Effectiveness of quality improvement strategies on the management of diabetes: a systematic review and meta-analysis

Andrea C Tricco, Noah M Ivers, Jeremy M Grimshaw, David Moher, Lucy Turner, James Galipeau, Ilana Halperin, Brigitte Vachon, Tim Ramsay, Braden Manns, Marcello Tonelli, Kaveh Shojania

Lancet 2012; 379: 2252–61
Published Online June 9, 2012
DOI:10.1016/S0140-6736(12)60480-2

See Comment page 2218

Li Ka Shing Knowledge Institute of St Michael's Hospital, Toronto, ON, Canada (A C Tricco PhD); **Women's College Hospital and Department of Family and Community Medicine** (N M Ivers MD) **and Division of Endocrinology, Department of Medicine** (I Halperin MD), **University of Toronto, Toronto, ON, Canada; Clinical Epidemiology Program, Ottawa Hospital Research Institute, Ottawa, ON, Canada** (Prof J M Grimshaw PhD, D Moher PhD, L Turner MSc, J Galipeau PhD, B Vachon PhD, T Ramsay PhD); **Department of Medicine** (Prof J M Grimshaw), **and Department of Epidemiology and Community Medicine** (D Moher, T Ramsay), **Faculty of Medicine, University of Ottawa, Ottawa, ON, Canada; Occupational Therapy Program, School of Rehabilitation, Université de Montréal, Montreal, QC, Canada** (B Vachon); **Department of Community Health Sciences** (B Manns MD) **and Libin Cardiovascular Institute and Department of Medicine** (B Manns, M Tonelli MD), **University of Calgary, Calgary, AB, Canada; and Sunnybrook Health Sciences Centre and University of Toronto Centre for Patient Safety, Toronto, ON, Canada** (K Shojania MD)

Correspondence to:
Dr Andrea C Tricco, Li Ka Shing Knowledge Institute of St Michael's Hospital, 30 Bond Street, Toronto, ON M5B 1W8, Canada
triccoa@smh.ca

Summary

Background The effectiveness of quality improvement (QI) strategies on diabetes care remains unclear. We aimed to assess the effects of QI strategies on glycated haemoglobin (HbA_{1c}), vascular risk management, microvascular complication monitoring, and smoking cessation in patients with diabetes.

Methods We identified studies through Medline, the Cochrane Effective Practice and Organisation of Care database (from inception to July 2010), and references of included randomised clinical trials. We included trials assessing 11 predefined QI strategies or financial incentives targeting health systems, health-care professionals, or patients to improve management of adult outpatients with diabetes. Two reviewers independently abstracted data and appraised risk of bias.

Findings We reviewed 48 cluster randomised controlled trials, including 2538 clusters and 84 865 patients, and 94 patient randomised controlled trials, including 38 664 patients. In random effects meta-analysis, the QI strategies reduced HbA_{1c} by a mean difference of 0·37% (95% CI 0·28–0·45; 120 trials), LDL cholesterol by 0·10 mmol/L (0·05–0.14; 47 trials), systolic blood pressure by 3·13 mm Hg (2·19–4·06, 65 trials), and diastolic blood pressure by 1·55 mm Hg (0·95–2·15, 61 trials) versus usual care. We noted larger effects when baseline concentrations were greater than 8·0% for HbA_{1c}, 2·59 mmol/L for LDL cholesterol, and 80 mm Hg for diastolic and 140 mm Hg for systolic blood pressure. The effectiveness of QI strategies varied depending on baseline HbA_{1c} control. QI strategies increased the likelihood that patients received aspirin (11 trials; relative risk [RR] 1·33, 95% CI 1·21–1·45), antihypertensive drugs (ten trials; RR 1·17, 1·01–1·37), and screening for retinopathy (23 trials; RR 1·22, 1·13–1·32), renal function (14 trials; RR 128, 1·13–1·44), and foot abnormalities (22 trials; RR 1·27, 1·16–1·39). However, statin use (ten trials; RR 1·12, 0·99–1·28), hypertension control (18 trials; RR 1·01, 0·96–1·07), and smoking cessation (13 trials; RR 1·13, 0·99–1·29) were not significantly increased.

Interpretation Many trials of QI strategies showed improvements in diabetes care. Interventions targeting the system of chronic disease management along with patient-mediated QI strategies should be an important component of interventions aimed at improving diabetes management. Interventions solely targeting health-care professionals seem to be beneficial only if baseline HbA_{1c} control is poor.

Funding Ontario Ministry of Health and Long-term Care and the Alberta Heritage Foundation for Medical Research (now Alberta Innovates—Health Solutions).

Introduction

Despite high-quality evidence showing improved clinical outcomes for patients with diabetes who receive various preventive and therapeutic interventions,[1] many patients with diabetes do not receive them.[2–5] The gap between ideal and actual care is not surprising in view of the complex nature of diabetes management, often needing coordinated services of primary-care physicians, allied health practitioners, and subspecialists. Moreover, it is a challenge to change patient behaviour and encourage healthy lifestyles.[6]

In view of the increasing prevalence of diabetes and the burgeoning cost of managing patients with this disease,[7] improving the efficiency of diabetes care is an important goal. Although clinicians, managers, and policy makers expend significant time and resources attempting to optimise care for patients with diabetes, the optimum approach to improving diabetes care (and outcomes) remains uncertain.

A previous systematic review[8] assessed the effect of quality improvement (QI) interventions to improve glycaemic control for patients with type 2 diabetes in 66 controlled studies published by April, 2006. Over a median follow-up of 13 months, the QI interventions significantly lowered glycated haemoglobin (HbA_{1c}) by a mean 0·42% (95% CI 0·29–0·54). After adjustment for study size and baseline HbA_{1c}, two of the 11 categories of QI strategies were associated with reductions in HbA_{1c} of at least 0·50%: team changes (26 trials; 0·67%, 95% CI 0·43–0·91) and case management (26 trials; 0·52%, 0·31–0·73). Only these two strategies led to significant incremental reductions

in HbA_{1c} (ie, interventions that included either of these two strategies achieved significantly greater improvements than strategies without them).

Since the previous review[8] noted a rapid growth of published work on this subject and did not assess the effect of QI strategies on outcomes other than HbA_{1c}, we sought to update and expand the review by considering the effect of QI interventions on glycaemic control, vascular risk-factor management, monitoring of microvascular complications, and smoking cessation in patients with diabetes.

