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Title

Process evaluation within pragmatic randomised controlled trials: what is it, why is it done, and can we find it? – a systematic review

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Abstract

Background

Process evaluations are increasingly conducted within pragmatic randomised controlled trials (RCTs) of health services interventions and provide vital information to enhance understanding of RCT findings. However, issues pertaining to process evaluation in this specific context have been little discussed. We aimed to describe the frequency, characteristics, labelling, value, practical conduct issues, and accessibility of published process evaluations within pragmatic RCTs in health services research.

Methods

We used a 2-phase systematic search process to 1) identify an index sample of journal articles reporting primary outcome results of pragmatic RCTs published in 2015, then 2) identify all associated publications. We used an operational definition of process evaluation based on the Medical Research Council's process evaluation framework to identify both process evaluations reported separately, and process data reported in the trial results papers. We extracted and analysed quantitative and qualitative data to answer review objectives.

Results

From an index sample of 31 pragmatic RCTs we identified 17 separate process evaluation studies. These had varied characteristics and only three were labelled 'process evaluation'. Each of the 31 trial results papers also reported process data, with a median of five different process evaluation components per trial. Reported barriers and facilitators related to real-world collection of process data, recruitment of participants to process evaluations, and health services research regulations. We synthesised a wide range of reported benefits of process evaluations to interventions, trials, and wider knowledge. Visibility was often poor, with 13/17 process evaluations not mentioned in the trial results paper, and 12/16 process evaluation journal articles not appearing in the trial registry.

Conclusions

In our sample of reviewed pragmatic RCTs the meaning of the label 'process evaluation' appears uncertain, and the scope and significance of the term warrant further research and clarification. Although there were many ways in which the process evaluations added value, they often had poor visibility. Our findings suggest approaches that could enhance the planning and utility of process evaluations in the context of pragmatic RCTs.

Registration

Not applicable for PROSPERO registration

Keywords

Process evaluation, pragmatic randomised controlled trials, health services research

Background

There are increasing calls for process evaluations alongside outcome evaluations of complex healthcare interventions (1-3). Defining features of 'complex interventions' include having multiple interacting components, addressing multiple outcomes, and targeting different levels of change within complex systems (4). Process evaluations increase understanding of complex healthcare interventions by studying aspects of implementation, mechanisms of impact, and context (4). They may thus shed light on the 'black box' of complex interventions and provide information to interpret outcome results and aid implementation into practice (4, 5). There has been similar increasing interest in the use of pragmatic randomised controlled trials (RCTs) to evaluate the outcomes of complex healthcare interventions (1, 6) . Pragmatic RCTs, in contrast to explanatory RCTs, aim to conduct 'real-world' evaluation of interventions, with findings that have enhanced generalisability to real world clinical practice (6).

Masterson-Algar et al. (7) highlight the importance of tailoring process evaluation guidance to the context in which it will be used, and accordingly this review aims to address gaps in knowledge about process evaluation conduct in the context of pragmatic RCTs of health services interventions. The UK Medical Research Council (MRC) published comprehensive guidance for designing and conducting process evaluations of complex interventions in 2014 (4), following earlier process evaluation frameworks by other authors (5, 8, 9). However, apart from Grant et al.'s framework (5), these were developed primarily for public health research. Although being described as applicable to health services research, many of the examples in the MRC's guidance (4) are from a public health perspective. It is therefore useful to review process evaluation conduct in health services settings as these are likely to present some unique challenges. The few published systematic reviews of process evaluation methodology focus on specific fields of clinical practice (10-15) rather than outcome evaluation methods. The pragmatic RCT method is not explicitly addressed in existing process evaluation guidance, although some pertinent methodological issues are discussed, for example avoiding Hawthorne effects from patients participating in process evaluation interviews (4). Nonetheless, concerns have been raised relating to pragmatic RCTs, such as the potential variability of usual care within control groups, and the potential impact of interventions beyond intervention recipients, such as to carers and family members (16). Process evaluations present opportunities to examine and address such issues.

This review aims to provide insight into the state of process evaluation in the context of pragmatic RCTs in health services research, along with the reported value, barriers, and facilitators to conducting them. We also examine two issues identified as problematic, both from our own experience and within the process evaluation literature. Firstly, we investigate labelling, as the label 'process evaluation' has been applied to many types of study (4), and previous reviews noted inconsistent use of the term (5, 10). We have also anecdotally encountered confusion and multiple interpretations of the meaning of the label. Secondly we examine accessibility as suboptimal

reporting has been highlighted, such as time delay and poor linkages between trial and process evaluation results publications (4).

Our aims were, within a systematically identified sample of published pragmatic health services research RCTs, to:

1. Describe the process data reported in trial results papers
2. Describe the frequency of separate process evaluation publications
3. Describe use of the label 'process evaluation'
4. Describe the characteristics of process evaluations
5. Synthesise reported practical barriers and facilitators to process evaluation conduct
6. Synthesise the reported values of the process evaluations
7. Describe the accessibility of process evaluation results

Methods

Similar to previous systematic reviews of process evaluations (11, 12) we used a 2-phase search process. We firstly systematically identified an index sample of journal articles reporting the primary outcome results of pragmatic RCTs evaluating health services interventions (hereafter referred to as 'trial results papers'), then systematically searched for all associated publications. Using an operational definition of process evaluation based on the MRC's framework (4) we then identified the process evaluations reported in associated publications, regardless of how they were labelled. We also identified any process data reported in index trial results papers which mapped to MRC process evaluation components. Figure 1 illustrates the methods and table 1 shows the MRC process evaluation components.

Figure 1: Methods overview

Table 1: MRC process evaluation components (adapted from (4), with definitions in italics where provided in original)

CONTEXT		
Causal mechanisms present within the context that act to maintain the status quo, or enhance effects	**Contextual factors** that shape theory of how the intervention works	**Contextual moderators** *Shape, and may be shaped by, implementation, intervention mechanisms, and outcomes*
IMPLEMENTATION		
Dose *How much intervention is delivered*	**Fidelity** *The consistency of what is implemented with the planned intervention*	**Adaptations** *Alterations made to an intervention in order to achieve better contextual fit*
How delivery is achieved *The structures, resources and mechanisms through which delivery is achieved*	**Reach** *Extent to which target audience comes into contact with intervention*	
MECHANISMS OF IMPACT		
Mediators *Intermediate processes which explain subsequent changes in outcome*	**Participant responses** *How participants interact with a complex intervention*	**Unanticipated pathways and consequences**

Search strategy, inclusion and exclusion criteria

In the first search phase we systematically identified an index sample of pragmatic RCTs. We limited the search to a single year, 2015, (selected to allow time for related publications to appear) and to Medline Core Clinical Journals to provide a feasible number of papers. We searched Medline (Ovid), the full search strategy is given in additional file 1.

Phase 1 inclusion criteria (PICOS)

- Population: any
- Intervention: any delivered by a health service
- Comparator: any

- Outcome: any
- Study: pragmatic randomised controlled trial (defined as use of the word 'pragmatic' to describe the RCT in the title or abstract)

Phase 1 exclusion criteria

1. Papers not reporting the primary trial outcome
2. RCTs labelled as pilot, feasibility, or implementation studies.
3. Trials of health interventions not delivered within health services, for example by charities

In phase 1, two reviewers (CF and IS) independently screened titles and abstracts against the inclusion and exclusion criteria, obtaining full-texts as necessary. Any disagreements were discussed with ST and HP to reach a final decision on inclusion.

In phase 2 (see figure 1) citation searches for each trial results paper were conducted using both Web of Science (Clarivate Analytics) and Google Scholar. Corresponding authors were sent one reminder if we received no reply following the first contact. The searches were originally conducted, and authors contacted, in March and April 2018. Search phase 2 was updated in December 2019 apart from author contact.

We used an operational definition of 'process evaluation' to identify papers for inclusion regardless of how they were labelled by the study authors. As shown in figure 1, included studies investigated one or more MRC process evaluation components and (to distinguish them from trial secondary analyses or sub-studies) were aimed at increasing understanding of the intervention or trial. One reviewer (CF) screened all publications and discussed all considered to possibly be process evaluations with HP and ST in a consensus meeting to agree the final sample of process evaluations.

Several index trials were funded by the UK National Institute for Health Research's *Health Technology Assessment* (HTA) programme. This programme requires results to be published as a monograph in the *Health Technology Assessment* journal, additional to any other journal

publications. We therefore reviewed the full texts of all HTA monographs to check for process evaluation results.

Data extraction and analysis

As this was a review of methodology rather than findings, we did not conduct any appraisal of quality of the included process evaluation studies. We extracted quantitative data to an Excel database and conducted descriptive analysis using SPSS v25. We extracted qualitative data as sections of text from PDFs of publications and used NVivo v11 for data management and to aid thematic analysis.

