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# Nationwide bowel cancer screening programme in England: cohort study of lifestyle factors affecting participation and outcomes in women

R G Blanks*[,1], V S Benson[1], R Alison[1], A Brown[1], G K Reeves[1], V Beral[1], J Patnick[1,2] and J Green[1]

[1]*Cancer Epidemiology Unit, Nuffield Department of Population Health, University of Oxford, Oxford, UK and* [2]*NHS Cancer Screening Programmes, Public Health England, Fulwood House, Old Fulwood Road, Sheffield S10 3TH, UK*

**Background:** In 2006, the National Health Service Bowel Cancer Screening Programme in England (NHSBCSP) began offering routine population-based biennial faecal occult blood testing (FOBt) at ages 60–69. There is, however, limited information on how characteristics of individuals affect participation and outcomes of screening, and we studied this association by linking NHSBCSP data to a large prospective cohort of women.

**Methods:** Electronic linkage of the NHSBCSP and Million Women Study records identified 899 166 women in the study cohort with at least one invitation for screening. NHSBCSP provided information on screening acceptance, FOBt results, screen-detected colorectal cancer and other outcomes. The Million Women Study provided prospectively collected information on personal and lifestyle factors. Multiple regression was used to estimate relative risks (RRs) of factors associated with acceptance and outcomes of screening.

**Results:** Overall, 70% of women (628 976/899 166) accepted their first invitation for bowel cancer screening, of whom 9133 (1.5%) were FOBt-positive, 743 (0.1%) had screen-detected colorectal cancer and 3056 (0.5%) had screen-detected colorectal adenoma. Acceptance was lower in women from the most than the least deprived tertile, in South Asians and in Blacks than in Whites, in current than in never smokers and in obese than in normal weight women: adjusted RRs (95% confidence interval) for acceptance *vs* not, 0.90 (0.90–0.90); 0.77 (0.75–79); 0.94 (0.92–0.96); 0.78 (0.77–0.78); and 0.88 (0.88–0.89), respectively: $P<0.001$ for each. These factors were also associated with an increased risk of being FOBt-positive and of having screen-detected adenoma, but were not strongly associated with the risk of screen-detected colorectal cancer. Relative risks for screen-detected adenoma were 1.22 (1.12–1.34), 2.46 (1.75–3.45), 1.61 (1.05–2.48), 1.53 (1.38–1.68) and 1.77 (1.60–1.95), respectively ($P<0.001$ for all, except for Blacks *vs* Whites $P=0.03$). Use of hormone therapy for menopause was associated with reduced risk of screen-detected adenoma, RR ever *vs* never use, 0.87 (0.81–0.93), $P<0.001$ and colorectal cancer, 0.78 (0.68–0.91), $P=0.001$.

**Interpretation:** Among women in England, socioeconomic and lifestyle factors strongly affect participation in routine bowel cancer screening, risk of being FOBt-positive and risk of having screen-detected colorectal adenoma. However, screen-detected colorectal cancer risk is not strongly related to these factors.

In 2006, a population-based nationwide organised screening programme, the National Health Service Bowel Cancer Screening Programme (NHSBCSP), began offering those aged 60–69 years routine biennial faecal occult blood testing (FOBt), with follow-up diagnostic testing for those positive for FOBt (www.cancerscreening.nhs.uk/bowel). Acceptance of bowel cancer screening in the

*Correspondence: Dr R Blanks; E-mail: roger.blanks@ceu.ox.ac.uk

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NHSBCSP has been shown to increase with age, to be greater in women than in men and to be lower in populations more deprived than the average (von Wagner *et al*, 2011; Lo *et al*, 2014). Existing studies have largely used routinely collected screening data, with limited information on individual characteristics of the invited or screened population other than age, sex and residence. Little is known about how other characteristics of individuals affect participation in bowel screening, or how lifestyle and other factors affect FOBt positivity and the risk of having screen-detected colorectal cancer. Recent reviews point out that despite evidence, recommendations and availability of screening tests, uptake for screening is disappointingly low (The Lancet, 2014).

Linkage of the NHSBCSP and an ongoing large population-based UK cohort, the Million Women Study, offers the opportunity to study individual lifestyle factors affecting participation and outcomes of routine bowel cancer screening. Here we investigate the associations between prospectively collected personal characteristics and screening acceptance, FOBt positivity and the risk of screen-detected colorectal cancer and adenoma.