Methods

Study selection and search strategy

Our systematic review was based on a protocol with input from experts in diabetes care, methods, and statistics.[9] We selected randomised clinical trials that assessed 11 predefined QI strategies or financial incentives targeting health-care professionals[8] for the management of adult outpatients with diabetes (panel). The QI strategies targeted health systems (eg, team changes), professionals (eg, professional reminders), or patients (eg, promotion of self management). By use of a framework of outcomes (appendix), we required that studies reported at least one process of care measure (proportion of patients taking aspirin, statins, antihypertensive drugs, screened for retinopathy, screened for foot abnormalities, monitored for renal function) or intermediate outcome (HbA_{1c} and LDL-cholesterol concentrations, diastolic and systolic blood pressure, proportion of patients with controlled hypertension, or who quit smoking). Consistent with the previous review, we excluded trials assessing the effect of QI strategies aimed solely at the patient (ie, with no associated health systems or professional change).

We identified studies through Medline (July, 2003 [last date of the original search[10]], to July, 2010), the Cochrane Effective Practice and Organisation of Care (EPOC) database (July, 2003, to July, 2010), and the references of included trials. An experienced librarian developed the search strategy, which was peer reviewed independently by another information specialist.[11] We restricted our final search strategy for Medline to reports in English (appendix); we adjusted it as necessary for searching the Cochrane EPOC database.

To ensure reliability, we undertook a training exercise before the screening process with a random 5% sample of search results. Two reviewers subsequently screened the records from the updated search. Two reviewers obtained the full text of potentially relevant articles and screened them independently for inclusion. Discrepancies were resolved by discussion or involvement of a third reviewer. Two reviewers independently rescreened all full-text articles from the previous review for inclusion, since our inclusion criteria were slightly different from the original report.[8] Since we relied on searches done in the previous review, we were unable to establish the reason for exclusion for about 4% (220 of 5592) of the citations.

We developed and modified a data abstraction form after a training exercise for reviewers. Data items were study details (eg, randomisation of clusters or patients , setting, duration of intervention, type of QI intervention), characteristics of participants (eg, mean age, proportion who were male), outcomes assessed, and study results (eg, mean HbA_{1c} and SDs at baseline and the end of the intervention for the control and intervention groups). Two reviewers abstracted data independently from all of the included studies from the updated search, and those from the original review. Furthermore, two reviewers independently classified the QI strategies with our framework (panel). We contacted authors of the trials we included to obtain further information for data items that needed clarification. The Cochrane EPOC method was used to assess the risk of bias in individual studies.[12,13] Discrepancies were resolved by discussion or the involvement of a third reviewer.

Statistical analysis

We used well established methods to adjust cluster-randomised controlled trials for meta-analysis with patient-randomised controlled trials.[14,15] As in the previous review,[8] many of the cluster trials we included did analyses at the patient level rather than the cluster level (ie, unit of analysis errors). In an attempt to avoid spurious estimates in patient-level outcomes, we calculated an effective sample size for each such trial by use of the intracluster correlation coefficient (ICC).[16–18] We imputed unreported ICCs based on ICCs reported in other included trials for each outcome. To ensure that we maintained the independence of studies, we included a maximum of two groups in our analysis even if trials had more than two groups.[19] For example, if a trial assessed team changes and education of patients versus education of patients alone versus usual care, we included only the team changes and education of patients versus usual care groups in our analysis. This restriction applied for only ten trials we included. We imputed unreported SDs by use of established methods.[15,20]

See Online for appendix

We assessed the effects of each QI strategy across the outcomes descriptively, assessing the data distributions, means, medians, and IQRs. We then used a random effects model to estimate the pooled risk ratio (RR, dichotomous data) or the mean difference (continuous data) across the included trials (Comprehensive Meta-analysis Version 2.2050).[21] We assessed the consistency of results across the studies by use of forest plots and the statistical heterogeneity with the I^2 statistic.[22] We did a post-hoc secondary analysis to explore whether the effectiveness of QI strategies varied in studies enrolling patients with diabetes who had poor baseline achievement of quality indicators (defined by baseline HbA_{1c}, LDL cholesterol, and diastolic and systolic blood pressures).

Panel: **Taxonomy of quality improvement strategies**

Quality improvement (QI) strategies targeting health systems

Case management

Any system for coordinating diagnosis, treatment, or routine management of patients (eg, arrangement for referrals, follow-up of test results) by a person or multidisciplinary team in collaboration with, or supplementary to, the primary-care clinician. For a randomised controlled trial to qualify, the case management had to happen more than once. Most of these studies had less involvement than in those with team changes (ie, case manager did not have to speak with primary-care physician). If the study called the intervention "case management" we classified it as such.

Team changes

Changes to the structure or organisation of the primary health-care team were defined as present if they met certain criteria:

- Adding a team member or shared care—eg, routine visits with people other than the primary physician (including physician or nurse specialists in diabetic care, pharmacists, nutritionists, podiatrists).
- Use of multidisciplinary teams—ie, active participation of professionals from more than one discipline (eg, medicine, nursing, pharmacy, nutrition) in the primary, routine management of patients.
- Expansion or revision of professional roles (eg, nurse or pharmacist has a more active role in monitoring of the patient or adjusting drug regimens).

To ensure that every study we classified as case management would not also qualify as a team change, we could classify a study that was already classified as case management also as a team change if at least two of the above conditions were met. Team changes involved more communication. If the study called the intervention "joint visits" or "shared care", we classified it as a team change. To qualify, the intervention had to be done by a health-care professional and had to happen more than once.

Electronic patient registry

General electronic medical record system or electronic tracking system for patients with diabetes. We did not include websites unless patients were tracked over time. To qualify, it had to be a part of the clinical trial as an intervention (ie, not pre-existing infrastructure unless used more actively).

Facilitated relay of information to clinicians

Clinical information collected from patients and transmitted to clinicians by means other than the existing medical record. We excluded conventional means of correspondence between clinicians. For example, if the results of routine visits with a pharmacist were sent in a letter to the primary-care physician, the use of routine visits with a pharmacist would count as a "team" change, but the intervention would not also be counted as "facilitated relay". However, if the pharmacist issued structured diaries for patients to record self-monitored glucose values, which were then taken to office visits to review with the primary physician, we would count the intervention as "facilitated relay". Other examples include electronic or web-based methods through which patients provided self-care data and which clinicians reviewed, as well as point-of-care testing supplying clinicians with immediate HbA_{1c} values. We included passports, referral systems, and dietary information (*vs* purely clinical information). In general, the patient should be facilitating the relay. To be included, the information must get to someone with prescribing or ordering ability. For example, if the nurse's role was expanded to make drug changes, the patient had a passport, and the nurse could directly make a change, we would classify the intervention as case management and facilitated relay of clinical information (depending on the study and situation). If the nurse alerted the primary-care provider that the patient had run out of drugs, we did not deem this facilitated relay of information, because that is a normal part of a nurse's role.