Where the methods or results from a single trial or process evaluation were reported in more than one publication (e.g. HTA monograph and separate journal paper) we extracted all available data from all publications but treated the publications as a single case. CF extracted and analysed all data independently, apart from the MRC process evaluation components as detailed below.

Data extracted from the trial results papers

We extracted descriptors of all trials, and the data fields and their operationalisation are shown in additional file 2. We mapped data items reported in the results sections to the MRC process evaluation framework (4) (see table 1) to identify process data within the trial results papers. For example, a trial flow diagram (process data item) mapped to the process evaluation component 'reach'. For each trial we recorded whether each process evaluation component was reported in the trial results paper at least once. We piloted this process, and as the MRC guidance does not provide clear definitions for some components, we made a list of the types of data which mapped to each component (for example subgroup analyses mapped to 'contextual moderators'). Three reviewers (CF, GF, and IS) independently extracted data from the first three trials, compared results, and agreed initial mappings. We used these to extract data from four further trials, and again compared

and discuss findings. CF then extracted data for the remaining trials, discussing any new mappings or uncertainties with the other authors.

Data extracted from process evaluation publications

Table 2 shows the outcomes extracted for each process evaluation publication. O'Cathain et al. (17) noted that the value of qualitative research within RCTs is often not clearly articulated in publications, and we noted the same during scoping this review. We therefore operationalised 'reported value' as any reported rationales for undertaking a process evaluation, or any reported implications of having undertaken it or of its findings. This allowed us to capture any anticipated or observed benefits of the process evaluation or use of the knowledge it produced.

Table 2: Data outcomes for process evaluation publications

Review objective	Type of data	Outcomes
Labelling	Quantitative	• Use of label 'process evaluation' anywhere in the set of papers for the trial • Use of keyword 'process evaluation' for indexing
Characteristics	Quantitative	• Process evaluation components (mapped from aims and qualitative findings) • Whether processes related to the intervention or trial • Methodology • Data collection method
Reported barriers and facilitators	Qualitative	• Practical issues relating to designing or operationalising the process evaluation
Reported value	Qualitative	• Reported rationales for undertaking, or implications of the process evaluation
Accessibility	Quantitative	• Publishing journal • Time to publication from trial results paper • Search method required to locate paper • Mention of the process evaluation in trial results paper • Where in paper the trial first named or referenced

		• Inclusion in trial registry

A completed PRISMA checklist is in additional file 3

Results

Figure 2 shows the results of search phases 1 and 2. The first search phase yielded 31 journal articles reporting primary outcome results from pragmatic RCTs, and the second phase located 133 associated publications. We categorised 21 of these 133 associated publications as process evaluation results. These covered 17 separate process evaluation studies, as some were published in more than one paper.

Figure 2: Adapted PRISMA flow diagram (18)

[footnote for figure 2] *searches conducted in order stated and each record included only under search method first found

Characteristics of the sample of pragmatic RCTs

The sample of pragmatic RCTs (n=31) was highly variable in terms of intervention and trial characteristics (see additional file 4 for details of the RCTs). They covered 20 different clinical specialties and 17 different combinations of professionals involved in intervention delivery. Most interventions (28/31) were received by patients only, with the remainder directed at staff or staff and patients. Table 3 summarises further characteristics of the included trials.

Table 3: Characteristics of the index sample of pragmatic RCTs

Randomisation level		**Comparator**	
Individual	25	Usual care	15
Cluster	6	Other intervention(s)	10
		Stepped-wedge control period	2
Design		Comparing two settings	1
2-arm	22	Comparing two deliverers	1
Non-inferiority (2-arm)	4	No intervention	1
3-arm	3	Sham clinical procedure	1
Crossover	1		
Stepped-wedge	1	**Publishing journal**	
		British Medical Journal	7
Primary outcome result		Lancet	7
No evidence of effect	15	JAMA	5
Evidence of effect	11	Canadian Medical Association Journal	2
Non-inferiority trial	4	JAMA Pediatrics	2
Unclear	1	Critical Care Medicine	1
		Gut	1
Funder		JAMA Internal Medicine	1
Public	25	JAMA Psychiatry	1
Multiple funders	3	Journal of Allergy and Clinical Immunology	1
Charity	1	New England Journal of Medicine	1
Independent Organisation	1	Nursing Research	1
Not reported	1	The American Journal of Psychiatry	1
Type of intervention		**Country**	
Pharmacological treatment strategy	9	UK	12
Clinical procedure	4	USA	8
Therapy intervention	4	Australia	3
Clinical treatment strategy	3	Netherlands	2
Model of care provision	3	Brazil	1
Reminder system	3	Canada	1
Health promotion	3	France	1
Medical device	2	France, Belgium and Switzerland	1
		Hong Kong	1
		North America*	1

*Countries not specified in original article

Process evaluations

Twelve of the 31 pragmatic RCTs had at least one associated publication which we classified as reporting process evaluation results. We identified 17 distinct process evaluation studies, with two trials (19, 20) having three process evaluations and one trial (21) having two process evaluations. Although it is likely that these multiple process evaluation studies in the same trials formed part of one overall process evaluation, as each was presented as a distinct study, we extracted data from each individually. The 17 process evaluation studies were published across 21 publications, as some were published in both a journal article and HTA monograph.

The 17 process evaluation studies are listed in table 4.

Table 4: Included process evaluation studies [multi-page table, please find at end of this document]

Labelling

In the trial results papers the label 'process evaluation' was never used to describe the process data. Five trials (19, 43-46) used variations of the labels 'process outcome' or 'process measure' for some data, although this use was infrequent and inconsistent.

Only three of the 17 studies we classified as process evaluations were labelled as process evaluations (30, 31, 33, 34). One further study was not explicitly labelled as a process evaluation but this was implied as the MRC process evaluation guidance was cited as a rationale for undertaking it (28). Only one of the three studies labelled as 'process evaluation' was clearly labelled as such in the article title (31). One was described as 'informing a process evaluation' in the main article text (30). The other was referred to as a process evaluation by the trial results paper (47), but not labelled as such in the journal article (33) or HTA monograph (34) reporting it.

Notably, one trial (19) had three qualitative studies published in the same journal: a qualitative interview study labelled as 'a process evaluation' (31), a qualitative questionnaire study reported as 'informing the process evaluation' (30), and a qualitative interview study labelled as a 'qualitative evaluation' (29). However the articles indicated that the studies were interlinked, and formed a 'sequential mixed-methods study' (31).

None of the journal articles reporting process evaluation results (n=16) used the keyword "process evaluation"**.**

Characteristics of process evaluation studies

Of the 17 process evaluation studies identified nine were quantitative (22, 24-28, 32, 37, 39, 40) and eight qualitative (23, 29-31, 34-36, 38, 41, 42). The three labelled as process evaluations were all qualitative (30, 31, 33, 34). There were a variety of data collection methods as can be seen in table

4, with the use of trial data (n=5), interviews (n=4), and questionnaires (n=3) being most common. The reporting articles of three quantitative process evaluations (25, 27, 37) also presented detailed descriptions of trial or process evaluation methods.

Twelve process evaluations evaluated only intervention processes (22, 24, 28-31, 33-36, 38-42), and five evaluated both trial and intervention processes (23, 25-27, 32, 37). Of the latter, one explored patients' experiences of trial participation qualitatively (23) and two described in detail the trial processes undertaken to ensure fidelity (27, 37). One investigated the trial processes for defining the pragmatic RCT trial population, by undertaking independent assessment of the radiographs used by recruiting surgeons to determine trial inclusion (25). Another investigated the impact of surgeon and patient treatment preferences on trial recruitment and adherence to trial follow up (32). Further details of the processes evaluated by all 17 studies can be found in table 4.

Process evaluation components reported in the trial results papers and process evaluation papers

All 31 pragmatic RCTs reported process data in their trial results paper(s), with a median of five different MRC process evaluation components (IQR=3; range 1-9) reported at least once per trial results paper. Further details can be found in additional file 4.

Figure 3 shows the percentages of pragmatic RCTs (n=31) reporting each MRC process evaluation component in their trial results paper(s), and the percentages of process evaluation studies (n=17) reporting each component.

Figure 3: MRC process evaluation components reported in the trial results papers and process evaluations

Although we found most of the identified process evaluation components to be reported in the main trial papers and/or in papers labelled process evaluations, the component 'how delivery is achieved' was only reported in process evaluation papers and 'dose' was only reported in trial results papers.

The other 'implementation' components – 'fidelity', 'adaptations', and 'reach' were more frequently reported in the trial results papers than the process evaluation papers.

