Title: Evaluating the impact of a very low-cost intervention to increase practices' engagement with data and change prescribing behaviour: a randomised trial in English Primary Care.

Running head: Increasing practices' engagement with data and changing prescribing behaviour

Article category: Health Service Research

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Key messages

- Audit-and-feedback can solicit modest changes in targeted clinical behaviour.
- There is a high cost barrier for one-off audit-and-feedback interventions.
- Open data platforms can provide a low-cost route for wide-scale audit-and-feedback.
- Our low cost intervention increased online dashboard use by almost 10%.
- Broad-spectrum antibiotic prescribing had a slight but non-significant improvement.
- Behavioural impact optimisation may have increased the effect on prescribing.

Abstract

Background: Unsolicited feedback can solicit changes in prescribing.

Objectives: Determine whether a low-cost intervention increases clinicians' engagement with data, and changes prescribing; with or without behavioural science techniques.

Methods: Randomised trial (ISRCTN86418238). The highest-prescribing practices in England for broad-spectrum antibiotics were allocated to: feedback with behavioural impact optimisation; plain feedback; or no intervention. Feedback was sent monthly for three months by letter, fax and email. Each included a link to a prescribing dashboard. The primary outcomes were: dashboard usage; and change in prescribing.

Results: 1401 practices were randomised: 356 behavioural optimisation, 347 plain feedback, 698 control. For the primary engagement outcome more intervention practices had their dashboards viewed compared to controls (65.7% versus 55.9%; RD 9.8%, 95% CI: 4.76% to 14.9%, p<0.001). More plain feedback practices had their dashboard viewed than behavioural feedback practices (69.1% vs 62.4%); but not meeting the p<0.05 threshold (6.8%, 95% CI: -0.19% to 13.8%, p=0.069). For the primary prescribing outcome, intervention practices possibly reduced broad-spectrum prescribing to a greater extent than controls (1.42% vs 1.12%); but again not meeting the p<0.05 threshold (coefficient -0.31%, CI: -0.7% to 0.1%, p=0.104). The behavioural impact group reduced broad spectrum prescribing to a greater extent than plain feedback practices (1.63% vs 1.20%; coefficient 0.41%, CI: 0.007% to 0.8%, p=0.046). No harms were detected.

Conclusions: Unsolicited feedback increased practices' engagement with data, with possible slightly reduced antibiotic prescribing (p=0.104). Behavioural science techniques gave greater prescribing effects. The modest effects on prescribing may reflect saturation from similar initiatives on antibiotic prescribing.

Key words

Anti-Bacterial Agents, Antimicrobial Stewardship, Feedback, General Practice, Information Dissemination, Information Seeking Behavior

Trial registration

ISRCTN, registered 03/05/2018 under ISRCTN86418238; http://www.isrctn.com/ISRCTN86418238. Recruitment start date 08/05/2018.

Introduction

There is wide variation in adherence to prescribing guidelines in English primary care[1]. "Audit and feedback" can have a modest impact[2]. However, there is no national monitoring system routinely alerting NHS practices to prescribing behaviours where they are an outlier, to instigate change where warranted. At the DataLab in Oxford, we run an openly accessible service presenting prescribing measures for every practice and clinical commissioning group (CCG) in England[3], with 130,000 users per year. Previous research suggests behavioural science techniques can augment the impact of audit and feedback[4,5]. However, studies typically compare a single design with usual care, leading to a lack of knowledge on how best to optimise them[6].

Antimicrobial stewardship is a critical public health issue to prevent resistant bacteria, with a national strategy led by the Chief Medical Officer, substantial expenditure and extensive research. Despite an overall reduction in antibiotic use in primary care over recent years, prescribing varies across the country[7]; and the NHS Long Term Plan states further progress is required[8]. Restricting broad-spectrum antibiotics is a key priority[9], as these should be reserved for "last resort" treatment, and are rarely indicated in primary care[10].