Continuous QI

Interventions explicitly identified as involving the techniques of continuous QI, total quality management, or plan-do-study-act, or any iterative process for assessing quality problems, developing solutions to those problems, testing their effects, and then reassessing the need for further action.

QI strategies targeting health-care providers

Audit and feedback

Summary of clinical performance of health care delivered by an individual clinician or clinic over a specified period, which was then transmitted back to the clinician (eg, the percentage of a clinician's patients who achieved a target HbA_{1c} concentration or who underwent dilated-eye examinations with a specified frequency). This strategy was strictly based on clinical data and excluded clinical skills. It could include the number of patients with missing tests and dropouts.

Clinician education

Interventions designed to promote increased understanding of principles guiding clinical care or awareness of specific recommendations for a target disorder or population of patients. Subcategories of clinician education included conferences or workshops, distribution of educational materials (written, video, or other), and educational outreach visits (ie, academic detailing). We excluded teaching how to educate patients, counselling skills, motivational interviewing, self-directed learning, and skills related to the intervention (eg, teaching how to use the website for the randomised controlled trial). We included all health-care providers. If the education was part of the individual's role (eg, teaching a case manager about diabetes) we did not categorise it as clinician education.

(Continues on next page)

(Continued from previous page)

Clinician reminders
Paper-based or electronic systems intended to prompt a health professional to recall patient-specific information (eg, most recent HbA_{1c} value) or to do a specific task (eg, foot examination). If the strategy was accompanied by a recommendation, we subclassified it as decision support (eg, giving targets to health-care providers). An example is a yellow piece of paper clipped to the medical record with the patient's information on it. This approach had to be systematic and part of the implementation of the intervention—we excluded ad-hoc clinician reminders.

Financial incentives
Interventions with positive or negative financial incentives directed at providers (eg, linked to adherence to some process of care or achievement of some target outcome). This strategy also includes positive or negative financial incentives directed at patients or system-wide changes in reimbursement (eg, capitation, prospective payment, or a shift from fee-for-service to salary pay structure).

QI strategies targeting patients
Education of patients
Interventions designed to promote greater understanding of a target disorder or to teach specific prevention or treatment strategies, or specific in-person education (eg, individual or group sessions with diabetes nurse educator; distribution of printed or electronic educational materials). Interventions with education of patients were included only if they also included at least one other strategy related to clinician or organisational change. We did not include occasions of optional education.

Promotion of self-management
Provision of equipment (eg, home glucose meters) or access to resources (eg, system for electronically transmitting home glucose measurements and receiving insulin dose changes based on those data) to promote self-management. Interventions promoting self-management were included only if they also included at least one other strategy related to clinician or organisational change. We also included established goals or a print off of a self-management plan (ie, did not necessarily require equipment or resources). If the study called the intervention promotion of self-management, personalised goal-setting, or action-planning, we included it here. We generally thought this a more active strategy than education of patients.

Reminder systems
Any effort (eg, postcards or telephone calls) to remind patients about upcoming appointments or important aspects of self care. Interventions with reminders were included only if they also included at least one other strategy related to clinician or organisational change. Examples included reminders to monitor glucose. If the intervention included case management, reminders to patients needed to be explicit and an extra task to the normal case management.

We decided a priori to do meta-regression with a linear fixed-effects model (Proc Mixed SAS Version 9.2) for studies reporting HbA_{1c}. Our meta-regression adjusted for two study characteristics, median baseline HbA_{1c} (<8·0% *vs* ≥8·0%) and median effective sample size (≤141 patients *vs* >141 patients). The sample size variable largely accounted for study design (ie, patient trials *vs* cluster trials), since cluster-randomised trials included many more patients than patient-randomised trials. We chose these characteristics a priori because they were methodologically relevant and significantly predicted HbA_{1c} concentrations in univariate analysis. Because of the complexity of the combination of QI strategies we assessed in each trial and the restricted number of similar combinations across all trials, we assessed the QI strategies separately in our analysis (ie, the QI strategies were dichotomised). For example, if a trial compared five different QI strategies versus usual care and reported a reduction of 0·3% in HbA_{1c}, we applied this result to each of the five QI strategies assessed for this trial. To assess the effects of individual QI strategies on the HbA_{1c} results, we also did meta-regression analyses of trials with a given QI intervention versus trials without the particular QI intervention. For example, we included all trials in the model and then we assessed the effect of a given QI intervention (eg, team changes) on the HbA_{1c} estimate by excluding the trials contributing data to team changes.

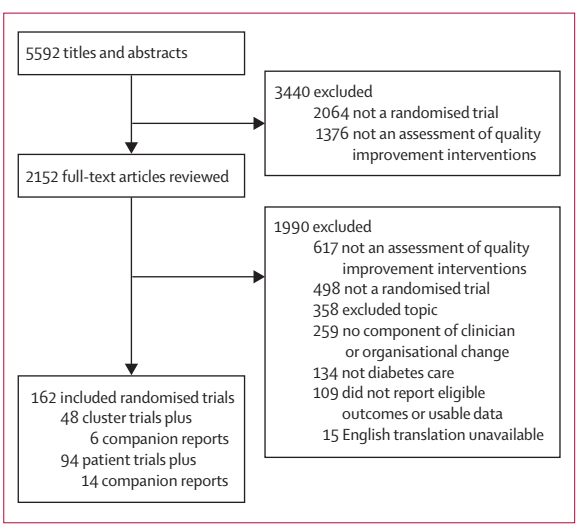

Figure 1: **Study profile**

Role of the funding source

The sponsor of the study had no role in study design, data collection, data analysis, data interpretation, or writing of the report. The corresponding author had full access to all the data in the study and had final responsibility for the decision to submit for publication.

Results

Figure 1 shows the study profile. 48 cluster-randomised trials, including 2538 clusters and 84865 patients, and 94 patient-randomised trials, including 38664 patients, fulfilled our inclusion criteria. 20 companion reports provided supplementary information (appendix).