Additional file 4 lists the included 31 pragmatic RCT results papers, and the process evaluation components reported in each. Additional file 5 shows the data items we mapped to each process evaluation component in the trial results papers and process evaluation papers.

Barriers and facilitators to conducting process evaluations

We identified three main themes of reported barriers and facilitators to conducting process evaluation within pragmatic RCTs, shown in figure 4. These themes were: collecting complete and accurate data in health services settings; recruiting the process evaluation participants; and complex regulatory systems (only barriers identified within this theme).

Figure 4: Reported barriers and facilitators

Reported value of the process evaluation studies

We identified three main themes relating to the reported value of the process evaluation: 1) whether the process evaluation added value to the intervention; 2) whether the process added value to the trial; or 3) whether the process evaluation's value related to something external to the trial and intervention. Figure 5 shows main themes and sub-themes, and table 5 shows the number of process evaluations mentioning each subtheme and examples of data relating to each subtheme. A full table of all data for each subtheme is in additional file 6.

Figure 5: Synthesis of reported values of process evaluation studies

Table 5: Reported value subthemes

Subtheme	Number of process evaluations reporting this value (n=17)	Examples of reported values in subtheme

Adding to wider knowledge	16	Informing future trial design (23, 25, 27, 28, 32, 33, 38) Improving future design of similar interventions (22, 24, 33)
Informing post-trial transfer of intervention to practice	15	Providing evidence of feasibility (28, 33) Highlighting potential disadvantages of intervention to facilitate consent discussions with patients (23)
Identifying intervention improvements	10	Adding stronger monitoring protocols to promote adherence (33) Recommendation to research effectiveness over time (29)
Providing reasons for trial results	8	Reasons for non-positive results (33, 38) Reasons for positive results (28-31, 35)
Addressing an identified concern about the intervention	7	Concern about effect of cognitive impairment on effectiveness (22) Concern about participant adherence (33, 35)
Adding information not provided by the trial	6	Participant and deliverer experiences and perceptions (23, 35) Nuance and context (23)
Increasing accuracy of trial results	6	Investigating threats to internal validity (26) Accurately defining trial population (25)
Understanding how the intervention works	4	Understanding what was delivered in a flexible intervention (38) Mechanisms of impact (28)
Building on trial data	2	Exploring findings of subgroup analysis (29)
Understanding applicability of trial results	2	Evaluating whether intended pragmatic trial population achieved (25)
Improving usual care at trial sites	1	Highlighting gaps in current care provision (27)
Meeting pragmatic RCT reporting requirements	1	Adhere to reporting standards for pragmatic and non-pharmacological trials (27)
Meeting recommendation to conduct process evaluation	1	Following MRC recommendations (28)

Reported value specifically relating to the pragmatic RCT

The reports of three process evaluations belonging to the same trial (25-27, 32) (not labelled as process evaluations) discussed the pragmatic nature of the trial and the process evaluations' contributions in detail. All highlighted how they supported validity of trial results, by addressing potentially problematic areas of the pragmatic trial design. In one process evaluation (25, 26) authors report it confirmed that the achieved trial sample was pragmatic as intended, and endorsed the pragmatic methods used to determine trial eligibility. In another (26, 27) authors describe how it provided evidence of a good standard of, and therefore comparable, real-world clinical practice in the intervention and usual care delivered in the pragmatic trial across trial sites. In the final process

evaluation (26, 32) the impact of patient and surgeon preference on internal and external validity is investigated, acknowledging that this is a threat to the validity of trial findings from the real-world setting.

No other reports explicitly discussed the pragmatic nature of the RCT. However one process evaluation (38) used a qualitative content analysis to 'describe the pragmatic reality' of intervention delivery, and its authors emphasise that this was important to allow post-trial replication of a flexible intervention with a large potential variability of delivery in a complex setting. In the report of a qualitative interview study with intervention recipients and providers (42), authors highlight that these process evaluation data provide real-life insights to aid post-trial implementation.

Accessibility of process evaluation studies

Thirteen of the 17 process evaluation studies (22, 24, 28-32, 35-38, 40-42) had no mention in their corresponding index trial results papers.

Journal articles reporting process evaluation results (n=16) were published a median of 15.5 months (range -3 – 42; IQR 18.25) after the corresponding index trial results papers. None were published in the same journals as the trial results papers. Two trials had multiple process evaluation studies published in the same journals (25, 27, 29-31). Twelve of the 16 process evaluation journal articles (22, 28-32, 35, 37-39, 41) were not included in the trial registry entries. A forward citation search of the index trial results paper was required to locate 9/16 of the process evaluation journal articles. Two process evaluation journal articles (37, 38) did not appear in the trial results paper, trial registry, or forwards citation searches. These were located by chance before contacting authors as they were mentioned in other papers associated with the trials. All process evaluation journal articles named or referenced the corresponding trial, however 9/16 did not name or explicitly link it to the trial in the title or abstract (22, 24, 25, 29-31, 39-41).

Six of the 12 trials with process evaluation(s) were funded by the UK NIHR HTA programme and published an HTA monograph (23, 26, 34, 36, 42, 48). One process evaluation was only reported in the HTA monograph (23), not a journal article. Six process evaluation studies were published at least in part in both a journal article (25, 27, 32, 33, 35, 41) and HTA monograph (26, 34, 36, 42). Two process evaluations were part of HTA funded trials, however results were not reported in the HTA monographs, only in journal articles (28, 38).

The five HTA monographs reporting process evaluation findings (23, 26, 34, 36, 42) all appeared in the trial registry and were published a median of 1 month (IQR 3; range 0-4) after the trial results papers. Combining publication data for journal articles and HTA monographs therefore improved these aspects of accessibility for the whole sample of process evaluations (n=17). If the earliest of the HTA monograph and journal article for each process evaluation is included, process evaluation studies (n=17) were published a median of five months (range 0-36; IQR 15.5) after the trial results. Similarly, 9/17 process evaluations were published in a publication included in the trial registry entry.

Discussion

Summary of findings

We identified a range of reported benefits of process evaluations to the interventions they evaluated, to the associated pragmatic RCTs, and beyond to wider knowledge. Nonetheless, only approximately one third (12/31) of the pragmatic RCTs included in this review had published process evaluations. However, many data items were reported in trial results papers, which we mapped to MRC-defined process evaluation components. Very few (3/17) studies which we categorised as process evaluations were labelled as such, and the label was used inconsistently in those which did employ it. The 17 process evaluations utilised a variety of qualitative and quantitative methods and examined a wide range of process evaluation components, including trial processes. We identified several practical barriers and facilitators to their design and conduct, and found visibility and

342 accessibility of process evaluation results were often suboptimal. We now discuss these findings and
343 draw recommendations, with a summary of recommendations presented in table 6.

344 **Value, inclusion, and definitions**

345 In the design and evaluation of complex interventions there is increasing recognition that process
346 evaluations are necessary (2), and calls for their routine inclusion (1). In support of this, we
347 identified a wide range of ways in which process evaluations may add value to interventions and
348 trials. Some of the values we identified resonate with previous reviews (10, 49), such as informing
349 post-trial implementation of interventions into practice and contributing to wider knowledge. We
350 also identified some less recognised, for example improving the standard of care at trial sites by
351 exposing gaps in current care provision (27). These findings are useful to researchers to aid
352 reflection on the potential value of process evaluations, and articulation of this to stakeholders. We
353 did not investigate whether the reported value of the process evaluations related to whether or not
354 the associated trial showed evidence of effect, however this would be useful to include in future
355 reviews.

356 Our findings suggest that, at least in 2015, process evaluations were far from routine in the health
357 services research context. Nonetheless, our mapping of process evaluation components to
358 outcomes reported in the trial results papers suggests that process was considered, even if they did
359 not publish a separate process evaluation paper. This leads us to question the definition of process
360 evaluation. Our perception of a process evaluation is that it is more substantial than measuring a
361 single process outcome, however when extensive process data are reported within trial results the
362 distinction between 'a process evaluation' and this suite of process data is less clear.

363 Further need for definitional clarity is demonstrated by the paucity and inconsistency of use of the
364 label 'process evaluation' in the 17 separate studies. This echoes a finding of a previous systematic
365 review (10), which reported only 32 of 124 'process evaluations' used the label – a similar proportion
366 to the labelling in our studies.