Using our existing infrastructure we set out to investigate the impact of a low-cost intervention to send practices tailored broad-spectrum antibiotic prescribing data feedback.The Behavioural Insights Team collaborated to optimise one version of our intervention. Our overall objective was to determine whether receipt of data feedback prompts practices to increase engagement with prescribing data, or change prescribing; and to evaluate the marginal benefit of behavioural science techniques.

Methods

Trial design

Randomised, controlled, parallel-group trial, registered prospectively[11]. Participants (general practices) were randomised to receive an intervention (one of two different variants) or no intervention. Interventions were a series of three data feedback communications sent May-July 2018 by fax, email and post. There were no substantial changes to methods after trial commencement; minor changes are described below.

Participants

Participants were NHS general practices in England[12]. Eligibility criteria, as at April 2018, were: standard general practices, with at least one method of contact (address/fax/email), with 'active' status, opened >=6 months before start of trial, >=1000 registered patients (with 10-85% aged 25-64); and, during the six-month baseline period (September 2017- February 2018), prescribing >=1000 total items/month, >=60 antibiotic items, in the highest 20% for broad-spectrum antibiotics as a proportion of all antibiotics (all established using datasets in OpenPrescribing.net; minor changes to inclusion criteria: Supplementary Note 1).

We obtained most contact details from: published addresses[12]; NHS Choices (automated web scrape); and FOI request (e.g. [13]; largely unsuccessful). Missing details were obtained commercially (474 emails, 57 faxes), for: practice managers (65%); otherwise a senior partner, other GP; or a generic practice email address (8.6%).

Randomisation

We identified practices, applied eligibility criteria and randomised, concurrently, using Python software[14]. Practices were allocated to "intervention" and "control" (1:1), block-randomised by

CCG. Intervention practices were further allocated to “behavioural impact” or “plain” feedback (1:1), block-randomised by CCG (Figure 1). Allocation was concealed: practices were automatically randomly assigned to each intervention group by computer software. Practices could not leave the trial. Participants were not informed that they were in a trial.

Interventions

The intervention consisted of short written feedback, sent on three occasions (“waves”), at 5-week intervals, highlighting the practice’s high antibiotic prescribing compared to other practices (e.g.s Supplementary material). The “Plain” interventions remained consistent, while the “Behavioural impact” interventions, optimised for engagement, varied by wave (Table S1; the third mentioned antibiotics and highlighted a cost-savings measure, tailored for each practice). Each intervention contained a prescribing data chart and a unique link. Upon accessing the link, practices were asked: “Did the message we sent give you new information about your prescribing? Yes/No”; before being redirected to their dashboard (e.g. Figure S1). Intervention templates were reviewed by practicing GPs (KM, CH) and pre-specified[11] with only minor modifications prior to commencement. Interventions were sent between 8/5/2018 and week beginning 16/7/2018, by email, fax, and letter, timed to arrive on the same day (see Supplementary Note 2).

Outcomes

Outcomes, detailed in Table S2, are described briefly below.

Engagement The baseline period was 15 weeks prior to first intervention, with follow-up (“intervention”) periods of 5 weeks following each wave (15 consecutive weeks total). Our primary outcome was the difference in the proportion of practices having their dashboard viewed during follow-up, for intervention versus control. A secondary outcome was the difference in mean dashboard views per practice. To assess behavioural optimisation, we compared the two intervention groups on: the above outcomes; proportion of links accessed; links accessed as a proportion of those opened (emails only); and questionnaire responses (Supplementary note 6). We compared links accessed for each medium of communication (email, fax, letter), plus emails opened, and exploratory analysis of browsing sessions. We additionally assessed: engagement for commercially obtained versus discoverable emails; link sharing (Supplementary Note 4b); and possible contamination. We summarised free-text responses.