	Patient trials (N=94; 38664 patients)*	Cluster trials (N=48; 84865 patients)
Duration of intervention (months)	12 (6–12)	12 (11·8–18)
Longest duration of follow-up (months)	12 (6–13)	12 (12–21)
Study outcomes		
Aspirin use	4 (4%)	7 (15%)
Statin use	7 (8%)	4 (8%)
Any hypertensive drug use	8 (9%)	3 (6%)
Retinopathy screening	10 (11%)	15 (31%)
Renal screening	4 (4%)	11 (23%)
Foot screening	9 (10%)	15 (31%)
HbA_{1c}	84 (89%)	32 (67%)
LDL cholesterol	31 (33%)	16 (33%)
Diastolic blood pressure	39 (42%)	23 (48%)
Systolic blood pressure	40 (44%)	25 (52%)
Hypertension control	10 (11%)	8 (17%)
Smoking cessation	6 (6%)	9 (19%)
Number of clusters	NA	29 (12–57)
Number of patients	127 (63–206)	684 (343–1549)
Mean age (years)	56·4 (51·6–60·7)	62·4 (58·1–65·1)
Percentage male	50·6 (38·8–59·1)	49 (44·7–52·7)
Type of diabetes		
Type 1	8 (6%)	1 (2%)
Type 2	52 (55%)	28 (58%)
Types 1 and 2	26 (28%)	8 (17%)
Type unclear or not reported	8 (9%)	11 (23%)
Administrators of interventions for patients		
Primary-care physician	18 (19%)	12 (25%)
Nurse	53 (56%)	14 (29%)
Pharmacist	17 (18%)	2 (4%)
Dietitian	19 (20%)	3 (6%)
Psychiatrist	3 (3%)	0
Psychologist	1 (1%)	1 (21%)
Ophthalmologist	2 (2%)	0
Specialist or endocrinologist	18 (19%)	3 (6%)
Other	34 (36%)†	15 (31%)
Masking		
Intervention masked from patients	3 (3%)	3 (6%)
Intervention masked from patients' assessors	11 (12%)	12 (25%)
Intervention masked from patients' providers	NA	2 (4%)
Number of QIs per trial	3 (2–4)	3 (2–3)

(Continues in next column)

Many characteristics of studies and patients were similar for patient and cluster trials (table 1, appendix). However, the two types differed with respect to sample size, masking, and who gave the intervention. For patient-randomised trials, most included the QI strategies of patients' education, promotion of self-management, team changes, and case management (table 1). By contrast, cluster-randomised trials mostly

	Patient trials (N=94; 38664 patients)*	Cluster trials (N=48; 84865 patients)
(Continued from previous column)		
Trials per QI strategies		
Audit and feedback	4 (4%)	11 (23%)
Case management	49 (52%)	7 (15%)
Team changes	46 (49%)	8 (17%)
Electronic patient registry	19 (20%)	12 (25%)
Clinician education	6 (6%)	20 (42%)
Clinician reminders	9 (10%)	13 (27%)
Facilitated relay	26 (28%)	8 (17%)
Patient education	41 (44%)	19 (40%)
Promotion of self-management	49 (52%)	14 (29%)
Patient reminders	15 (16%)	8 (17%)
Continuous quality improvement	0	4 (8%)
Financial incentives	0	1 (2%)
Country of publication		
USA	46 (49%)	22 (46%)
Canada	9 (10%)	2 (4%)
UK	8 (9%)	6 (13%)
South Korea	7 (8%)	..
China	2 (2%)	..
Netherlands	2 (2%)	6 (13%)
Australia	3 (3%)	3 (6%)
Denmark	2 (2%)	1 (2%)
Thailand	1 (1%)	..
Norway	1 (1%)	1 (2%)
Finland	1 (1%)	..
France	2 (2%)	..
Germany	2 (2%)	..
Taiwan	1 (1%)	..
Israel	1 (1%)	2 (4%)
Italy	1 (1%)	1 (2%)
Spain	3 (3%)	..
Switzerland	1 (1%)	1 (2%)
United Arab Emirates	1 (1%)	..
Belgium	..	1 (2%)
Ireland	..	1 (2%)
Mexico	..	1 (2%)
New Zealand	..	1 (2%)

Data are median (IQR) or n (%). HbA_{1c}=glycated haemoglobin. NA=not applicable. QI=quality improvement. *Includes three crossover trials and two quasi-randomised trials. †Includes investigators and community workers.

Table 1: **Characteristics of studies and patients**

included patients' education, clinicians' education, and promotion of self-management (table 1).

Only 39% of the trials (55 of 142) adequately reported allocation sequence generation and 42% (60 of 142) adequately reported concealing the allocation sequence. The corresponding proportion for differences in baseline outcome measures was 10% (14 of 142), for differences in baseline characteristics (eg, demographics) was 16% (23 of 142), for incomplete outcome data was 17% (24 of 142), for potential knowledge of allocated interventions was 8% (11 of 142), for inadequate protection against contamination was 6% (nine of 142), and for potential for selective outcome reporting was 1% (one of 142; appendix).

120 trials reported a mean decrease in HbA_{1c} concentration over a median follow-up of 12 months associated with QI interventions (table 2, figure 2). QI strategies were associated with lower LDL-cholesterol concentrations across 47 trials, lower systolic blood pressure across 65 trials, and lower diastolic blood pressure across 61 trials over a median follow-up of 12 months (table 2, figure 2).

QI strategies were associated with an increase in use of aspirin over a median follow-up of 18 months and any antihypertensive drugs over a median follow-up of 13 months (table 2). There were no significant differences associated with QI strategies for use of statins over a median follow-up of 19 months and achievement of adequate control of hypertension over a median follow-up of 12 months (table 2).

QI strategies were associated with increases in retinopathy screening, screening for renal involvement, and foot screening over a median follow-up of 12 months (table 2). QI strategies were not associated with a significant difference in smoking cessation rates over a median follow-up of 12 months (table 2). The six trials that included smoking cessation counselling as part of their QI strategy did not achieve greater cessation rates.

In studies enrolling patients who had poor baseline achievement of quality indicators, QI strategies were associated with larger effects across HbA_{1c}, systolic and diastolic blood pressure, and LDL cholesterol (table 3). The effectiveness of each QI strategy varied by baseline HbA_{1c} concentration. Decreases in HbA_{1c} of more than 0·5% were noted for four QI strategies (team changes, case management, patients' education, and promotion of self-management) in trials enrolling patients with HbA_{1c} greater than 8·0%, and one QI strategy (facilitated relay) in trials enrolling patients with HbA_{1c} of 8·0% or less (table 4).