## MATERIALS AND METHODS

The NHSBCSP collects individual data on invitations, acceptance and FOBt results. For those who are FOBt-positive, findings of further investigations are also recorded by the NHSBCSP. In 2006–2010, the NHSBCSP sent biennial invitation letters to men and women aged 60–69 years who were registered with the National Health Service (NHS) (after 2010 the age range was extended to 60–74). About 2 weeks after the invitation letter, a FOBt kit is sent by mail, with instructions on how to use the kit, and return it to the screening programme. Those who test FOB-positive are invited for further diagnostic tests, which can include colonoscopy (the default test, used for the great majority), flexible sigmoidoscopy and radiological investigations. Outcomes for these analyses are as follows: uptake (acceptance) of screening (defined in the screening programme as a record of a completed FOBt within 13 weeks of invitation); FOBt positivity; completion of a diagnostic test following screening; and diagnosis of screen-detected colorectal adenoma or invasive cancer.

The Million Women Study cohort includes 1.2 million women from England recruited in 1996–2001 through NHS breast screening clinics. Women completed a questionnaire about sociodemographic, medical and lifestyle factors, and provided signed consent for linkage to their medical records. The study has ethical approval from Oxford and Anglia Multi-Centre Research Ethics Committee (now Cambridge South Research Ethics Committee). Details of the study design have been published (Million Women Study Collaborative Group, 1999 and 2003) and questionnaires can be viewed at www.millionwomenstudy.org.

**Population available for the linkage study.** The 1.2 million women from England taking part in the Million Women Study were aged between 55 and 74 years (average 64 years) in 2006, when the NHS began to roll out the bowel-screening programme across the country. Those women in the Million Women Study in the target age group of 60–69 (60–74 after 2010) at or after the start of the bowel-screening programme in their residential area will have received such an invitation, and have a record in the bowel-screening system; they form the population eligible for data linkage and subsequent analysis. In this study only the first invitation to bowel screening for each individual is considered.

**Data linkage.** Electronic linkage was performed in 2013 by NHS Connecting for Health (now part of the Health and Social Care Information Centre), using NHS number and date of birth of Million Women Study participants recruited in England, provided by the study investigators. Detailed information on those who had been invited to screening by the NHSBCSP was then sent to the Million Women Study investigators, and linked for analysis with prospectively collected personal characteristics recorded in study participants. Approval for linkage was given by the Cambridge South Research Ethics Committee and by the NHS Bowel Cancer Screening Programme Research Committee.

**Statistical analysis.** All analyses refer to the first invitation sent by NHSBCSP. Multiple regression methods were used. To study factors associated with acceptance of screening, we calculated adjusted risk ratios, referred to here as relative risks (RRs), and 95% confidence intervals (CIs) for acceptance (that is, returning a completed FOB test kit) *vs* not (mostly by not returning a completed FOBt kit, but sometimes by declining to participate after receiving the initial letter of invitation). For study factors associated with FOBt positivity, with undergoing subsequent diagnostic testing and with clinical diagnoses we calculated adjusted RRs and 95% CIs among those who returned a completed FOBt kit; had a positive FOB test result; or had undergone diagnostic testing, as appropriate.

Analyses were adjusted as appropriate by socioeconomic status (tertiles of the Townsend deprivation index (Townsend *et al*, 1988), ethnicity (White, Black and South Asian), smoking status (never, past and current), body mass index (BMI; $<25$, 25–29.9, $30+$ kg m$^{-2}$), parity (nulliparous and parous), past use of oral contraceptives (never and ever), use of hormone therapy (HT) for the menopause (never and ever), strenuous exercise ($<1$, $1+$ times per week), alcohol intake ($<20$ g, $\geqslant 20$ g per week), region of residence, age at invitation ($<61.9$, 62–63.9, 64–65.9, 66–67.9 and $68+$ years) and year of birth (1930–1944 and 1945–1959). Women with missing values for any of the adjustment variables ($<2\%$ in all categories other than ethnicity, which was unknown for 9% of women invited to screening) were assigned to a separate category for that variable. Information on variables was as reported at the Million Women Study recruitment except for ethnicity, which was derived from the ethnic group self-reported by women responding to a resurvey questionnaire sent $\sim 3$ years after recruitment, and/or ethnicity as recorded for hospital admissions, as previously described (Gathani *et al*, 2014). Scores for the Townsend Index of Deprivation were assigned by postcode at recruitment according to Enumeration District (ED) of the 1991 Census; EDs contain on average some 200 households/500 people, and are the smallest available area for which a measure of deprivation is available in England (http://www.ons.gov.uk/ons/guide-method/census/census-2001/glossary/a—g/index.html).