Prescribing The baseline period for prescribing was Sept 2017-Feb 2018, follow-up Sept 2018-Feb 2019. Our primary outcome measure was the difference in proportion of antibiotics which were broad-spectrum, for intervention versus control, during follow-up, using multivariable linear regression. We estimated the overall effect on the number of broad-spectrum prescriptions. To assess wider impact, we measured three other national antibiotic prescribing measures (Table S2). We compared the primary and secondary outcomes between plain feedback and behavioural impact.

Data were analysed using Python scripts, (https://github.com/ebmdatalab/antibiotics-rct-analysis)[15], pre-specified[11] except where otherwise stated (minor changes described in Supplementary Note 3). History of analysis code is also available online[16,17].

Sample size

All practices in England meeting eligibility criteria (1,401) were included. An illustrative power calculation indicated 80% power to detect a difference of 0.53% on our primary prescribing outcome at 95% significance; and similarly a change of 7.42% on our primary engagement outcome, i.e. 52 out of 700 interventions leading to a dashboard view[11].

Data collection

Prescribing and practice characteristics data were from public sources[7,18], extracted using code[15]; dashboard usage data from Google Analytics (Supplementary Note 4). Questionnaire responses and free-text responses were recorded anonymously in spreadsheets.

Statistical analysis

Statistical analyses were prespecified[11] except where stated (minor changes, Supplementary Note 3). Full details online[15].

Engagement outcomes Primary and secondary outcomes measured as proportions are compared with confidence intervals (CIs) and chi-squared tests; except for proportion of links accessed by each method of contact, where a McNemar paired-sample test accounted for non-independence. A sensitivity analysis restricted to practices contacted by all three methods (e.g. practices with a discoverable fax number may be less responsive to email). Browsing sessions are explored by distribution and basic descriptive statistics. All other additional/subgroup analyses detailed in analytic code[15].

Prescribing outcomes Primary, secondary outcomes and subgroup analyses were compared using regression models, with baseline value and intervention group as dependent variables. For subgroup analyses and list size effects, these were included as additional dependent variables.

Results

Participant flow

We identified and randomised 1,401 practices immediately before trial commencement. 703

were allocated to the intervention group, without requiring opt-in (participant flow Figure 1). The trial ran to completion. Interventions were delivered to 99.3% of all 703 intervention practices; 98.2% by letter, 90.3% by fax and 90.6% by email (Table S3, Supplementary note 5).

Baseline characteristics

Intervention and control groups were broadly similar (Table 1), including broad-spectrum prescribing (mean 12.7% in each); but controls had slightly more single-handed practices (6.6% vs 5.4%) and fewer with at least one dashboard page view (56.4% vs 60.9%). Practices in the two intervention groups were similar except the behavioural impact group having relatively more small practices (9.4% vs 6.8%).

Dashboard engagement

Practice dashboard page views The intervention led to more practices viewing their dashboard at least once (65.7% vs 55.9%; difference in proportion 9.8%; 95% CI: 4.76% to 14.9%, χ^2=13.8, p<0.001; Table 2). Dashboards for intervention practices were viewed 1.51 times each on average during the intervention period, up 0.24 from baseline (1.75), compared to a reduction of 0.02 for the control group (1.44 to 1.42). Regression analysis indicated significance at p<0.005 (Table S4, not pre-specified). Plain feedback led to more practices viewing their dashboard at least once than the behavioural intervention, but not significant at p<=0.05 (69.1% vs 62.4%; difference in proportion 6.8%, 95% CI: -0.19% to 13.8%; χ^2=3.32, p=0.069; Table 2). There was no significant difference between the two arms in the change from baseline in the number of times practices viewed their dashboard (1.40 to 1.66 vs 1.63 to 1.84, p=0.67, Table S4).