After adjustment for median baseline HbA_{1c} values and effective sample size, the QI strategies were associated with significantly lower HbA_{1c} than usual care was (figure 3). All QI strategies were associated with significant changes in HbA_{1c}, except for clinician education.

In our planned analysis in which we sequentially omitted all trials with a given QI strategy from our meta-regression model, HbA_{1c} was further lowered when the QI strategy included team changes (0·33%), case management (0·21%), promotion of self-management (0·21%), clinician education (0·19%), patient education (0·16%), facilitated relay (0·12%), an electronic patient registry (0·08%), and patient reminders (0·02%).

	Studies (imputed SDs)	Number of patients	Median baseline compliance (IQR)	Median baseline values (IQR)	I^2	Pooled effect (95% CI)*
Dichotomous outcomes						
Aspirin use	11	2258	10·5% (0·2 to 25·8)	NA	38·5%	1·33 (1·21 to 1·45)
Statin use	10	1853	32·76% (20·4 to 42·8)	NA	58·2%	1·12 (0·99 to 1·28)
Antihypertensive drug use	10	2264	61·35% (55·0 to 74·0)	NA	91·4%	1·17 (1·01 to 1·37)
Retinopathy screening	23	10 455	84·53% (57·4 to 98·0)	NA	80·4%	1·22 (1·13 to 1·32)
Renal screening	14	7317	50·5% (21·3 to 67·8)	NA	91·6%	1·28 (1·13 to 1·44)
Foot screening	22	8144	47·0% (39·0 to 65·0)	NA	89·4%	1·27 (1·16 to 1·39)
Hypertension control	18	3813	69·5% (44·5 to 76·0)	NA	67·5%	1·01 (0·96 to 1·07)
Smoking cessation	13	3231	19·8% (16·3 to 31·8)	NA	5·3%	1·13 (0·99 to 1·29)
Hypoglycaemia	5	987	NA	NA	0	0·99 (0·75 to 1·31)
Severe hypoglycaemia	6	1450	NA	NA	66·8%	1·0 (0·66 to 1·51)
Hyperglycaemia	2	450	NA	NA	87·4%	0·74 (0·28 to 1·92)
Continuous outcomes						
HbA_{1c} (%)	120 (28)	22 811	NA	8·19 (7·57 to 9·20)	73·5%	−0·37 (−0·45 to −0·28)
LDL cholesterol (mmol/L)	47 (15)	11 676	NA	2·93 (2·71 to 3·20)	48·3%	−0·10 (−0·05 to −0·14)
Systolic blood pressure (mm Hg)	65 (19)	14 791	NA	139·75 (132·69 to 145·06)	60·3%	−3·13 (−4·06 to −2·19)
Diastolic blood pressure (mm Hg)	61 (4)	12 808	NA	80·00 (76·67 to 83·27)	59·0%	−1·55 (−2·15 to −0·95)

Effective sample size was used for cluster trials. HbA_{1c}=glycated haemoglobin. NA=not applicable. *Data are relative risk for dichotomous outcomes and mean difference for continuous outcomes.

Table 2: **Meta-analysis results across all outcomes**

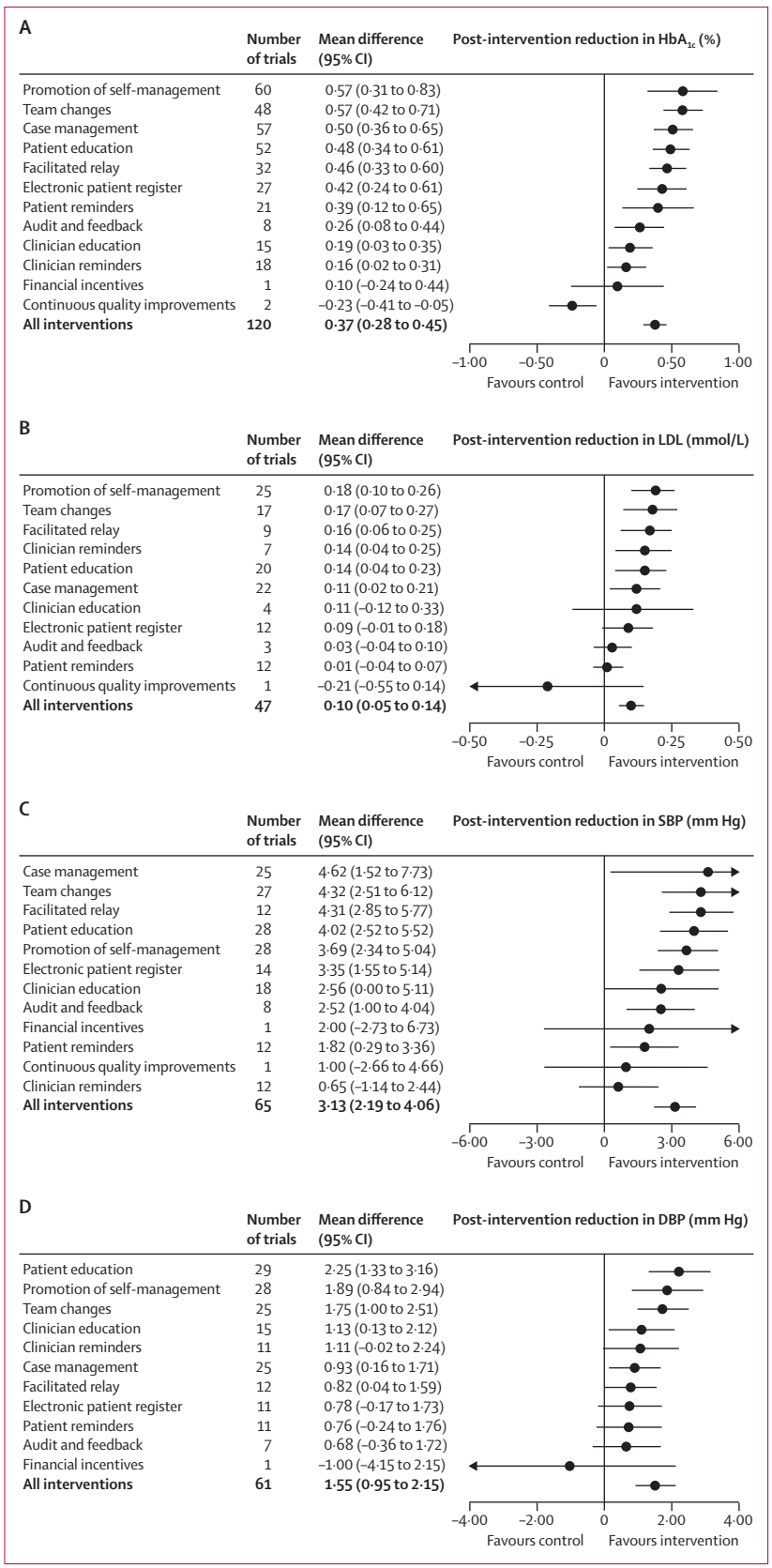

Figure 2: **Findings from meta-analyses**
Findings of the meta-analyses for biological markers: glycated haemoglobin (HbA_{1c}; A), LDL cholesterol (LDL; B), systolic blood pressure (C), and diastolic blood pressure (D). Quality improvement strategies with one trial are not based on meta-analysis (we present the individual trial result).

