tests; raw numbers.
GP, general practitioner; km, kilometre; No, number; PC, postal code; SHC, sexual health centre; STI, sexually transmitted infection.

times as high (75.8 vs 33.2 per 1000 residents). Compared with cluster 1 (high R-high TR), cluster 2 (high R-low TR) was characterised by a higher proportion of residents with a western background (77.5% vs 51.8%), a higher proportion of older residents (above 35 years: 38.8% vs 31.2%), less urbanisation, a higher median household income and a greater distance to GP and SHC. This was also found in our multivariable regression analysis identifying factors associated with living in cluster 2 (high R-low TR) compared with cluster 1 (high R-high TR) (table 2). Large differences in the strength of the associations were observed, with the strongest associations for area-level characteristics. Weak associations were found for the individual characteristics sex, age and education level. The association was stronger for migratory background. In general, non-Dutch residents lived less often

Table 2 Determinants of individuals in cluster 2 (high R-low TR) compared with individuals in cluster 1 (high R-high TR),* the greater Rotterdam area, the Netherlands (2015–2019)

Determinants	Univariable OR (95% CI)†	Multivariable OR (95% CI)†
Individual		
Sex		
Men	REF	REF
Women	1.02 (1.01 to 1.03)	0.98 (0.97 to 1.00)
Age (years)		
15–19	1.15 (1.14 to 1.16)	1.06 (1.05 to 1.07)
20–24	REF	REF
25–29	0.98 (0.97 to 0.99)	1.05 (1.04 to 1.06)
30–34	1.12 (1.11 to 1.12)	1.14 (1.12 to 1.15)
35–39	1.28 (1.27 to 1.29)	1.22 (1.21 to 1.24)
40 and older	1.41 (1.40 to 1.42)	1.29 (1.28 to 1.31)
Migratory background‡		
Native Dutch	REF	REF
Middle and East European	0.33 (0.32 to 0.33)	0.87 (0.84 to 0.90)
Other Western	0.36 (0.35 to 0.37)	0.71 (0.69 to 0.73)
Dutch Antillean	0.26 (0.25 to 0.26)	0.34 (0.33 to 0.36)
Surinamese	0.29 (0.28 to 0.30)	0.39 (0.38 to 0.40)
Turkish	0.27 (0.26 to 0.27)	1.07 (1.04 to 1.10)
Moroccan	0.21 (0.20 to 0.22)	0.78 (0.76 to 0.81)
Other non-Western	0.31 (0.30 to 0.32)	0.56 (0.54 to 0.57)
Sub-Saharan African§	0.27 (0.26 to 0.28)	0.51 (0.48 to 0.53)
Cape Verdean	0.20 (0.19 to 0.21)	0.66 (0.63 to 0.70)
Education level (imputed)¶		
Low	REF	REF
Middle	0.99 (0.98 to 0.99)	0.98 (0.97 to 0.98)
High	0.96 (0.95 to 0.97)	1.00 (0.98 to 1.01) ■
Area		
Degree of urbanisation		
Very high (≥2500 addresses/km^2)	REF	REF
Other (<2500 addresses/km^2)	20.96 (20.8 to 21.1)	9.03 (8.95 to 9.11)
Median household income		
Other (≥€22 200)	REF	REF
Lowest/lower middle (<€22 200)	0.12 (0.11 to 0.12)	0.33 (0.32 to 0.33)
Distance to closest general practice (in km)**		
<1	REF	REF
1 to 3	1.99 (1.97 to 2.00)	0.96 (0.95 to 0.97)
>3	3.13 (2.98 to 3.28)	1.98 (1.77 to 2.23)
Distance to SHC (in km)		
<5	REF	REF
5 to 10	7.14 (7.09 to 7.19)	2.00 (1.98 to 2.02)
>10	29.33 (29.05 to 29.71)	3.51 (3.46 to 3.56)