The MRC guidance (4) states that there is no unified definition of process evaluation, and the theoretical scope laid out in process evaluation frameworks and guidance (4, 5, 8, 9) is very broad, encompassing many methods, areas of investigation, and scales of study. This wide variety of possible characteristics of process evaluation is likely to generate confusion and may explain the inconsistent use of the label. Furthermore, the MRC guidance (4) only discusses process evaluation of interventions, however in common with other authors (5, 50-53) we identified the important role for process evaluation in evaluating trial processes, such as recruitment and patient experience of trial participation. We therefore believe simply repeating previous calls for clearer labelling (5) is insufficient and recommend further discussion about the meaning of the term 'process evaluation'.

Barriers and facilitators

We identified several barriers and facilitators to process evaluation researchers collecting optimal data, recruiting participants, and working within regulatory frameworks in the real-world health service contexts in which pragmatic RCTs operate. Several of these identified challenges and enablers are not addressed in the MRC guidance (4), however a previous systematic review (10) recommended monitoring and reporting process evaluation recruitment. We recommend researchers continue to share their experiences of challenges and successful strategies for conducting process evaluations in this context.

Indexing and visibility

Process evaluations often had poor visibility through not being mentioned in trial results papers, and/or not included in trial registries. Furthermore, time delay to publication, not naming trials in titles or abstracts, and not labelling or indexing as process evaluations were significant barriers to locating articles in citation searches. Reporting guidance for process evaluations is available (4, 5), emphasising the importance of linking outcome and process evaluation papers. Our findings demonstrate the importance of following these recommendations, specifically that outcome results journal articles should mention that a process evaluation was undertaken, and process evaluation

journal articles should name or explicitly link to the trial in their title or abstract. We additionally recommend process evaluation articles are included in trial registries, and that mention of any process evaluation undertaken could usefully be added to relevant CONSORT trial reporting checklists (54, 55). We also highlight that some HTA monographs reported process evaluations alongside trial outcomes and integrated discussion of findings (23, 26, 34, 36, 42), and therefore demonstrate a useful reporting format.

Table 6: Summary of recommendations

Recommendations for process evaluation design	• Consider the identified potential values of process evaluation within pragmatic RCTs and how these may be realised and articulated to stakeholders • We encourage debate about the meaning of the label 'process evaluation' and how it may be more consistently applied
Recommendations for process evaluation conduct	• Consider the identified barriers and facilitators and how to address these when conducting process evaluations in health services settings
Recommendations for process evaluation dissemination	• Ensure process evaluation publications are included in the trial registry entry • Ensure process evaluations are mentioned in journal articles reporting the parent trial, and consider adding this item to relevant CONSORT checklists • Ensure process evaluation publications name or refer to the parent trial in the title or abstract • Publish strategies for conducting successful process evaluations and addressing challenges in health services settings, such as to recruiting process evaluation participants and collecting data

Strengths and limitations

The key design strength of this review was using an index sample of pragmatic RCTs, then identifying any reported 'process evaluation' using an operational definition. This provided valuable information on process evaluation frequency and accessibility, and highlighted inconsistency of use of the 'process evaluation' label. However, a limitation is that we could include only a sample of pragmatic RCTs. Limiting to trials published in MEDLINE *Core Clinical Journals* means findings are likely reflective of well-funded health services research trials but may not be representative of trials

published elsewhere. We also only included RCTs described as 'pragmatic' in the title or abstract. As such labelling is not an essential reporting criterion for pragmatic RCTs (54), trials were not identified for inclusion if they only used the term 'pragmatic' elsewhere in the paper.

Limiting index trial inclusion to publication in 2015 ensured a reasonable length of time for publication of process evaluation papers, and indeed two process evaluations were published in 2019. However, this also means findings may not be representative of process evaluations being designed and conducted now. Our findings can therefore only highlight potential areas of uncertainty, difficulty, or opportunity, with alternative research approaches such as surveys or interviews needed to examine current practice. We also acknowledge as a limitation that we used the MRC process evaluation framework to identify and describe process evaluations, when most process evaluations in our sample (associated with trials published in 2015) would very likely have been designed prior to publication of the MRC guidance (4).

The search methods for identifying associated publications were comprehensive, with a good response rate from authors. We used a robust process for deciding which publications to categorise as process evaluations, and the team included highly experienced health service researchers with experience of designing and conducting process evaluations. We acknowledge others may disagree with our operational definition and categorisations, however highlight this ambiguity is itself an important finding.

Double data extraction was carried out on fields we considered to be subjective, increasing the reliability of findings. There are currently no agreed quality assessment standards for process evaluations (4) and therefore we did not appraise the quality of included studies, however doing so would add to and strengthen the findings.

Conclusion

This review provides valuable insight into the frequency and characteristics of process evaluations, within a sample of systematically identified index pragmatic RCTs published in a single year, and highlights challenges and enablers to their practical conduct in health services settings. Significantly, it suggests that the definition of process evaluation is inconsistent, and that the meaning of the term requires clarification. Despite the wide range of identified values of process evaluations this review highlights important problems with accessibility, which are likely barriers to fully realising this value. Often process evaluations are invisible in pragmatic RCT reporting, and we therefore make several straightforward but significant reporting recommendations.

List of abbreviations

HTA – Health Technology Assessment (UK *National Institute of Health Research* funding programme)

MRC – Medical Research Council

RCT – randomised controlled trial

Additional files

File	File name	Title	Description
Additional file 1	Additional file 1.doc	MEDLINE (Ovid) search strategy	MEDLINE (Ovid) search strategy
Additional file 2	Additional file 2.doc	Trial descriptor data fields	Trial descriptor data fields
Additional file 3	Additional file 3.doc	PRISMA 2009 checklist	Completed PRISMA checklist (NB: page numbers correct in submitted manuscript)
Additional file 4	Additional file 4.doc	Included pragmatic RCTs	Details and references of the 31 index pragmatic RCTs
Additional file 5	Additional file 5.doc	Items mapped to each process evaluation component	Items mapped to each process evaluation component

Additional file 6	Additional file 6.doc	All extracted values of process evaluation	All extracted values of process evaluation

446

447

448 **Declarations**

449 **Ethics approval and consent to participate**

450 Not applicable

451 **Consent for publication**

452 Not applicable

453 **Availability of data and materials**

454 The datasets used and/or analysed during the current study are available from the corresponding
455 author on reasonable request.

456 **Competing interests**

457 The authors declare they have no competing interests

458 **Funding**

459 CF was funded by a PhD studentship awarded by Queen Mary University of London. This report is
460 independent research supported by the National Institute for Health Research. ST is supported by
461 the National Institute for Health Research ARC North Thames. The views expressed in this
462 publication are those of the authors and not necessarily those of the National Institute for Health
463 Research, the NHS or the Department of Health and Social Care.

464 **Authors' contributions**

CF, supervised by ST and HP, designed the review and conducted the searches, data extraction, and analysis. GF and IS undertook double data extraction and checking. All authors read and approved the final manuscript.

Acknowledgements

Thank you to all corresponding authors.

Thank you to Dr Nina Fudge for reviewing draft manuscripts, and to Paula Funnell, faculty liaison librarian, for advising on the search strategy.

Table 4

Reference(s)	Description of process evaluation	Methodology and data collection methods	Intervention or trial processes	Process evaluation components	Labelled as process evaluation
Ball 2018 (22)	Investigated effect of mild cognitive impairment in participants on intervention outcome	Quantitative, Trial dataset	Intervention	Contextual moderators	No
Clark 2015 (23)	Explored patient perceptions of acceptability of intervention in both groups, and motivations for agreeing or refusing to participate in the trial	Qualitative, Interviews	Intervention and trial	Participant responses Reach Contextual moderators Unintended consequences Causal mechanisms in context	No
Grubbs 2015 (24)	Investigated which factors predicted patient uptake of an element of the intervention found to mediate the primary outcome	Quantitative, Medical record review	Intervention	Contextual moderators	No
Handoll 2016 (25) Handoll 2015 (26)	Described how the intended fracture population was practically achieved in pragmatic RCT, including results of formal independent assessment and classification of trial fractures	Quantitative, Detailed author description, Trial dataset	Intervention and trial	Reach	No
Handoll 2014 (27) Handoll 2015 (26)	Described processes undertaken to ensure usual care received by both groups in trial was good quality and comparable, including results of methods described	Quantitative, Detailed author description, Deliverer self-report	Intervention and trial	How delivery is achieved Fidelity	No
Hall 2017 (28)	Investigated mediators of intervention outcome	Quantitative, Trial dataset	Intervention	Mediators	No
Hill 2016 (29)	Explored perceptions of ward staff about how intervention contributed to outcome, and experience of	Qualitative, Focus groups	Intervention	How delivery is achieved Participant responses Contextual moderators	No