Links accessed

Each communication contained a unique link to the practice's dashboard. Overall, 215 links were accessed for 178 practices, 25.3% of those contacted. 101 practices (14.4%) accessed a link in wave 1, 32 of which had not viewed their dashboard during the baseline period (Figure 2, Table S3). There was little difference in link access between behavioural impact (93/356, 26.1%) versus plain feedback (85/347, 24.5%). The most effective medium was email, with 64 links accessed in wave 1, 9.4% of the 680 emails delivered (41% of 155 emails opened), compared to 26 from letters (3.7%) and 19 from faxes (2.9%) (Figure 2, Table S3; McNemar paired sample tests for email vs fax and email vs post p<0.001, Table S5). However, commercially-obtained email addresses had an access rate of 18.1% (86/474), versus 10.9% (23/211) for publically discoverable email addresses (difference in proportion 7.2%; 95% CI: 1.8% to 12.7%, χ^2=5.2, p=0.0226; not pre-specified). Links from emails were accessed most often, mean 3.6 views each, median 3 (IQR 1-4), versus letters (mean 3.2, median 2, IQR 1-4) and faxes (mean 2.3, median 2, IQR 1-3; not pre-specified). Participants typing links from faxes tended to browse for longest, median 35min (IQR 0-102.75), versus 30min for letters (IQR 8.25-67.75) and 23min (IQR 0-78.50) for emails (not pre-specified).

Link sharing and contamination We did not find evidence of extensive link sharing: 72.9% (78) wave 1 links were accessed by a single user, and 18.7% (20) by two different users. Only three control practices had dashboard views following a link being clicked (either from intervention practices looking at others, or link sharing).

Questionnaire responses There were 172 responses to "Did the message we sent give you new information about your prescribing?" (24.5% of intervention practices); 70.3% "yes" (121/172; Table S6). The proportion saying "yes" was similar for behavioural impact and plain feedback

(68.9% vs 72.0%). Those saying "yes" were less likely to have used their dashboard in the baseline period (59.5% vs 70.6%), and less likely to click through to their dashboard from the landing page (80.2% vs 86.3%, Table S7).

Prescribing behaviour

Primary Prescribing Outcome Sixteen practices with no antibiotic prescribing during the follow-up period were excluded from analysis as planned. The primary outcome, the mean proportion of antibiotics which were broad-spectrum, reduced by 1.42% for the intervention group (from 12.67% at baseline to 11.25% during follow-up), compared to 1.12% for controls (from 12.71% to 11.59%; Figure 3a), representing a reduction of approximately 3,500 (2.1%) more broad-spectrum prescriptions. However, our regression model indicated this was not statistically significant at $p<0.05$ (coefficient -0.31%, CI: -0.7% to 0.1%, $p=0.104$; Table S8). The behavioural impact group reduced their broad spectrum prescribing by 1.63% (12.70% to 11.07%), compared to 1.20% for plain feedback (12.64% to 11.44%, Figure 3b), representing an additional reduction of approximately 1,700 (2.1%) broad-spectrum prescriptions. This difference was significant at $p<0.05$ (coefficient 0.41%, CI: 0.007% to 0.8%, $p=0.046$; Table S8).

Wider Effects on Prescribing and subgroup analyses We found no significant effect on the three other national antibiotic prescribing measures (defined in Table S2; Figure S2; Table S8). We found no significant association between the primary prescribing outcome and practice population size (as deciles, $p=0.141$); accessing a link ($p=0.805$); or opting out (N=9, $p=0.895$; Table S8).

Qualitative analysis

There were fifteen responses from participants containing comments or questions: the majority were from the behavioural impact group (N=12) and after wave 2 (N=8), the only intervention directly inviting comments. Six reported action being undertaken (audit, practice discussion, or contact with CCG). However, not all explicitly stated they were prompted by our intervention. Five responders provided possible explanations, e.g. low overall antibiotic prescribing, unusual population (e.g. care homes), or prescribing for a specific condition; only one raised the possibility of inappropriate over-use. Nine responses made a request or asked a question, for example requesting overall antibiotic prescribing rates. Two disputed the figures, citing disagreement with local information. Among the other emails, seven were opt-outs (six from behavioural impact), with three mentioning lack of consent.