*Clusters are identified with two-step cluster analysis. Cluster 1 (high risk -high testing rate): n=1 187 499; cluster 2 (high risk - low testing rate): n=1 258 621. Individuals in cluster 3 (low) are excluded for this analysis.
†p<0.01 unless otherwise indicated: ■ not significant.
‡Migratory background was encoded according to the Statistics Netherlands' coding scheme. Western if at least one parent was born in another country in Europe (excluding Turkey), North America, Oceania, Indonesia or Japan. Non-Western when at least one parent was born in a country in Africa, Latin America or Asia (excluding Indonesia and Japan) or Turkey.
§Without Cape Verdean.
¶Multiple imputation via chained equations (MICE) using ten iterations of five multiple imputations. The International Standard Classification of Education was used as basis. Low: no education, elementary school, pre-vocational secondary education, senior general secondary education (first 3 out of 5 years), pre-university education (first 3 out of 6 years), secondary vocational education level 1. Middle: senior general secondary education (last 2 out of 5 years), pre-university education (last 3 out of 6 years), secondary vocational education level 2 to 4. High: university of applied sciences, university.
**Based on address of residential location. Other area characteristics are based on the four-digit postal code of residential location.
km, kilometre; REF, reference; SHC, sexual health centre.

in a high R-low TR area, in particular, Dutch Antilleans (OR: 0.34; 95% CI 0.33 to 0.36) and Surinamese (OR: 0.39; 95% CI 0.38 to 0.40). In a sensitivity analysis with area STI positivity in quartiles (based on those tested) as an extra determinant, all associations remained similar (not shown). STI positivity itself had no clear association with living in a high R-low TR area. Compared with people in quartile 1 areas (STI positivity 0.0%–15.4%), people living in quartile 2 (15.4%–17.6%) and quartile 3 areas (17.6%–19.2%) were less likely to live in a high R-low TR area (OR of 0.61 and 0.65), while people in quartile 4 (19.2%–30.4%) were somewhat more likely to live in these areas (OR: 1.19; 95% CI 1.18 to 1.20).

DISCUSSION

In this cross-sectional, population-based register study, we found large spatial differences in STI testing, positivity and risk in greater Rotterdam, with the highest rates generally observed in urban areas. We identified three clusters of PC areas based on area-specific risk score and STI testing rates (high R-high TR, high R-low TR, low). Although the community STI risk levels of high R-high

TR and high R-low TR areas were similar, the testing rates differed greatly (75.8 vs 33.2 per 1000 residents). Compared with residents from high R-high TR areas, residents from high R-low TR areas had more often a non-migratory background and tended to come from less urbanised, less well-off areas and lived further away from GP and SHC.

We found considerable geographical differences in testing rates, even between areas where the resident populations had comparable STI risk and positivity. For area-specific prevention programmes and to optimise resource allocation, we think it is imperative to account for area-specific STI testing rates. Other studies suggest that areas with elevated STI positivity, cases or key populations ('clusters') might benefit from targeted STI service allocation.[20] A limited number of studies investigated spatial differences in STI testing on population level. A Dutch study found large nationwide differences in STI testing in the general population,[1] but no studies investigated differences in STI testing at a smaller geographical level. Although testing rates may not be directly associated with area-specific positivity, it is likely that it drives the relative number of observed cases, for example, as observed by a study on pertussis.[21] Provision of local programmes based on elevated case numbers only may be insufficient, especially when resources are limited. The finding that testing rates differ between areas, despite comparable STI risk levels, seems to indicate that it is appropriate to consider (also) testing rates and to initiate or expand additional interventions in areas with lower test rates.

For insight into appropriate interventions, we were especially interested in differences between areas with comparable community STI risk but that had different testing rates (high 75.8/1000 residents vs low 33.2/1000 residents). Compared with areas with high testing rates, low testing rate areas with comparable risk were less urbanised and residents lived further away from GP and SHC, implying reduced accessibility to testing services. These results correspond with the previous literature.[22 23] In addition to physical accessibility, people living in less urbanised areas may also be less likely to seek sexual healthcare themselves because of barriers such as lack of anonymity, social stigma and privacy concerns.[24 25] Also, healthcare providers in rural areas may contribute to lower testing rates because they are less likely to offer an STI test.[26 27] Educational training, including information about STI testing guidelines and local STI testing practices, could motivate and increase STI test provision by the GP.[28–30] Apart from migratory background, individual factors (sex, age, education level) had a minor effect. This may be explained by relatively small geographical differences for these individual factors within the area.

Strengths and limitations

A major strength of this study is the design, linking all residents with STI testing data from the main sexual healthcare providers within one geographical area, closely mirroring reality. Herewith, we clearly demonstrate a novel and objective method, without recall or registration bias as may be the case with questionnaires or sentinel databases. This design and method can be repeated in other regions or countries with multiple providers and access to population microdata. In addition, this is the first study that considers the underlying STI risk at community level while examining determinants associated with different STI testing levels. We found several factors associated with low testing rate areas such as longer distance to testing sites, which would allow for more targeted local interventions.