Reference(s)	Description of process evaluation	Methodology and data collection methods	Intervention or trial processes	Process evaluation components	Labelled as process evaluation
	intervention being delivered on their ward			Causal mechanisms in context Contextual factors shaping intervention theory	
Hill 2016 (30)	Explored patient experiences of intervention and perceived barriers to engagement	Qualitative, Semi-structured questionnaires	Intervention	Participant responses Causal mechanisms in context Contextual factors shaping intervention theory	Yes
Hill 2015 (31)	Explored perceptions of intervention deliverers of delivering intervention and how the intervention worked	Qualitative, Focus groups, interview, field notes, intervention notes	Intervention	How delivery is achieved Contextual factors shaping intervention theory Participant responses Causal mechanisms in context	Yes
Keding 2019 (32) Handoll 2015 (26)	Explored how patient and surgeon treatment preferences impacted recruitment, trial conduct, and patient outcomes	Quantitative, Trial dataset	Intervention and trial	Reach Participant responses Contextual moderators	No
Knowles 2015 (33) Littlewood 2015 (34)	Explored patient experiences of the intervention, including acceptability, ease of use, barriers to engagement, content, accessibility, and support. Also explored healthcare professional perceptions of feasibility and which patients intervention most suited to.	Qualitative, Interviews	Intervention	Participant responses How delivery is achieved Reach Causal mechanisms in context Contextual moderators Unintended consequences Contextual factors shaping intervention theory	Yes
Nichols 2017 (35) Williams 2015 (36)	Explored experiences of patients about intervention, with focus on patient adherence, and how changed over time	Qualitative, Interviews (longitudinal)	Intervention	Participant responses Causal mechanisms in context Contextual moderators How delivery is achieved	No
Novak 2015 (37)	Investigated whether and how trial sites supplied thawed plasma in a timely manner	Quantitative, Detailed author description,	Intervention and trial	Fidelity How delivery is achieved	No

Reference(s)	Description of process evaluation	Methodology and data collection methods	Intervention or trial processes	Process evaluation components	Labelled as process evaluation
		Observation, reports from sites			
Sands 2016 (38)	Explored how the flexible complex intervention was delivered in real-world complex settings	Qualitative, Trial dataset	Intervention	How delivery is achieved Adaptations Contextual moderators Participant responses Unintended consequences Contextual factors shaping intervention theory Fidelity	No
Saville 2016 (39)	Explored preferences and experiences of intervention deliverers about various aspects of intervention	Quantitative, Questionnaire	Intervention	How delivery is achieved	No
Tjia 2017 (40)	Investigated patients' perceptions of benefits and drawbacks of intervention	Quantitative, Questionnaire	Intervention	Participant responses	No
Vennik 2019 (41) Williamson 2016 (42)	Explored views and experiences of parents and practice nurses of intervention and usual care	Qualitative, Interviews	Intervention	Participant responses How delivery is achieved Contextual factors shaping intervention theory Causal mechanisms in context Unintended consequences	No

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Figure 1

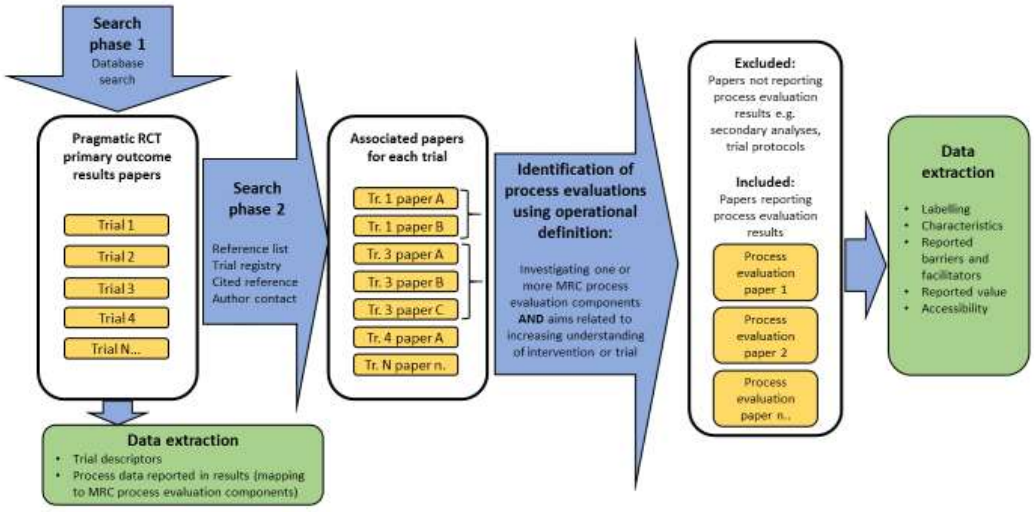
Search phase 1
Database search
Pragmatic RCT primary outcome results papers
Trial 1
Trial 2
Trial 3
Trial 4
Trial N...
Search phase 2
Reference list
Trial registry
Cited reference
Author contact
Associated papers for each trial
Tr. 1 paper A
Tr. 1 paper B
Tr. 3 paper A
Tr. 3 paper B
Tr. 3 paper C
Tr. 4 paper A
Tr. N paper n.
Identification of process evaluations using operational definition:
Investigating one or more MRC process evaluation components AND aims related to increasing understanding of intervention or trial
Excluded:
Papers not reporting process evaluation results e.g. secondary analyses, trial protocols
Included:
Papers reporting process evaluation results
Process evaluation paper 1
Process evaluation paper 2
Process evaluation paper n..
Data extraction
Labelling
Characteristics
Reported barriers and facilitators
Reported value
Accessibility
Data extraction
Trial descriptors
Process data reported in results (mapping to MRC process evaluation components)

Figure 2

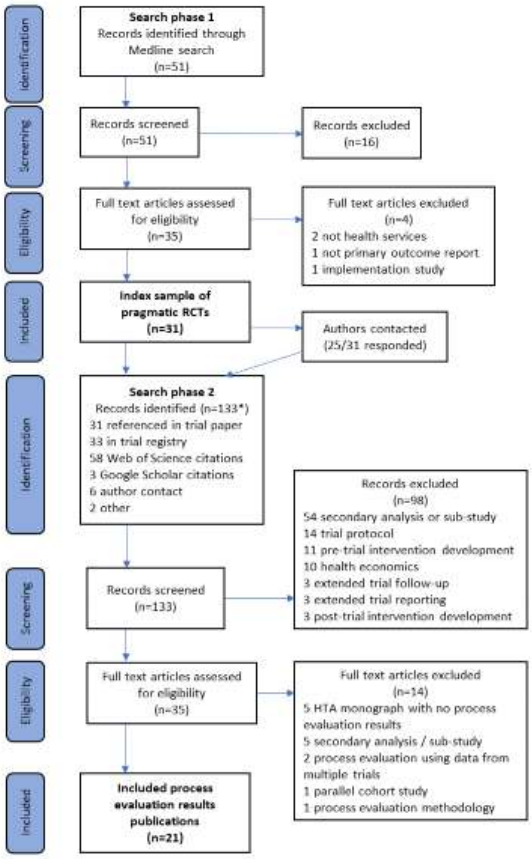
Identification
Search phase 1
Records identified through Medline search (n=51)
Screening
Records screened (n=51)
Records excluded (n=16)
Eligibility
Full text articles assessed for eligibility (n=35)
Full text articles excluded (n=4)
2 not health services
1 not primary outcome report
1 implementation study
Included
Index sample of pragmatic RCTs (n=31)
Authors contacted (25/31 responded)
Identification
Search phase 2
Records identified (n=133*)
31 referenced in trial paper
33 in trial registry
58 Web of Science citations
3 Google Scholar citations
6 author contact
2 other
Screening
Records screened (n=133)
Records excluded (n=98)
54 secondary analysis or sub-study
14 trial protocol
11 pre-trial intervention development
10 health economics
3 extended trial follow-up
3 extended trial reporting
3 post-trial intervention development
Eligibility
Full text articles assessed for eligibility (n=35)
Full text articles excluded (n=14)
5 HTA monograph with no process evaluation results
5 secondary analysis / sub-study
2 process evaluation using data from multiple trials
1 parallel cohort study
1 process evaluation methodology
Included
Included process evaluation results publications (n=21)