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## RESULTS

A total of 899 166 Million Women Study participants received at least one invitation from the NHSBSP for screening. We report results for the first invitation to screening only. Invited women had been sent their first invitation for routine bowel cancer screening between 7 December 2006 and 28 March 2012. Their mean age at first invitation was 65.3 (s.d. 3.6) years. Of the 899 166 women invited, 628 976 (70%) accepted the invitation by completing an FOB test. Of the 270 190 women who did not accept, 17 851 declined to receive a FOBt kit after the initial invitation letter, 250 748 were sent a kit but did not return it and 1591 returned at least one kit but did not complete the process (spoilt kit, technical failure, failure to respond to further kits and did not complete the process for other reason). Characteristics of the women who accepted or did not accept bowel cancer screening are shown in Table 1; and Table 2 shows adjusted RRs for acceptance of bowel cancer screening *vs* nonacceptance. Acceptance was significantly

**Table 1. Characteristics of Million Women Study participants by acceptance of first invitation for screening by the NHS Bowel Cancer Screening Programme in England**

| | Bowel-screening accepted (*N* = 628 976) | Bowel-screening not accepted (*N* = 270 190) | Total invited for screening (*N* = 899 166) |
|---|---|---|---|
| Mean age at first invitation to bowel screening, years (s.d.) | 65.2 (3.6) | 65.3 (3.8) | 65.3 (3.6) |
| Socioeconomic group (% in upper third) | 36 | 28 | 33 |
| Current smoker, % | 17 | 31 | 21 |
| Body mass index $\geqslant 30\,kg\,m^{-2}$, % | 16 | 22 | 18 |
| Ever had full-term pregnancy, % | 90 | 89 | 90 |
| Ever used oral contraceptives, % | 66 | 62 | 65 |
| Ever used HT, % | 55 | 50 | 53 |
| Strenuous physical activity $\geqslant 1$ times per week, % | 42 | 35 | 40 |
| Alcohol intake $\geqslant 20\,g$ per week, % | 49 | 42 | 47 |

Abbreviation: HT = hormone therapy for menopause.

**Table 2. Adjusted[a] RRs and 95% CIs for acceptance of screening in 899 166 women invited to bowel cancer screening**

| | *n* Cases accepted/invited | RR (95% CI) |
|---|---|---|
| **Socioeconomic level (tertiles)** | | |
| Least deprived | 225 928/299 952 (75%) | 1.00 |
| Medium | 213 066/296 443 (72%) | 0.98 (0.97–0.98) |
| Most deprived | 185 246/296 097 (63%) | 0.90 (0.90–0.90) |
| **Ethnic group** | | |
| White | 571 645/800 958 (71%) | 1.00 |
| Black | 2234/3598 (62%) | 0.94 (0.92–0.96) |
| South Asian | 2783/5375 (52%) | 0.77 (0.75–0.79) |
| **Smoking status** | | |
| Never | 319 603/430 627 (74%) | 1.00 |
| Past | 176 156/240 928 (73%) | 0.98 (0.98–0.98) |
| Current | 99 159/176 939 (56%) | 0.78 (0.77–0.78) |
| **Body mass index ($kg\,m^{-2}$)** | | |
| <25 | 294 937/402 658 (73%) | 1.00 |
| 25–29 | 211 025/300 104 (70%) | 0.97 (0.96–0.97) |
| 30+ | 95 471/151 090 (63%) | 0.88 (0.88–0.89) |
| **Full-term pregnancy** | | |
| Never | 64 403/94 204 (68%) | 1.00 |
| Ever | 563 797/803 588 (70%) | 1.04 (1.03–1.04) |
| **Oral contraceptive use** | | |
| Never | 212 320/312 617 (68%) | 1.00 |
| Ever | 411 766/578 068 (71%) | 1.02 (1.02–1.02) |
| **HT use** | | |
| Never | 281 419/415 220 (68%) | 1.00 |
| Ever | 341 919/474 460 (72%) | 1.04 (1.04–1.05) |
| **Strenuous exercise** | | |
| <1 Per week | 353 722/522 151 (68%) | 1.00 |
| 1+ Per week | 257 287/346 552 (74%) | 1.04 (1.04–1.04) |
| **Alcohol (g per week )** | | |
| <20 | 321 029/474 789 (68%) | 1.00 |
| 20+ | 304 526/418 087 (73%) | 1.04 (1.03–1.04) |
| **Region** | | |
| South | 302 043/428 801 (70%) | 1.00 |
| Midlands | 141 596/198 368 (71%) | 1.03 (1.02–1.03) |
| North | 185 337/271 997 (68%) | 0.99 (0.99–0.99) |