Harms

We did not detect any signals indicating harm.

Discussion

Summary

We sent three brief data feedback interventions to 703 practices in England ranking within the top 20% for prescribing broad-spectrum antibiotics. Engagement with data increased: 9.8% more practices in the intervention group viewed their dashboard (65.7% versus 55.9%, 95% CI: 4.76% to 14.9%, p<0.001); one quarter accessed a link we supplied and most reported the intervention gave them new information (70.3%, 121/172). The apparent impact on broad-spectrum prescribing, was not statistically significant at p<0.05 (absolute reduction 1.43% vs 1.14%; CI: -0.07% to 0.01%, p=0.104). The behavioural impact group had similar or slightly lower engagement than the plain feedback group, but more reduced broad spectrum prescribing (absolute reduction 1.66% vs 1.19%, CI: 0.007% to 0.82%, p=0.046).

Strengths and Limitations

Our intervention was a low-cost mechanism, built on existing infrastructure. We included a large sample (20%) of English NHS practices. Participants required no specific software, logins, opt-in or face-to-face contact. Our code is freely available online, the gold standard for reproducible research, and could be adapted to other prescribing issues, and other countries.

The national prescribing dataset is considered highly accurate. Page views will include non-participants and be affected by e.g. site updates, social media, and newsletters; but likely equally affecting both groups. We also measured link access; but some recipients may have used alternative data tools which were not captured.

Comparison with existing literature

Performance feedback is an established mechanism for improvement in clinical practice, including prescribing[19]. Our study was similar to a recent UK trial with a small impact on overall antibiotic prescribing (3.3%), but did not monitor engagement[20]. One-off interventions may only have a temporary effect[2], whilst our approach, timely, routine, and linking to a live updated website, was intended to impact multiple areas of prescribing and facilitate monitoring over the longer term[5] at very low cost.

Despite practices' engagement, we found only weak evidence of an impact on prescribing, more significant with behavioural optimisation. This may reflect saturation: broad spectrum prescribing was already declining, particularly among higher prescribers, thanks to national policies and incentives[7]. However, a small change across many practices could represent an important impact. Previous interventions targeting broad-spectrum antibiotics typically include more complex (and costly), educational interventions, and largely in the USA[21,22].

Another UK study had a small impact on antibiotic prescribing, but with a small sample size (41), requiring opt-in, and a wide range of baseline prescribing rates[23]. A Swiss study of quarterly feedback interventions had 11% engagement over two years[24]. However, additional online information was limited to antibiotics and required login. Our 25% engagement rate is higher, but measured whole practices over only 15 weeks.

We found some evidence of marginal improvement with “behavioural insights”, but with slightly lower engagement. A variety of behavioural impact approaches have been recommended[5,25], and we included basic concepts across both interventions, including: targeting highest prescribers (avoiding licensing effects); a simple peer-comparison method; and regular messages. Our optimisation additionally featured evolving messages, an invitation to contact us, provision of evidence of effectiveness of previous feedback, and more emotionally laden messages. By directly comparing two versions, our study helps address the knowledge gap on designing effective audit-and-feedback interventions[6].

Implications for research and/or practice

Given our intervention’s success in increasing interaction with data and low implementation cost, alongside the small positive impact on prescribing in other trials, unsolicited feedback is worthy of further investigation. We previously found practices accessing unique cost-saving opportunities made a large collective saving[18]. We are also assessing a data feedback intervention delivered to CCGs by NHS England[26]. Further research using our methods is impeded by difficulty accessing practice contact details, particularly emails, which the NHS could not supply[27]. Those obtained commercially had higher engagement, perhaps reaching more clinical staff.

Conclusion

A series of simple low-cost tailored written communications had a marginal, but significant increase in information-seeking behaviour among primary care staff. There may have been a small impact on prescribing behaviour. Techniques from "behavioural insights" did not improve engagement compared with a simple communication, but had a greater impact on prescribing.