However, none of these results were significantly different from the overall HbA_{1c} effect.

Five trials reported the proportion of hypoglycaemic events, six trials reported the proportion of severe hypoglycaemic events, and two trials reported the proportion of hyperglycaemic events in patients in the intervention and control groups. We did not identify any significant differences across all adverse events for patients in the intervention or control groups over a median follow-up of 12 months (table 2).

Discussion

Our systematic review is an update of a previous review that assessed the effects of QI strategies on glycaemic control,[8] includes more than twice as many trials, and reports the effects of QI strategies on other important aspects of diabetes management. By including outcomes that are deemed quality indicators in the management of diabetes, such as diastolic and systolic blood pressure, LDL cholesterol, medication use, and monitoring for diabetes complications, we were able to assess the effect of QI strategies on a broader range of diabetes care. On the basis of evidence from more than 140 trials, the QI strategies we assessed significantly improved HbA_{1c}, LDL cholesterol, diastolic and systolic blood pressure, aspirin use, antihypertensive drug use, retinopathy screening, renal screening, and foot screening. We noted greater improvements in HbA_{1c} control for QI strategies targeting health systems and patients. We also noted potentially clinically important but non-statistically significant improvements for statin use and smoking cessation. However, more evidence is needed to clarify these potential improvements, since only 13 trials (involving 3231 patients) were included in the smoking cessation meta-analysis and ten trials (involving 1853 patients) in the statin use meta-analysis. We noted no improvement in hypertension control.

Since we did not include trials with interventions directed only towards the patient, the effectiveness of patients' education, patients' reminders, and promotion of self-management QI strategies should be interpreted as implemented in combination with QI strategies targeting health-care professionals. However, high-quality systematic reviews published in the past 5 years assessing the effects of patient-mediated interventions alone strongly support the benefits of these interventions.[23,24]

Across most outcomes of interest, most studies enrolled patients who were not achieving diabetes-relevant quality indicators (ie, HbA_{1c} or blood pressure). For example, median HbA_{1c} concentrations across all studies were 8·19%, the median proportion of patients on statins was

32·8%, and the median proportion of patients receiving foot screening was 47·0% at baseline. Our secondary meta-analysis showed that the effectiveness of QI strategies varied depending on baseline glycaemic control. For example, we noted that team changes, case management, patients' education, and promotion of self-management were the most effective strategies in trials that enrolled patients with mean baseline HbA_{1c} concentrations greater than 8·0%. We noted similar results in our meta-regression analysis when we sequentially omitted each QI strategy, with the most effective strategies being team changes, case management, and promotion of self-management. By contrast, the most effective strategies in trials that included patients with mean baseline HbA_{1c} concentrations of 8·0% or less were facilitated relay, team changes, patients' reminders, and electronic register of patients.

Our findings suggest that QI strategies that intervened upon the entire system of chronic disease management were associated with the largest effects irrespective of baseline HbA_{1c}. The effectiveness of interventions targeting health professionals and patients seemed to vary with baseline HbA_{1c}. For example, clinicians' education and audit and feedback led to an HbA_{1c} reduction of 0·33% and 0·44%, respectively, when baseline HbA_{1c} concentrations were greater than 8·0%, but no improvement when baseline HbA_{1c} was less than 8·0%. Patients' education seemed more effective than reminders when baseline HbA_{1c} was greater than 8·0% but less effective when the HbA_{1c} was less than 8·0%. These findings suggest that QI strategies that aim to optimise the systems of care should (whenever feasible) be included in programmes to improve diabetes management, irrespective of HbA_{1c}. Interventions targeting patients might be beneficial irrespective of baseline HbA_{1c}, whereas interventions targeting providers only seem beneficial when baseline HbA_{1c} is greater than 8·0%.

Our systematic review has some limitations. We were unable to include 15 trials published in languages other than English, although we did contact authors for English translations. Limitations of our data analysis include the complexity of the QI strategies, which were difficult to classify consistently, and we could not control for all potential confounding factors. We were unable to assess interactions in the meta-regression analysis (because too few trials per outcome were included), many of the analyses had substantial heterogeneity (which is to be expected in view of the large number of trials included and number of QI strategies assessed), and the definition of usual care was not consistent across the studies. Most trials reported HbA_{1c} concentrations, with fewer reporting other key aspects of diabetes management, showing that glycaemic control remains (rightly or wrongly) the major focus for management of diabetes. As a result, we were unable to undertake meta-regression for other outcomes. We cannot tell whether the interventions that seemed more effective for HbA_{1c} would have similar effects on other key endpoints, although our preliminary analysis suggests some consistency across outcomes. The data on

	Number of trials	Mean difference (95% CI)	I^2
Glycated haemoglobin (%)			
<8·0	46	−0·23 (0·34 to −0·13)	69·8
≥8·0	70	−0·46 (−0·58 to −0·35)	72·5
LDL cholesterol (mg/dL)			
<2·59	20	−0·05 (−0·09 to −0·01)	57·5
≥2·59	27	−0·15 (−0·23 to −0·08)	53·0
Systolic blood pressure (mm Hg)			
<140	32	−2·92 (−4·13 to −1·70)	72·0
≥140	33	−3·35 (−4·69 to −2·00)	38·3
Diastolic blood pressure (mm Hg)			
<80	29	−1·13 (−1·98 to −0·29)	53·3
>80	32	−1·76 (−2·47 to −1·05)	71·0