Abbreviations: CI = confidence interval; HT = hormone therapy for menopause; RR = relative risk.
[a]Adjusted by age at invitation and calendar year categories, and all other factors listed above as appropriate.

($P<0.001$) lower in women from the most deprived than the least deprived tertile of the population, RR 0.90, (95% CI 0.90–0.90); in South Asian and in Black than White women: RRs 0.77 (95% CI 0.75–0.79) and 0.94 (95% CI 0.92–0.96), respectively; in current than never smokers, 0.78 (95% CI 0.77–0.78); and in obese women than those with a normal BMI, 0.88 (95% CI 0.88–0.89). Acceptance was slightly higher in parous women and in those who reported more frequent strenuous physical activity, drank more alcohol and had used HT for menopause.

Table 3 summarises the outcome of the screening FOBt in those who accepted. Of the 628 976 women who completed the FOB test, 9133 (1.5%) had a positive FOBt result and were referred for further diagnostic tests. Most of those referred attended for diagnostic testing (87%; 7911 out of 9133), and diagnostic test results were recorded for all but 17 women. Colonoscopy was the sole diagnostic test in 91% of those tested. Colorectal cancer was diagnosed in 743 women (0.1% of all women screened, 8% of those who were FOBt-positive and 9% of those who had a diagnostic test) and 3056 were diagnosed with colorectal adenoma (0.5% of all women screened, 33% of those who were FOBt-positive and 39% of those who completed a diagnostic test). Only 13 women with colorectal cancer also had reported screen-detected adenoma, and they are included just in analyses relating to cancer. Of those who had a diagnostic test result, 2214 (28%) had only a condition other than neoplasia recorded; the most common specific other diagnoses were diverticular disease and haemorrhoids. In almost a quarter of those who were FOBt-positive (1881, 24%), the diagnostic test record identified no abnormality.

Table 4 shows the RRs and 95% CIs for being FOBt-positive, and for having a diagnosis of colorectal cancer or colorectal adenoma, in those screened. FOBt positivity was most strongly associated with deprivation, Non-White ethnicity, smoking and obesity. These factors were also associated with an increased risk of having screen-detected adenoma. Relative risks in the most *vs* least deprived tertile, South Asian and Black *vs* White ethnicity, current *vs* never smokers and obese *vs* not, for screen-detected adenoma were 1.22 (1.12–1.34), 2.46 (1.75–3.45), 1.61 (1.05–2.48), 1.53 (1.38–1.68) and 1.77 (1.60–1.95), respectively. Being physically active, parous and having used menopausal HT were associated with small reductions in the risk of having a screen-detected adenoma.

Risk factors for screen-detected colorectal cancer were often not the same as for screen-detected adenoma. There was no significant association with deprivation, smoking or obesity (numbers in subgroups by ethnicity were too small to allow reliable analysis). The only statistically significant association was a decreased risk associated with ever use of menopausal HT: RR 0.78 (0.68–0.91), $P = 0.001$.

The 13% of women (1222 out of 9133) who were FOBt-positive but had no further diagnostic tests within the screening programme were more likely than those who had diagnostic tests to be current smokers or of South Asian ethnicity (Table 5). Some of these women are known to have refused further tests; however, for over half, the reason for not having diagnostic tests is not

**Table 3. Outcome of screening (FOBt) and diagnostic tests for 628 976 women who accepted bowel cancer screening**

| Bowel-screening outcome | Number of women (%) |
|---|---|
| **Screening test outcome** | |
| FOBt-positive | 9133 |
| FOBt-negative | 619 843 |
| **Attendance for further investigations of 9133 who were FOBt-positive** | |
| Attended for diagnostic test | 7911 |
| Did not attend diagnostic test | 1222 |
| **Diagnostic test results for 7911 who attended for further investigation** | |
| Colorectal cancer | 743 |
| Colorectal adenoma | 3056 |
| Non-neoplastic condition only* | 2214 |
| No abnormality recorded | 1881 |
| No result from diagnostic tests | 17 |

Abbreviation: FOBt = faecal occult blood testing. *That is, recorded abnormalities other than cancer or adenoma; includes diverticular disease, haemorrhoids, inflammatory bowel disease, and so on.

recorded in the NHS Bowel Cancer Screening Programme database.