Declarations/Acknowledgements

Ethical approval

Health Research Authority (IRAS 231358); Medical Sciences IDREC (R55595/RE001).

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Conflict of interest

BG has also received research funding from Health Data Research UK (HDRUK), the Laura and John Arnold Foundation, the Wellcome Trust, the NIHR Oxford Biomedical Research Centre (BRC), the NIHR School of Primary Care Research (SPCR), the Mohn-Westlake Foundation, the Good Thinking Foundation, and the WHO; he also receives personal income from speaking and writing for lay audiences on the misuse of science. RC is also employed by a CCG (excluded from the trial). CH has received expenses and fees for media work (including BBC Radio 4 Inside Health), from the WHO, FDA; and holds grant funding from the NIHR, SPCR, Oxford BRC and the WHO. He has received financial remuneration from an asbestos case and given legal advice on mesh cases. He has received income from the publication of a series of toolkit books (Blackwells), expenses for teaching EBM and paid for GP work in NHS out of hours. He is Director of CEBM, Editor in Chief of BMJ Evidence-Based Medicine and is an NIHR Senior Investigator. RP acknowledges part-funding from the Oxford BRC, the NIHR Oxford Medtech and In-Vitro Diagnostics Co-operative (MIC), the NIHR Applied Research Collaboration (ARC) Oxford and Thames Valley, and the Oxford Martin School. HC, AW, SB, MH and HH declare no competing interests.

Disclaimer

The views expressed here represent the views of the authors and not necessarily those of the host institution, the NHS, the NIHR, or the Department of Health and Social Care.

Data availability statement

Data are available in GitHub (https://github.com/ebmdatalab/antibiotics-rct-analysis)[15].

References

1. Walker AJ, Pretis F, Powell-Smith A, Goldacre B. Variation in responsiveness to warranted behaviour change among NHS clinicians: novel implementation of change detection methods in longitudinal prescribing data. *BMJ*. 2019;367:l5205.

2. Ivers N, Jamtvedt G, Flottorp S, et al. Audit and feedback: effects on professional practice and healthcare outcomes. *Cochrane Database Syst Rev*. 2012;(6):CD000259.

3. The DataLab, University of Oxford. OpenPrescribing. OpenPrescribing.net. Published 2020. Accessed January 24, 2020. openprescribing.net

4. Ivers NM, Sales A, Colquhoun H, et al. No more "business as usual" with audit and feedback interventions: towards an agenda for a reinvigorated intervention. *Implement Sci*. 2014;9:14.

5. Brehaut JC, Colquhoun HL, Eva KW, et al. Practice Feedback Interventions: 15 Suggestions for Optimizing Effectiveness. *Ann Intern Med*. 2016;164(6):435-441.

6. Grimshaw JM, Ivers N, Linklater S, et al. Reinvigorating stagnant science: implementation laboratories and a meta-laboratory to efficiently advance the science of audit and feedback. *BMJ Qual Saf*. 2019;28(5):416-423.

7. Curtis HJ, Walker AJ, Mahtani KR, Goldacre B. Time trends and geographical variation in prescribing of antibiotics in England 1998–2017. *J Antimicrob Chemother*. Published online September 15, 2018. doi:10.1093/jac/dky377

8. NHS. The NHS long term plan. Published 2019. Accessed February 27, 2019. https://www.longtermplan.nhs.uk/wp-content/uploads/2019/01/nhs-long-term-plan.pdf

9. NICE. Antimicrobial stewardship: prescribing antibiotics. Published 2015. Accessed September 6, 2017. https://www.nice.org.uk/advice/ktt9/chapter/Prescribing-data

10. The DataLab. Antibiotic stewardship: co-amoxiclav, cephalosporins & quinolones (KTT9) by all CCGs | OpenPrescribing. Published 2019. Accessed August 8, 2019. http://web.archive.org/web/20190808161856/https://openprescribing.net/measure/ktt9_cephalosporins/