Figure 3

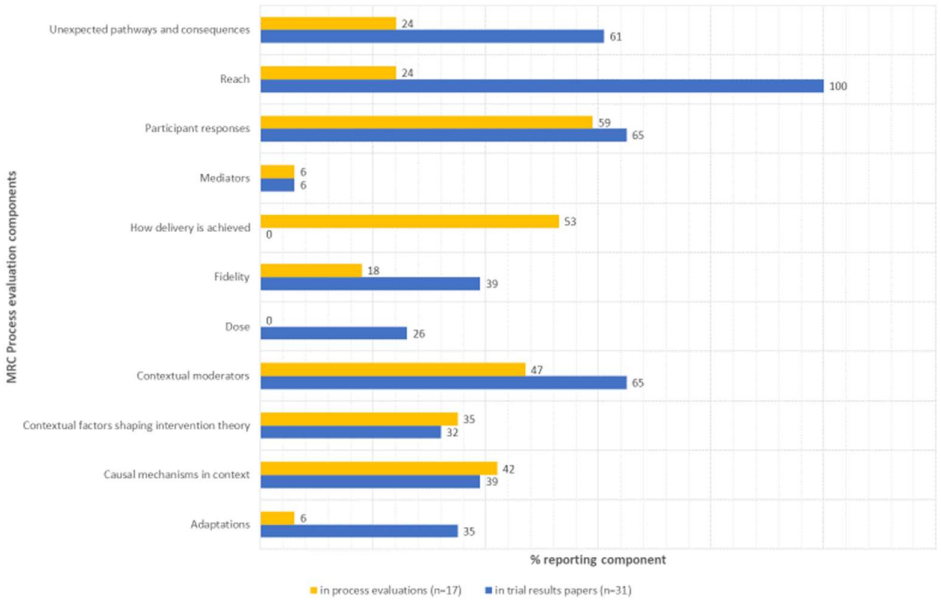
Unexpected pathways and consequences
24
61
Reach
24
100
Participant responses
59
65
Mediators
6
6
How delivery is achieved
53
0
Fidelity
18
39
Dose
0
26
Contextual moderators
47
65
Contextual factors shaping intervention theory
35
32
Causal mechanisms in context
42
39
Adaptations
6
35
MRC Process evaluation components
% reporting component
in process evaluations (n=17)
in trial results papers (n=31)

Figure 4

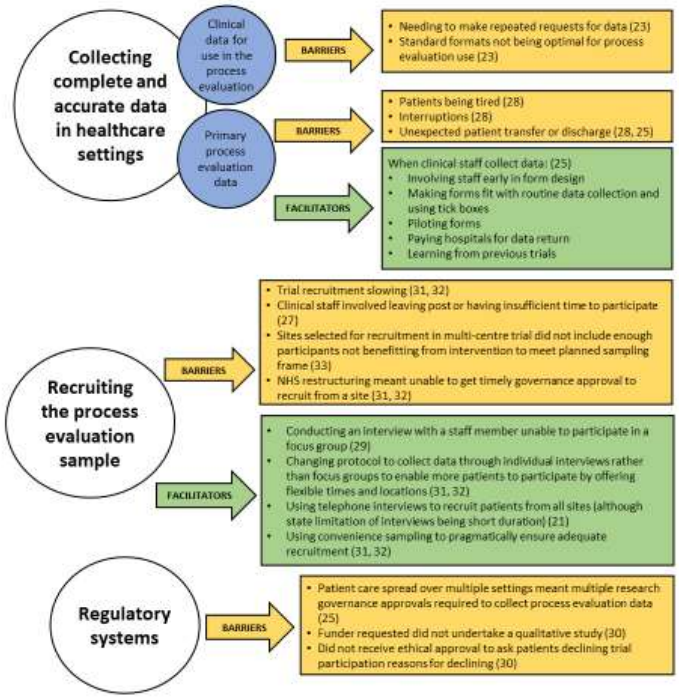
Collecting complete and accurate data in healthcare settings
Clinical data for use in the process evaluation
Primary process evaluation data
BARRIERS
Needing to make repeated requests for data (23)
Standard formats not being optimal for process evaluation use (23)
BARRIERS
Patients being tired (28)
Interruptions (28)
Unexpected patient transfer or discharge (28, 25)
FACILITATORS
When clinical staff collect data: (25)
Involving staff early in form design
Making forms fit with routine data collection and using tick boxes
Piloting forms
Paying hospitals for data return
Learning from previous trials
Recruiting the process evaluation sample
BARRIERS
Trial recruitment slowing (31, 32)
Clinical staff involved leaving post or having insufficient time to participate (27)
Sites selected for recruitment in multi-centre trial did not include enough participants not benefitting from intervention to meet planned sampling frame (33)
NHS restructuring meant unable to get timely governance approval to recruit from a site (31, 32)
FACILITATORS
Conducting an interview with a staff member unable to participate in a focus group (29)
Changing protocol to collect data through individual interviews rather than focus groups to enable more patients to participate by offering flexible times and locations (31, 32)
Using telephone interviews to recruit patients from all sites (although state limitation of interviews being short duration) (21)
Using convenience sampling to pragmatically ensure adequate recruitment (31, 32)
Regulatory systems
BARRIERS
Patient care spread over multiple settings meant multiple research governance approvals required to collect process evaluation data (25)
Funder requested did not undertake a qualitative study (30)
Did not receive ethical approval to ask patients declining trial participation reasons for declining (30)

Figure 5


Build on trial data
Meet recommendation to conduct process evaluation
Add to wider knowledge
Reasons for trial results
Improve care standards at trial sites
Meet trial reporting requirement
Value to the pragmatic RCT
External value
Understand applicability of results
Understand how it works
Value to the intervention
Improve accuracy of results
Address an identified concern
Identify improvements
Add information trial unable to provide
Inform post-trial transfer to practice

Additional file 1

MEDLINE (Ovid) search strategy

Search conducted via Ovid (MEDLINE)® and EPub Ahead of Print In-Process & Other Non-Indexed Citations, Daily and Versions®

1. (pragmatic and trial).mp. [mp=title, abstract, original title, name of substance word, subject heading word, keyword heading word, protocol supplementary concept word, rare disease supplementary concept word, unique identifier, synonyms]
2. limit 1 to (english language and humans and "core clinical journals (aim)" and yr="2015" and (clinical trial, all or clinical trial or controlled clinical trial or pragmatic clinical trial or randomized controlled trial))

Additional file 2 - trial descriptor data fields

Data field	Operationalisation	Extract from	Extract as
Funder	Who funded the trial	Trial results paper, or trial registry if not stated	Free text
Publication month	Month the trial results paper was published in print, or online for online only journals	Medline search result	Month
Publication year	Year the trial results paper was published in print, or online for online only journals	Medline search result	2015
Country	The country / countries the intervention was delivered in during the trial	Trial results paper	Country
Journal	The journal the trial results paper was published in	Trial results paper	Journal name
Intervention	Brief description of intervention(s)	Trial results paper	Free text
Comparator	What was received by the control / comparator group(s)	Trial results paper	Free text
Intervention recipients	Who received the intervention	Trial results paper	Free text
Intervention deliverer	Who administered / delivered the intervention(s) during the trial	Trial results paper	Free text
Clinical specialty	The clinical field the intervention was intended for	Trial results paper	Free text
Setting	The setting of intervention delivery.	Trial results paper	Free text
Randomisation level	Whether participants were individually or cluster randomised	Trial results paper	Individual Cluster
Primary outcome result	Whether the primary outcome result was stated as being statistically significant in the abstract of the paper (p value or confidence interval)	Trial results paper – abstract If not clear from abstract class as unclear If classification does not fit e.g. non-inferiority, multiple outcomes, class as n/a	Positive Not positive n/a if does not fit
Trial design	Further details of the trial design	Trial results paper	2-arm 3-arm Non-inferiority Stepped-wedge Crossover

Additional file 3

Section/topic	#	Checklist item	Reported on page #
TITLE			
Title	1	Identify the report as a systematic review, meta-analysis, or both.	1
ABSTRACT			
Structured summary	2	Provide a structured summary including, as applicable: background; objectives; data sources; study eligibility criteria, participants, and interventions; study appraisal and synthesis methods; results; limitations; conclusions and implications of key findings; systematic review registration number.	2-3
INTRODUCTION			
Rationale	3	Describe the rationale for the review in the context of what is already known.	3-5
Objectives	4	Provide an explicit statement of questions being addressed with reference to participants, interventions, comparisons, outcomes, and study design (PICOS).	5
METHODS			
Protocol and registration	5	Indicate if a review protocol exists, if and where it can be accessed (e.g., Web address), and, if available, provide registration information including registration number.	3
Eligibility criteria	6	Specify study characteristics (e.g., PICOS, length of follow-up) and report characteristics (e.g., years considered, language, publication status) used as criteria for eligibility, giving rationale.	6-7
Information sources	7	Describe all information sources (e.g., databases with dates of coverage, contact with study authors to identify additional studies) in the search and date last searched.	6-7
Search	8	Present full electronic search strategy for at least one database, including any limits used, such that it could be repeated.	6 (Add. file 1)
Study selection	9	State the process for selecting studies (i.e., screening, eligibility, included in systematic review, and, if applicable, included in the meta-analysis).	6-8
Data collection process	10	Describe method of data extraction from reports (e.g., piloted forms, independently, in duplicate) and any processes for obtaining and confirming data from investigators.	7-9
Data items	11	List and define all variables for which data were sought (e.g., PICOS, funding sources) and any assumptions and simplifications made.	8-9 (add. File 2)