## DISCUSSION

Our results illustrate the potential of using linked routinely collected and cohort study data in investigating associations between lifestyle factors and participation in a national cancer-screening programme. Women who were obese, current smokers, of non-White ethnicity and from more deprived areas were less likely to take part in bowel cancer screening in England; these factors were also associated with an increased risk of FOBt positivity and of having screen-detected colorectal adenoma, but not of screen-detected colorectal cancer.

While not strongly related to acceptance or FOBt positivity, ever use of menopausal HT was associated with a decreased risk of adenoma and of colorectal cancer.

Our findings for factors affecting participation in bowel cancer screening add to the evidence currently available. Studies of

**Table 4. Adjusted[a] RRs and 95% CIs for FOBt-positive result and screen-detected colorectal cancer and adenoma in screened women**

| | FOBt positive ($N = 9133$) | | Colorectal cancer ($N = 743$) | | Colorectal adenoma ($N = 3056$) | |
|---|---|---|---|---|---|---|
| | *n* cases | RR (95% CI) | *n* cases | RR (95% CI) | *n* cases | RR (95% CI) |
| **Socioeconomic level (tertiles)** | | | | | | |
| Least deprived | 2840 | 1.00 | 274 | 1.00 | 943 | 1.00 |
| Medium | 3028 | 1.08 (1.03–1.14) | 237 | 0.90 (0.75–1.07) | 1028 | 1.11 (1.01–1.21) |
| Most deprived | 3202 | 1.21 (1.14–1.27) | 229 | 0.98 (0.82–1.17) | 1067 | 1.22 (1.12–1.34) |
| **Ethnic group** | | | | | | |
| White | 8595 | 1.00 | 722 | 1.00 | 2910 | 1.00 |
| Black | 75 | 1.86 (1.49–2.33) | 3 | Insufficient data | 21 | 1.61 (1.06–2.49) |
| South Asian | 149 | 3.45 (2.94–4.05) | 2 | Insufficient data | 34 | 2.49 (1.74–3.50) |
| **Smoking status** | | | | | | |
| Never | 4216 | 1.00 | 367 | 1.00 | 1364 | 1.00 |
| Past | 2744 | 1.16 (1.11–1.22) | 231 | 1.15 (0.97–1.35) | 907 | 1.18 (1.09–1.29) |
| Current | 1649 | 1.29 (1.22–1.37) | 110 | 1.03 (0.83–1.28) | 621 | 1.53 (1.38–1.68) |
| **Body mass index (kg m$^{-2}$)** | | | | | | |
| <25 | 3292 | 1.00 | 312 | 1.00 | 1120 | 1.00 |
| 25–29 | 3164 | 1.31 (1.24–1.37) | 261 | 1.12 (0.95–1.33) | 1124 | 1.37 (1.26–1.49) |
| 30+ | 2172 | 1.93 (1.83–2.04) | 130 | 1.22 (0.99–1.50) | 665 | 1.77 (1.61–1.95) |
| **Full-term pregnancy** | | | | | | |
| Never | 1014 | 1.00 | 86 | 1.00 | 356 | 1.00 |
| Ever | 8105 | 0.88 (0.82–0.93) | 654 | 0.85 (0.68–1.07) | 2698 | 0.84 (0.75–0.94) |
| **Oral contraceptive use** | | | | | | |
| Never | 3290 | 1.00 | 280 | 1.00 | 1159 | 1.00 |
| Ever | 5741 | 0.99 (0.95–1.04) | 445 | 1.02 (0.87–1.19) | 1875 | 0.93 (0.86–1.01) |
| **HT use** | | | | | | |
| Never | 3983 | 1.00 | 367 | 1.00 | 1442 | 1.00 |
| Ever | 5049 | 1.02 (0.98–1.06) | 369 | 0.78 (0.68–0.91) | 1583 | 0.87 (0.81–0.93) |
| **Strenuous exercise (per week)** | | | | | | |
| <1 | 5542 | 1.00 | 448 | 1.00 | 1850 | 1.00 |
| 1+ | 3241 | 0.89 (0.85–0.93) | 276 | 0.87 (0.74–1.01) | 1099 | 0.89 (0.83–0.96) |
| **Alcohol (g per week)** | | | | | | |
| <20 | 4885 | 1.00 | 381 | 1.00 | 1550 | 1.00 |
| 20+ | 4170 | 1.01 (0.97–1.05) | 353 | 1.05 (0.91–1.22) | 1484 | 1.13 (1.05–1.22) |
| **Region** | | | | | | |
| South | 4550 | 1.00 | 360 | 1.00 | 1526 | 1.00 |
| Midlands | 2007 | 0.92 (0.87–0.97) | 175 | 1.03 (0.86–1.23) | 634 | 0.86 (0.78–0.94) |
| North | 2576 | 0.92 (0.87–0.96) | 208 | 0.97 (0.82–1.16) | 896 | 0.94 (0.86–1.02) |