Our study also has some limitations. First, the usage of administrative PC units to distinguish areas with different STI testing and risk levels may not exactly differentiate social characteristics or health status. Another level of aggregation may provide a different distribution and the results of the regression analysis might differ. More precise measures, such as street-level addresses, limit the arbitrariness of administrative boundaries but may violate privacy. Therefore, we analysed our data at the smallest possible spatial scale that is relevant for healthcare providers and policymakers in our study area. Our results may not be generalisable to other areas. Second, the identified clusters consist of up to 100 PC areas, which could largely differ in underlying risk, for example, a PC area may be designated as high risk due to a high proportion of youngsters, while another due to a high proportion of migrants. Third, we calculated community STI risk scores, but we realise that this is not the same as individual STI risk and that STI risk depend on more than age, migratory background, education level and urbanisation. We possibly also missed associations with testing or could not account for them because information was not available at population level. Sexual behaviour is, in this respect, probably the most important factor, for example, MSM are advised to test regularly.[31] However, factors such as sexual behaviour, partner selection and sociocultural determinants that are (partly) affected by residential area were indirectly included in the analyses by accounting for area characteristics.[9–13 32] Fourth, we only had GP testing data from one laboratory. Although the estimated data coverage was high and we corrected our aggregated analyses for incomplete data, it is still possible that people tested at GPs that use this laboratory differ from people tested at GPs that use another laboratory for diagnostics. Finally, we suggest that additional interventions should be implemented in low testing rate areas, but it remains unknown whether the current rates are sufficient in high testing rate areas. Additional research is required to fully understand whether people with high STI risk are reached and whether there may be self-selection among higher risk individuals in low testing rate areas. Qualitative research could help to further elucidate this and provide more insight into the underlying reasons for suboptimal testing in our region. Previous research shows that testing is hampered for different reasons, including lack of trust in healthcare providers or authorities, fear of stigma and judgement and underestimating risk.[26 33–35] Some of these

barriers may be even greater for certain groups such as migrants and sex workers.

CONCLUSIONS

We are confident that our approach provides an objective and practical method to identify characteristics that distinguish areas with high risk and high testing rates from areas with high risk and low testing rates. Although there is substantial literature on STI testing and its associated risk factors, local analyses using data from multiple providers combined with population data may help to target available (financial) resources more efficiently. Population-based estimates of MSM would be a valuable addition to the study design in future research. Further actions could include a proof-of-principle intervention, targeting PC areas with low testing rates, to investigate whether persons with high STI risk can be reached by increasing test volumes in these areas. Interventions that could be considered, to overcome challenges such as long distances to specialised STI care, include opening a local SHC branch location or working with mobile clinics. Additional localised qualitative research can increase understanding of reasons for not visiting (traditional) testing services. Increasing knowledge and awareness about current differences in local STI testing practices through continued medical education can be valuable to motivate GPs, especially in rural areas, to offer STI tests.

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Ethics approval To ensure data confidentiality and safety, a third trusted party (Statistics Netherlands) was involved in the provision of a pseudonymised version of the data. The research design was audited on General Data Protection Regulation compliance (art 9.2.j & art. 89) and the Statistics Netherlands reviewed and approved the usage of their data for our study purposes (no. 8871). All data and analysis results were checked on identifiability of individuals by an independent employee of the Statistics Netherlands before releasing results for publication. No other formal ethical assessment and approval was needed under prevailing laws in the Netherlands as this study used retrospective data originated from standard care and were analysed anonymously (Medial Research Involving Human Subjects Act [https://wetten.overheid.nl/BWBR0009408/2022-01-31] and Dutch General Data Protection Regulation Implementation Act [https://wetten.overheid.nl/BWBR0040940/2021-07-01]).

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Data availability statement Data are available upon reasonable request. Data may be obtained from a third party and are not publicly available. This study used non-public microdata from Statistics Netherlands. Statistics Netherlands prohibits data sharing to guarantee the anonymity of the individuals in its databases. The datasets are generated and analysed in a secured environment of Statistics Netherlands and are not publicly available. STI testing data (de-identified and aggregated) and analysis scripts are available upon reasonable request from the corresponding author. Under certain conditions, non-public population microdata are accessible for statistical and scientific research by authorised institutions at Statistics Netherlands (fees apply). Procedures can be found at https://www.cbs.nl/; for further information, email microdata@cbs.nl.

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