Risk of bias in individual studies	12	Describe methods used for assessing risk of bias of individual studies (including specification of whether this was done at the study or outcome level), and how this information is to be used in any data synthesis.	n/a
Summary measures	13	State the principal summary measures (e.g., risk ratio, difference in means).	n/a
Synthesis of results	14	Describe the methods of handling data and combining results of studies, if done, including measures of consistency (e.g., I^2) for each meta-analysis.	8-9

Additional file 4 - included pragmatic RCTs

		MRC process evaluation components reported in index trial results paper(s)											
Reference of index trial results paper *Journal* Country Further references*	**Intervention**	**Reach**	**Fidelity**	**Dose**	**How delivery is achieved**	**Adaptations**	**Contextual moderators**	**Contextual factors that shape intervention theory**	**Causal mechanisms that maintain status quo or enhance effects**	**Mediators**	**Unanticipated pathways and consequences**	**Participant responses**	**Separate process evaluation paper(s)**
Bartels 2015 (1) *American Journal of Psychiatry* USA	Health promotion coaching for obesity in serious mental illness	Y					Y	Y	Y	Y		Y	No (included process evaluation but using data from multiple trials so excluded from review)
Bender 2015 (2) *JAMA Pediatrics* USA	Speech recognition telephone calls to improve adherence to child asthma treatment	Y					Y	Y				Y	No
Boulvain 2015 (3) *Lancet* France, Belgium, Switzerland	Induction of labour vs expectant management for large-for-date foetuses	Y											No
Cooper 2015 (4) *BMJ* UK Clark 2015 (5)	Outpatient vs inpatient uterine polyp treatment	Y					Y		Y		Y	Y	Yes
Curtis 2015 (6) *Canadian Medical Association Journal* Canada	Ultrasound or near-infrared vascular imaging to guide peripheral intravenous catheterisation	Y					Y	Y					No
El-Khoury 2015 (7) *BMJ* France	Balance training to prevent fall-induced injuries	Y		Y							Y	Y	No

		MRC process evaluation components reported in index trial results paper(s)											
Reference of index trial results paper *Journal* Country Further references*	**Intervention**	**Reach**	**Fidelity**	**Dose**	**How delivery is achieved**	**Adaptations**	**Contextual moderators**	**Contextual factors that shape intervention theory**	**Causal mechanisms that maintain status quo or enhance effects**	**Mediators**	**Unanticipated pathways and consequences**	**Participant responses**	**Separate process evaluation paper(s)**
Fortney 2015 (8) *JAMA Psychiatry* USA	Telemedicine-based collaborative care for veterans with PTSD	Y	Y	Y		Y				Y		Y	Yes
Gilbody 2015 (9) *BMJ* UK Littlewood 2015 (10)	Computerised cognitive behavioural therapy for depression	Y					Y		Y		Y	Y	Yes
Hill 2015 (11) *Lancet* Australia	Individualised falls-prevention education for hospital patients, with training and feedback for staff	Y	Y	Y			Y	Y			Y	Y	Yes
Holcomb 2015 (12) *JAMA* North America Baraniuk 2014 (13) Zhu 2016 (14)	Comparison of 2 different ratios of blood products in patients with major trauma	Y	Y			Y							Yes
Honkoop 2015 (15) *Journal of Allergy and Clinical Immunology* Netherlands	Comparison of 3 treatment strategies targeting different levels of asthma control	Y	Y									Y	No
Hui 2015 (16) *Gut* Hong Kong	Comparison of medical and nurse endoscopists performing colonoscopy	Y				Y	Y					Y	No

		MRC process evaluation components reported in index trial results paper(s)											
Reference of index trial results paper *Journal* Country Further references*	**Intervention**	**Reach**	**Fidelity**	**Dose**	**How delivery is achieved**	**Adaptations**	**Contextual moderators**	**Contextual factors that shape intervention theory**	**Causal mechanisms that maintain status quo or enhance effects**	**Mediators**	**Unanticipated pathways and consequences**	**Participant responses**	**Separate process evaluation paper(s)**
Kempe 2015 (17) *JAMA Pediatrics* USA	Collaborative centralised reminder/recall system to increase immunisation rates in young children	Y				Y		Y			Y		Yes
Knowles 2015 (18) *Lancet* UK Horrocks 2015 (19)	Percutaneous tibial nerve stimulation for treatment of faecal incontinence	Y	Y				Y				Y	Y	No
Kutner 2015 (20) *JAMA Internal Medicine* USA	Statin discontinuation in advanced life-limiting illness	Y									Y	Y	Yes
Lamb 2015 (21) *Lancet* UK Williams 2015 (22)	Exercises to improve hand function in rheumatoid arthritis	Y	Y	Y		Y	Y	Y	Y		Y	Y	Yes
Moreira 2015 (23) *Nursing Research* Brazil	Nursing case management for patients with type 2 diabetes	Y					Y		Y				No
Moseley 2015 (24) *JAMA* Australia	Exercise programme for rehabilitation following ankle fracture	Y	Y				Y		Y		Y	Y	No
Mouncey 2015a (25) *NEJM* UK Mouncey 2015b (26)	Early, Goal-Directed Resuscitation protocol for septic shock	Y	Y			Y	Y	Y	Y		Y		No

		MRC process evaluation components reported in index trial results paper(s)											
Reference of index trial results paper *Journal* Country Further references*	**Intervention**	**Reach**	**Fidelity**	**Dose**	**How delivery is achieved**	**Adaptations**	**Contextual moderators**	**Contextual factors that shape intervention theory**	**Causal mechanisms that maintain status quo or enhance effects**	**Mediators**	**Unanticipated pathways and consequences**	**Participant responses**	**Separate process evaluation paper(s)**
Noto 2015 (27) *JAMA* USA	Chlorhexadine bathing in intensive care units	Y	Y				Y						No
Perkins 2015 (28) *Lancet* UK Gates 2017 (29)	Mechanical vs manual chest compression for out of hospital cardiac arrest	Y	Y				Y		Y		Y		No
Rangan 2015 (30) *JAMA* UK Handoll 2015 (31)	Surgical vs non-surgical treatment for adults with displaced fracture of proximal humerus	Y	Y			Y	Y		Y		Y	Y	Yes
Sackley 2015 (32) *BMJ* UK Sackley 2016 (33)	Occupational therapy for care home residents with stroke disability	Y		Y			Y	Y			Y		Yes
Scott 2015 (34) *BMJ* UK Scott 2014 (35)	Tumour necrosis factor inhibitors versus combination intensive therapy with conventional disease modifying anti-rheumatic drugs	Y				Y		Y			Y	Y	No
Semler 2015 (36) *Critical Care Medicine* USA	Electronic sepsis evaluation and management tool in intensive care	Y		Y		Y	Y					Y	No
Smith 2015a (37) *BMJ* UK	Patient-controlled analgesia for patients in emergency	Y									Y	Y	No

		MRC process evaluation components reported in index trial results paper(s)											
Reference of index trial results paper *Journal* Country Further references*	**Intervention**	**Reach**	**Fidelity**	**Dose**	**How delivery is achieved**	**Adaptations**	**Contextual moderators**	**Contextual factors that shape intervention theory**	**Causal mechanisms that maintain status quo or enhance effects**	**Mediators**	**Unanticipated pathways and consequences**	**Participant responses**	**Separate process evaluation paper(s)**
	department with pain from traumatic injuries												
Smith 2015b (38) *BMJ* UK	Patient-controlled analgesia for patients in emergency department with pain from non-traumatic abdominal injuries	Y									Y	Y	No
Stewart 2015 (39) *Lancet* Australia	Standard vs atrial-fibrillation specific management strategy	Y	Y	Y		Y			Y				Yes
Wechsler 2015 (40) *JAMA* USA	Anticholinergic vs long-acting β-agonist in combination with inhaled corticosteroids in black adults with asthma	Y				Y	Y				Y	Y	No
Westendorp 2015 (41) *Lancet* Netherlands	Preventive antibiotics in stroke	Y		Y			Y	Y	Y		Y		No
Williamson 2015 (42) *Canadian Medical Association Journal* UK Williamson 2015 (43)	Nasal balloon autoinflation in children with otitis media with effusion in primary care	Y					Y		Y		Y	Y	Yes