Abbreviations: CI = confidence interval; FOBt = faecal occult blood testing; HT = hormone therapy for menopause; RR = relative risk.
[a]Adjusted for age at invitation and calendar year categories, and all other factors listed above as appropriate.

**Table 5. Adjusted[a] RRs and 95% CIs for acceptance of diagnostic test in 9133 women with positive FOBt**

| | *n* cases accepted/invited | RR (95% CI) |
|---|---|---|
| | 7911/9133 (87%) | |
| **Socioeconomic level (tertiles)** | | |
| Least deprived | 2484/2840 (88%) | 1.00 |
| Medium | 2640/3028 (87%) | 1.00 (0.98–1.02) |
| Most deprived | 2735/3202 (85%) | 0.99 (0.97–1.01) |
| **Ethnic group** | | |
| White | 7483/8595 (87%) | 1.00 |
| Black | 66/75 (88%) | 1.01 (0.93–1.10) |
| South Asian | 120/149 (81%) | 0.93 (0.86–1.01) |
| **Smoking status** | | |
| Never | 3693/4216 (88%) | 1.00 |
| Past | 2377/2744 (87%) | 0.99 (0.97–1.00) |
| Current | 1391/1649 (84%) | 0.96(0.94–0.99) |
| **Body mass index (kg m$^{-2}$)** | | |
| <25 | 2848/3292 (87%) | 1.00 |
| 25–29 | 2777/3164 (88%) | 1.02 (0.99–1.04) |
| 30+ | 1856/2172 (86%) | 0.99 (0.97–1.01) |
| **Full-term pregnancy** | | |
| Never | 872/1014 (86%) | 1.00 |
| Ever | 7026/8105 (87%) | 1.01 (0.98–1.04) |
| **Oral contraceptive use** | | |
| Never | 2837/3290/ (86%) | 1.00 |
| Ever | 4984/5741 (87%) | 1.00 (0.98–1.02) |
| **HT use** | | |
| Never | 3448/3983 (87%) | 1.00 |
| Ever | 4374/5049 (87%) | 1.00 (0.98–1.02) |
| **Strenuous exercise (per week)** | | |
| <1 | 4764/5542 (86%) | 1.00 |
| 1+ | 2858/3241 (88%) | 1.02 (1.00–1.04) |
| **Alcohol (g per week)** | | |
| <20 | 4188/4885 (86%) | 1.00 |
| 20+ | 3657/4170 (88%) | 1.02 (1.01–1.04) |
| **Region** | | |
| South | 3949/4550 (87%) | 1.00 |
| Midlands | 1738/2007 (87%) | 1.00 (0.98–1.02) |
| North | 2224/2576 (86%) | 1.00 (0.97–1.03) |

Abbreviations: CI = confidence intervals; FOBt = faecal occult blood testing; HT = hormone therapy; RR = relative risks.
[a]Adjusted by age at invitation and calendar year categories, and all other factors listed above as appropriate.

population-level data from UK bowel-screening programmes have consistently found lower uptake of the FOB screening test among those living in more deprived and more ethnically diverse areas, in younger than in older people and in men than in women; in screening rounds later than the first, participation is also strongly linked to past screening history (Steele *et al*, 2010; von Wagner *et al*, 2011; Moss *et al*, 2012; Lo *et al*, 2014). Our findings are consistent with these studies and provide the first direct evidence on individual-level ethnic group and bowel cancer-screening uptake in the United Kingdom. Similar associations of age, sex and deprivation with nonparticipation have been reported for FOBt-based bowel cancer-screening programmes elsewhere in Europe (Frederikson *et al.*, 2010; Blom *et al*, 2014) and in Australia (Weber *et al*, 2008) and in relation to uptake of screening for other conditions (Moser *et al*, 2009; Lo *et al*, 2013).