11. Curtis H, Walker A, Bacon S, et al. The Effect of Audit & Feedback on Prescribing Behaviour and Engagement with Data on OpenPrescribing.net - A Randomised Controlled Trial Protocol. Published online April 26, 2018. doi:10.6084/m9.figshare.6188633.v1

12. NHS Digital. GP and GP practice related data. Published 2018. Accessed December 7, 2018. https://digital.nhs.uk/services/organisation-data-service/data-downloads/gp-and-gp-practice-related-data

13. Medicine Optimisation contact information for GP practices in your CCG - a Freedom of Information request to NHS Manchester Clinical Commissioning Group. WhatDoTheyKnow. Published June 13, 2017. Accessed September 5, 2018. https://www.whatdotheyknow.com/request/medicine_optimisation_contact_in_191

14. Curtis HJ. *Cephalosporin Measure for RCT (inc Allocation)*. Github Accessed January 20,

2019. https://gist.github.com/HelenCEBM?page=2

15. Curtis HJ. Antibiotics RCT analysis and data. GitHub. Published May 2020. Accessed July 31, 2020. https://github.com/ebmdatalab/antibiotics-rct-analysis

16. Curtis HJ. Page Views and links analysis (Original). Gist. Published May 8, 2018. Accessed August 31, 2018. https://gist.github.com/HelenCEBM/529525b355508b5a5575f156c56acbfe/39e64bb9acbf58141bbdc355ec84ace9f799003a

17. Curtis HJ. Prescribing outcome measures (Original). Gist. Published August 29, 2018. Accessed July 31, 2020. https://gist.github.com/HelenCEBM/f989bcc10f24d50aba1c6cc5b66fcc2e/a555cc57a910cab19c7401ca38a05df2703e8a64

18. Walker AJ, Curtis HJ, Croker R, Bacon S, Goldacre B. Measuring the Impact of an Open Online Prescribing Data Analysis Service on Clinical Practice: a Cohort Study in NHS England Data. *JMIR Res Protoc*. Published online October 1, 2018. doi:10.2196/10929

19. Chauhan BF, Jeyaraman M, Mann AS, et al. Behavior change interventions and policies influencing primary healthcare professionals' practice-an overview of reviews. *Implement Sci*. 2017;12(1):3.

20. Hallsworth M, Chadborn T, Sallis A, et al. Provision of social norm feedback to high prescribers of antibiotics in general practice: a pragmatic national randomised controlled trial. *Lancet*. 2016;387(10029):1743-1752.

21. Teixeira Rodrigues A, Roque F, Piñeiro-Lamas M, Falcão A, Figueiras A, Herdeiro MT. Effectiveness of an intervention to improve antibiotic-prescribing behaviour in primary care: a controlled, interrupted time-series study. *J Antimicrob Chemother*. 2019;74(9):2788-2796.

22. Donà D, Barbieri E, Daverio M, et al. Implementation and impact of pediatric antimicrobial stewardship programs: a systematic scoping review. *Antimicrob Resist Infect Control*. 2020;9:3.

23. Gulliford MC, Juszczyk D, Prevost AT, et al. Electronically delivered interventions to reduce antibiotic prescribing for respiratory infections in primary care: cluster RCT using electronic health records and cohort study. *Health Technol Assess*. 2019;23(11):1-70.

24. Hemkens LG, Saccilotto R, Reyes SL, et al. Personalized Prescription Feedback Using Routinely Collected Data to Reduce Antibiotic Use in Primary Care: A Randomized Clinical Trial. *JAMA Intern Med*. 2017;177(2):176-183.

25. Linder JA. Moving the mean with feedback: insights from behavioural science. *NPJ Prim Care Respir Med*. 2016;26:16018.