*If applicable - references of additional publications reporting trial results from which we extracted data on process evaluation components

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Additional file 5

Items mapped to each process evaluation component

MRC component	Included items
Implementation	
Adaptations *Alterations made to an intervention in order to achieve better contextual fit*	Trial papers • Time taken to deliver interventions where this was not specified by a protocol • Means through which the intervention was delivered where this was flexible, e.g. qualifications of staff delivering the intervention • Which intervention components were delivered to participants as part of flexible interventions • Description of alternative materials used by sites to trial materials Process evaluation papers • Description of how a flexible intervention was delivered in practice
Dose *How much intervention is delivered*	Trial papers • Numbers of intervention sessions delivered to participants • Numbers of 'occurrences' of optional intervention components delivered to participants • Numbers of times the intervention electronic tool was opened • Time spent by deliverers on intervention components
Fidelity *The consistency of what is implemented with the planned intervention*	Trial papers • Whether or not intervention components were delivered • The quality or standard of (components of) interventions delivered • Reasons for non-adherence or protocol deviations • Fidelity scores, adherence percentages • Whether or not the correct randomised intervention was delivered • Analyses to examine the effect of non-fidelity on the primary outcome – e.g. per-protocol, complier average causal effect analyses Process evaluation papers • Whether and how centres delivered interventions in accordance with intervention protocols
How delivery is achieved	Process evaluation papers • Qualitative exploration of perceptions of intervention deliverers

MRC component	Included items
The structures, resources and mechanisms through which delivery is achieved	• Measures taken to ensure fidelity to intervention and usual care protocols
Reach *Extent to which target audience comes into contact with intervention*	Trial papers • Trial flow diagrams / CONSORT diagrams • Reasons for non-participation, exclusion, drop-out • Participant and site characteristics • Numbers of participants recruited from different sites • Numbers of participants who received the randomised intervention • Comparison of demographics between those who declined participation and trial participants • Characteristics of screened but not randomised patients • Reach of interventions delivered to randomised populations • Comparison of demographics between participants completing and not completing follow-up • Comparison of site characteristics with all departments in the country • Comparison of participant characteristics with national patient population • Length of time sites open to recruitment, length of time between obtaining site NHS permission and opening to recruitment • Independent rating of reasons for patients being judged ineligible by sites • Subgroup analysis comparing outcomes between patients randomised to receive the intervention who answered and did not answer at least one call. • Sample attrition bias • Sensitivity analysis of primary outcome including participants with missing outcomes • Sensitivity analysis excluding participants from 2 poorly recruiting centres • Associations between participant characteristics and the completeness of response to providing follow-up data Process evaluation papers • Interviews with healthcare professionals about the degree to which they targeted recruitment to patients deemed most suitable, and perceptions about which patients were most suitable for the intervention.

MRC component	Included items
	• Patient motivations for agreeing or declining trial participation • Measures taken to ensure inclusion of intended trial population in pragmatic trial
Context	
Causal mechanisms that act to maintain the status quo, or enhance effects	Trial papers • Details of usual care received by participants • Use of similar interventions by usual care group, impact of use on outcomes • Change in medication use by trial participants during the intervention period • Impact of concurrent interventions • Seasonal effects Process evaluation papers • Participant reported barriers and facilitators to engaging with or adhering to the intervention
Contextual factors that shape theory of how the intervention works	Trial papers • Effect of time on effectiveness of the intervention – e.g. cumulative unit level effect of intervention, learning curve effects • Effect of intervention variables e.g. phone calls by answering machine or in person • Ceiling effect of intervention depending on participant baseline level of disability • Comparison of outcomes between participants who kept taking same regime and those who switched partway through Process evaluation papers • Qualitative findings discussing potential factors influencing intervention outcomes e.g. skills, experience, personalities and abilities of intervention deliverers
Contextual moderators *Shape, and may be shaped by, implementation, intervention mechanisms, and outcomes*	Trial papers • Analyses of effect of moderators on outcomes, e.g. participant age, gender, smoking status, cognition, treatment preferences, site characteristics Process evaluation papers • In qualitative studies – findings about factors which could potentially modify intervention effect

MRC component	Included items
Mechanisms of impact	
Mediators *Intermediate processes which explain subsequent changes in outcome*	Trial papers • Effect of participant usage of different intervention components on primary outcome Process evaluation papers • Mediation analysis of proximal intervention effects
Participant responses *How participants interact with a complex intervention*	Trial papers • Uptake and use of the intervention, or components of the intervention, by trial participants, e.g. number of sessions attended • Analyses to examine the effect of adherence to or completion of an intervention or its components on the primary outcome • Subgroup analyses to investigate the effect of certain participant characteristics on level compliance with intervention • Participant satisfaction with treatment • Participant perceptions of which treatment they had received, treatment preferences at end of trial • Procedure acceptability to participants • Process-of-care outcome e.g. medication adherence, accessing therapies Process evaluation papers • Qualitative research exploring patient adherence, perceptions, experiences of interventions • Quantitative questionnaire about participant perceptions of the benefits and harms of the intervention
Unintended pathways and consequences	Trial papers • Participant adverse events Process evaluation papers • Qualitative findings included reports of unanticipated consequences

Additional file 6

All extracted values of process evaluation

Value category with details	Process evaluations reporting this value (n=17)
Adding value to the intervention	
Supporting implementation of the intervention into practice • Targeting or tailoring the intervention to specific patients • Aiding replication of a complex intervention • Understanding how patients engage with the intervention • Understanding providers' viewpoints and willingness to collaborate • Developing tools / strategies for implementation • Targeting the intervention to specific groups • Highlighting important components of the intervention to implementers • Highlighting benefits of the intervention to promote uptake • Highlighting effective delivery strategies • Providing evidence of feasibility / acceptability • Tailoring delivery to different groups • Highlighting importance of roles of different people / agencies in ensuring successful delivery • Addressing barriers to implementation or uptake of the intervention • Recommendations for training or support to participants or deliverers • Suggesting how intervention could fit into existing care pathways • Highlighting potential disadvantages of the intervention • Recommendations for information to give to patients considering intervention • Recommendations for clinicians to help decide between interventions • Recommendations for further intervention implementation research • Highlighting lack of equipoise in deliverers	15
Improving the intervention Recommendations for further development of the intervention based on process evaluation findings: • Recommendations to keep all components of the intervention • Adding stronger monitoring protocols to promote adherence • Adaptations to design for patients with reduced cognition Recommendations for further research relating to the intervention:	10

Value category with details	Process evaluations reporting this value (n=17)
• Effectiveness over time • Effectiveness in different contexts • Different modes of delivery e.g. group settings • Intervention refinement, e.g. to improve patient experience	
Addressing a concern identified about the intervention • Acceptability of the intervention to patients / deliverers • Participant adherence • Complexity of intervention delivery • Influence of participant cognition on intervention effectiveness	7
Understanding how the intervention works • Intervention mechanisms • Content delivered in a flexible intervention	4
Adding value to the RCT	
Providing reasons for trial results • Possible reasons for non-positive trial results • Explanations for positive trial results • Explanations for other trial data	8
Adding information not provided by the trial • Participant or deliverer concerns • Key components of intervention • Added clarification, nuance, context • Perspectives of participants after time for reflection • Concurrent treatments received by trial participants • Experiences and perceptions – things important to participants, minority views	6
Increasing accuracy of trial results • Assessing comparability of standard care between both randomised groups • Qualitative findings helping confirm quantitative data on satisfaction • Avoid survivor bias • Accurately define the trial population and facilitate purpose and interpretation of trial • Investigating threats to internal and external validity	6

Value category with details	Process evaluations reporting this value (n=17)
Building on trial data • Explore findings from a subgroup analysis conducted in the main trial • Expand on the quantitative questionnaire data collected in the main trial about participant acceptability and satisfaction • Identified adverse events not reported in the main trial data collection	3
Understanding the applicability of trial results • Evaluating whether the intended pragmatic trial population was achieved in the trial • Investigating threats to external validity from patient or provider treatment preference	2
Meeting trial reporting requirements • Meeting CONSORT requirements for pragmatic and nonpharmacologic trials	1
Meeting recommendation to conduct process evaluation • Citing recommendation by MRC process evaluation framework to conduct mediation analysis	1
Explaining issues with trial conduct • Reasons for requiring recruitment extension	1
Adding value external to the intervention or RCT	
Contributing to wider knowledge • Future trial design • Understanding patient populations and patient experiences • Understanding the problem addressed by the intervention • Improving clinical practice in the field • Informing design of similar interventions • Highlighting that findings supported or refuted the existing knowledge base • Methodological recommendations	16
Improving usual care at trial sites • Highlighting gaps in current care provision	1