Table 3: **Effects of quality improvement interventions by baseline levels**

	All studies			Glycated haemoglobin >8·0%			Glycated haemoglobin ≤8·0%		
	Rank	Number of trials	Mean difference (95% CI)	Rank	Number of trials	Mean difference (95% CI)	Rank	Number of trials	Mean difference (95% CI)
Promotion of self management	1	60	−0·57 (−0·83 to −0·31)	4	37	−0·56 (−0·70 to −0·42)	6	23	−0·29 (−0·47 to −0·12)
Team changes	2	47	−0·57 (−0·71 to −0·42)	1	31	−0·62 (−0·79 to −0·46)	2	17	−0·46 (−0·71 to −0·21)
Case management	3	57	−0·50 (−0·65 to −0·36)	2	37	−0·61 (−0·80 to −0·42)	7	17	−0·25 (−0·44 to −0·07)
Patient education	4	52	−0·48 (−0·61 to −0·34)	3	39	−0·59 (−0·74 to −0·43)	5	13	−0·39 (−0·71 to −0·06)
Facilitated relay	5	32	−0·46 (−0·60 to −0·33)	6	19	−0·42 (−0·56 to −0·29)	1	13	−0·54 (−0·79 to −0·30)
Electronic patient register	6	27	−0·42 (−0·61 to −0·24)	5	9	−0·47 (−0·79 to −0·14)	4	18	−0·41 (−0·60 to −0·22)
Patient reminders	7	21	−0·39 (−0·65 to −0·12)	8	10	−0·39 (−0·77 to −0·00)	3	11	−0·42 (−0·70 to −0·15)
Audit and feedback	8	8	−0·26 (−0·44 to −0·08)	7	5	−0·40 (−0·77 to −0·03)	9	3	−0·06 (−0·16 to 0·06)
Clinician education	9	15	−0·19 (−0·35 to 0·03)	10	10	−0·33 (−0·57 to −0·10)	10	5	0·03 (−0·18 to 0·25)
Clinician reminders	10	18	−0·16 (−0·31 to −0·02)	9	9	−0·35 (−0·56 to −0·13)	8	9	−0·06 (−0·15 to 0·04)
All interventions		120	−0·37 (−0·45 to −0·28)		70	−0·46 (−0·58 to −0·35)		46	−0·23 (−0·34 to −0·13)

Table 4: **Ranking of quality improvement strategies across glycated haemoglobin primary and secondary meta-analyses**

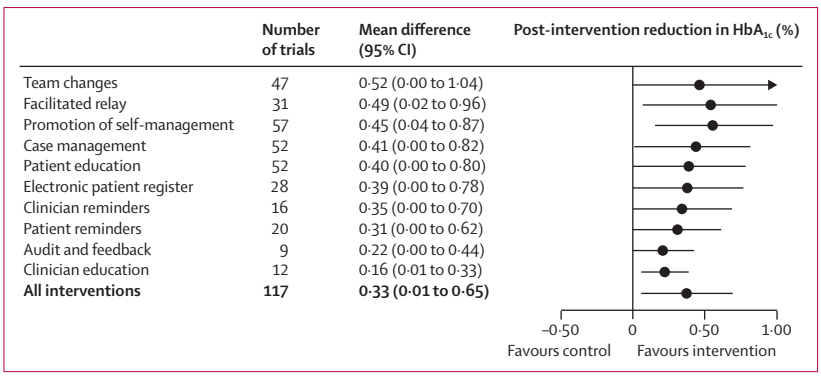

Figure 3: **Glycated haemoglobin meta-regression results**
We derived estimates from a meta-regression model, adjusting for median baseline glycated haemoglobin values (<8·0% *vs* ≥8·0%) and the median number of patients included in the randomised clinical trials (≤141 patients *vs* >141 patients).

adverse events should be interpreted with caution, since few trials reported safety data and those trials might differ systematically from trials that did not report safety data with respect to adverse events. Furthermore, trials reporting this data followed up patients for only a short duration (longest duration of follow-up was 12 months) and included a small number of patients. Most studies had short intervention durations and brief follow-up, meaning that we were unable to assess longer-term outcomes, such as mortality.

Our findings suggest that key aspects and intermediate outcomes of diabetes care can be improved and that a larger effect is evident when baseline achievement of quality indicators is poor. If implemented widely, the population benefits of the observed effects are potentially important. For example, data from the United Kingdom Prospective Diabetes Study (UKPDS) suggested that a 1% reduction in mean HbA_{1c} results in 21% fewer deaths, 14% fewer myocardial infarctions, and a 37% decrease in microvascular complications at the population level.[25] We recorded a 0·33% reduction in mean HbA_{1c}, which, if the QI strategies are employed, might translate to 7% fewer deaths, 5% fewer myocardial infarctions, and 12% fewer microvascular complications at the population level. It is plausible that further population-level improvements in these outcomes could be achieved through improved vascular risk-factor management (eg, better blood pressure and lipid control). Larger population benefits would probably accrue in populations with poor-quality indicators.

The large I^2 values from our meta-analysis results suggest that some of the QI interventions might be more effective than others. Detailed descriptions of the QI strategies were lacking in many of the trial reports and optimum combinations of the QI strategies, as well as ways of implementing and delivering the QI interventions, remain unclear. As such, although our report provides information on the relative effectiveness of the different QI strategies, how best to deliver the most effective QI strategies remains uncertain. This information is crucial, since it will allow policy makers to tailor the choice of intervention to the desired outcome, available resources, and local health-care context. Since the strategies seem more effective in patients not achieving quality indicators, careful selection of patients who will benefit most from these QI strategies needs consideration by decision makers. Moreover, since several strategies were marginally beneficial relative to other strategies, and the resource intensity of the different strategies varied significantly (probably being highest for case management and team changes), further exploration of the relative cost-effectiveness of these QI strategies is needed. Decision makers might also consider how they value the expected benefits before widely implementing such QI strategies.

Future assessments should explicitly build on the present evidence base by targeting a broad range of important diabetes process and outcome measures and carefully assessing the role of context. The QI strategy should be carefully tailored (eg, intervention mapping[26]) and the interventions should be thoroughly described.[27] Stakeholders should prioritise testing different QI strategies head-to-head in adequately powered, multi-group trials and assess explicitly postulated mechanisms of action of the interventions (ie, process assessments) to inform generalisation to different settings. Further research is needed to identify which interventions and combination of QI strategies will optimally improve important outcomes in patients with diabetes at an acceptable cost to aid health-system planning.

Contributors
JMG and KS conceived the systematic review. JMG, KS, ACT, and DM designed the systematic review. ACT, NMI, LT, JG, IH, and BV selected studies for inclusion and abstracted data. LT and TR analysed the data. ACT wrote the first draft, which was revised by all authors. All authors approved the final draft.