26. MacKenna B, Curtis H, Walker A, Bacon S, Goldacre B. Protocol for a Randomised controlled trial of structured Educational sessions to Clinical Commissioning Groups and Assessing the impact on primary care Prescribing. *Figshare*. Published online October 2018. doi:10.6084/m9.figshare.7201079.v1

27. Bacon S, Goldacre B. Barriers to Working With National Health Service England's Open

Data. *J Med Internet Res*. 2020;22(1):e15603.

Tables

Table 1 - Baseline characteristics of all 1,401 English general practices included in the study

Measure	**Timepoint**	**Control group** (n=698)	**Intervention group** (n=703)	**Intervention group breakdown**	
				Behavioural impact (n=356)	**Plain feedback** (n=347)
Practice list size[1] (mean)	Feb 2018	8,120	8,517	8,487	8,550
Small practices[2] (%)	Feb 2018	7.7%	8.1%	9.4%	6.8%
Single-handed practices[3] (%)	Feb 2018	6.6%	5.4%	5.6%	5.2%
Number of GPs[4] (mean)	Feb 2018	6.0	6.2	6.3	6.1
Dispensing practices[5] (%)	Feb 2018	21%	22%	22%	22%
Index of Multiple Deprivation[6] (mean)	2015	20.0	19.9	20.1	19.6
Total antibiotics prescribed per STAR-PU[7] (mean)	Sept 2017-Feb 2018	0.50	0.51	0.50	0.51
Antibiotics prescribed as broad-spectrum[7] (%)	Sept 2017-Feb 2018	12.7%	12.7%	12.7%	12.6%
Practices having at least one dashboard view[8] (%)	15-week baseline	56.4%	60.9%	61.2%	60.5%
Page views per practice[8] (mean)	15-week baseline	1.4	1.5	1.4	1.6

[2] <3000 patients.

[3] one GP.

[5] at least one dispensing patient.

Data sources: [1-5]NHS Digital; [6]Public Health England (Fingertips tool); [7]OpenPrescribing data (from NHSBSA and NHS Digital); [8]Google Analytics for OpenPrescribing.net usage for individual practice pages.

Table 2. Count of practices having dashboard pages viewed at least once, and mean page views per practice dashboard, for practices in the intervention (n=703) and control groups (n=698), during the 15-week baseline and follow-up periods. *Figures representing the primary outcome are shaded. SD, Standard Deviation.*

		Control group (n=698)		**Intervention group** (n=703)		**Intervention group breakdown**			
						Behavioural impact (n=356)		**Plain feedback** (n=347)	
Practices having at least one dashboard view	**Baseline**	394	(56.4%)	428	(60.9%)	218	(61.2%)	210	(60.5%)
	Follow-up	390	**(55.9%)**	462	**(65.7%)**	222	(62.4%)	240	(69.1%)
	(change)	-4		+34	(+4.8%)	+4		+30	
Page views per practice (mean +/- SD)	**Baseline**	1.44	+/-2.09	1.51	+/-1.99	1.40	+/-1.78	1.63	+/-2.18
	Follow-up	1.42	+/-2.11	1.75	+/-2.12	1.66	+/-2.12	1.84	+/-2.12
	(change)	-0.02		+0.24		+0.24		+0.21	

Figure captions

Figure 1. *Participant flow diagram, beginning with all practices in England as of May 2018. Includes number of participants opting out of further interventions, as indicated. One additional participant "opted out" after wave 3.*

Figure 2. Number of practices in the intervention group (n=703) accessing links supplied in the intervention during the 15-week follow-up period, per wave, and according to feedback group and means of communication (email, fax, letter). *Blue, turquoise, green indicate whether each practice had looked at their dashboard during the baseline period, clicked on a link from a previous wave, or had done neither, respectively.*

Figure 3. Proportion of antibiotics prescribed as broad spectrum, April 2017- May 2019, for practices included in the (a) intervention and control groups and (b) behavioural impact and plain feedback groups. *The baseline, intervention, and follow-up periods are shaded. SD=standard deviation.*