Evidence on other characteristics related to uptake of FOBt is sparse; to our knowledge, ours is the first study to link prospectively collected information on individual lifestyle characteristics with data from a population-based screening programme. There is some evidence from case–control studies with retrospective ascertainment of individual characteristics that smokers are less likely than non-smokers to attend bowel cancer screening (Senore *et al*, 2010; van Dam *et al*, 2013); however, such studies are likely to be affected by response rate and recall biases. In a cross-sectional analysis of recruitment data reported by participants in the 45 and up Australian cohort, a recent history of FOBt screening was less common in current smokers, the obese and those with a sedentary lifestyle (Weber *et al*, 2008). Among women accepting screening, we found considerable variation in the risk of being FOBt-positive, with deprivation, Non-White ethnicity, smoking and obesity all associated with an increased risk. All of these factors were also associated with an increased risk of having screen-detected colorectal adenoma, but not of having screen-detected colorectal cancer. The risk of screen-detected colorectal cancer was reduced in ever users of menopausal hormones and in women who were physically active. This echoes findings from epidemiological studies of colorectal cancer (Green *et al*, 2012; Robsahm *et al*, 2013); however, we cannot easily interpret our findings for screen-detected cancer in terms of aetiology, as in these analyses potential risk factors can be related to screening test uptake and performance, and hence to the likelihood of undergoing a diagnostic test, as well as to the risk of underlying disease. Our analyses were also limited by the relatively small number of cases of screen-detected cancer in some subgroups. The prospective collection of exposure data is a strength of this study; a potential limitation is that information on exposure variables was collected several years before the invitation to bowel cancer screening.

We found that among those with a positive FOB test, smokers and those of South Asian ethnicity were somewhat less likely to go on to have a diagnostic test (usually colonoscopy) within the screening programme. Little is known about who chooses not to pursue diagnostic testing after a positive screening test, and why. Population-level studies do not show much variation by age, sex or deprivation (Morris *et al*, 2012; Ferrat *et al*, 2013); for screening rounds later than the first, screening history is associated with uptake of colonoscopy (Ferrat *et al*, 2013; Lo *et al*, 2014). In this study 13% of those with a positive FOBt did not receive diagnostic testing within the screening programme; this is consistent with rates of non-uptake of colonoscopy of 10–20% reported for FOBt-based bowel-screening programmes in the United Kingdom (Morris *et al*, 2012; Moss *et al*, 2012; Lo *et al*, 2014) and elsewhere, including in randomised trials (Hewitson *et al*, 2008).

Uptake of bowel cancer screening in our study population (70%) was greater than that reported by the screening programme for all women in England (54%; Logan *et al*, 2012); this is not surprising, since Million Women Study participants were recruited via the NHS screening programme for breast cancer and would be expected to be more likely than average to take part in screening for other cancer types. It is however noteworthy, and consistent with other findings (Lo *et al*, 2013), that even among this group, almost a third of those invited did not participate in the bowel cancer-screening programme. The higher uptake of screening in this study compared with the general population is, however, unlikely to affect comparisons within the cohort of factors affecting uptake of screening or its outcomes. Of the women in our study who attended for diagnostic testing, some 9% were diagnosed with colorectal cancer, very similar to the national figure for women of 8%.

In summary, linkage of data from a large population-based bowel cancer-screening programme to prospectively collected personal data in a large cohort provides a powerful way of identifying factors associated with participation and outcomes of screening. Deprivation, South Asian and Black ethnicity, smoking and obesity were associated with reduced participation in the screening programme. These factors were also associated with an increased risk of being FOBt-positive and of having colorectal adenoma, but were not strong predictors of screen-detected colorectal cancer risk.

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## CONFLICT OF INTEREST

The authors declare no conflict of interest.

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