Conflicts of interest
We declare that we have no conflicts of interest.

Acknowledgments
We acknowledge the generous funding from the Ontario Ministry of Health and Long-term Care and the Alberta Heritage Foundation for Medical Research Interdisciplinary Team Grants program (now Alberta Innovates—Health Solutions). NI is supported by a Canadian Institutes for Health Research (CIHR) Fellowship Award; JMG and MT are supported by Canada Research Chairs. DM is supported by a University of Ottawa Research Chair. BM and MT are also supported by the Alberta Heritage Foundation for Medical Research Population Health Scholar awards. We thank the Advisory Board, Joan Canavan, Michael Hillmer, Erin Keely, and Baiju Shah for their guidance on the systematic review protocol. We thank Michelle Fiander for undertaking the searches of published work, Raymond Daniel for obtaining the articles, Steve Doucette for his statistical analysis expertise, and Alain Mayhew for guiding the review conceptualisation. We thank Natasha Wiebe, Natasha Krahn, Avtar Lal, and Mohammad Karkhaneh for their assistance with abstracting some of the included studies and appraising their study quality.

References
1 American Diabetes Association. Standards of medical care in diabetes—2010. *Diabetes Care* 2010; **33** (suppl 1): S11–61.
2 Braga M, Casanova A, Teoh H, et al. Treatment gaps in the management of cardiovascular risk factors in patients with type 2 diabetes in Canada. *Can J Cardiol* 2010; **26:** 297–302.

3 Saaddine JB, Engelgau MM, Beckles GL, Gregg EW, Thompson TJ, Narayan KM. A diabetes report card for the United States: quality of care in the 1990s. *Ann Intern Med* 2002; **136:** 565–74.

4 McFarlane SI, Jacober SJ, Winer N, et al. Control of cardiovascular risk factors in patients with diabetes and hypertension at urban academic medical centers. *Diabetes Care* 2002; **25:** 718–23.

5 Narayan KM, Benjamin E, Gregg EW, Norris SL, Engelgau MM. Diabetes translation research: where are we and where do we want to be? *Ann Intern Med* 2004; **140:** 958–63.

6 Kogan AJ. Overcoming obstacles to effective care of type 2 diabetes. *Am J Manag Care* 2009; **15** (9 suppl)**:** S255–62.

7 Simpson SH, Corabian P, Jacobs P, Johnson JA. The cost of major comorbidity in people with diabetes mellitus. *CMAJ* 2003; **168:** 1661–67.

8 Shojania KG, Ranji SR, McDonald KM, et al. Effects of quality improvement strategies for type 2 diabetes on glycemic control: a meta-regression analysis. *JAMA* 2006; **296:** 427–40.

9 Moher D, Liberati A, Tetzlaff J, Altman DG. Preferred reporting items for systematic reviews and meta-analyses: the PRISMA statement. *BMJ* 2009; **339:** b2535.

10 Shojania KG, Ranji SR, Shaw LK, et al. Diabetes Mellitus Care—vol 2. In: Shojania KG, McDonald KM, Wachter RM, Owens DK. Closing the quality gap: a critical analysis of quality improvement strategies—technical review 9. Rockville, MD: Agency for Healthcare Research and Quality, 2004.

11 Sampson M, McGowan J, Cogo E, Grimshaw J, Moher D, Lefebvre C. An evidence-based practice guideline for the peer review of electronic search strategies. *J Clin Epidemiol* 2009; **62:** 944–52.

12 Armstrong R, Waters E, Doyle J, eds. Chapter 21: reviews in public health and health promotion. In: Higgins JPT, Green S, eds. Cochrane handbook for systematic reviews of interventions version 5.1.0. Oxford: The Cochrane Collaboration, 2011.

13 Cochrane Effective Practice and Organisation of Care Group. Risk of bias—EPOC specific. http://epoc.cochrane.org/epoc-author-resources (accessed July 1, 2009).

14 Rao JN, Scott AJ. A simple method for the analysis of clustered binary data. *Biometrics* 1992; **48:** 577–85.

15 Higgins JPT, Green S, eds. Cochrane handbook for systematic reviews of interventions version 5.1.0. Oxford: The Cochrane Collaboration, 2011.

16 Kerry SM, Bland JM. The intracluster correlation coefficient in cluster randomisation. *BMJ* 1998; **316:** 1455.

17 Donner A, Klar N. Issues in the meta-analysis of cluster randomized trials. *Stat Med* 2002; **21:** 2971–80.

18 Campbell M, Grimshaw J, Steen N. Sample size calculations for cluster randomised trials. Changing Professional Practice in Europe Group (EU BIOMED II Concerted Action). *J Health Serv Res Policy* 2000; **5:** 12–16.

19 Cook C. Julia H Littell, Jacqueline Corcoran, Vijayan Pillai, Systematic reviews and meta-analysis (2008) Oxford University Press, New York 202 ISBN: 978-0-19-532654-3. *Child Youth Serv Rev* 2009; **31:** 495–96.

20 Furukawa TA, Barbui C, Cipriani A, Brambilla P, Watanabe N. Imputing missing standard deviations in meta-analyses can provide accurate results. *J Clin Epidemiol* 2006; **59:** 7–10.

21 DerSimonian R, Laird N. Meta-analysis in clinical trials. *Control Clin Trials* 1986; **7:** 177–88.

22 Higgins JP, Thompson SG. Quantifying heterogeneity in a meta-analysis. *Stat Med* 2002; **21:** 1539–58.

23 Allemann S, Houriet C, Diem P, Stettler C. Self-monitoring of blood glucose in non-insulin treated patients with type 2 diabetes: a systematic review and meta-analysis. *Curr Med Res Opin* 2009; **25:** 2903–13.

24 Duke SA, Colagiuri S, Colagiuri R. Individual patient education for people with type 2 diabetes mellitus. *Cochrane Database Syst Rev* 2009; **1:** CD005268.

25 Stratton IM, Adler AI, Neil HA, et al. Association of glycaemia with macrovascular and microvascular complications of type 2 diabetes (UKPDS 35): prospective observational study. *BMJ* 2000; **321:** 405–12.

26 van Bokhoven MA, Kok G, van der Weijden T. Designing a quality improvement intervention: a systematic approach. *Qual Saf Health Care* 2003; **12:** 215–20.

27 Michie S, Fixsen D, Grimshaw JM, Eccles MP. Specifying and reporting complex behaviour change interventions: the need for a scientific method. *Implement Sci* 2009; **4:** 40.