# British Journal of General Practice

## Do digital interventions for parents of acutely ill children improve treatment-seeking behaviour?

SCHOLARONE™
Manuscripts

## Do digital interventions for parents of acutely ill children improve treatment-seeking behaviour?

Donovan E[1], Wilcox CR[1, 2], Patel S [3], Hay AD[4], Little P[1], Willcox ML[1]

1: Department of Primary Care and Population Sciences, Aldermoor Health Centre, University of Southampton, Southampton, UK

2: NIHR Clinical Research Facility, University Hospital Southampton NHS Foundation Trust, Southampton, UK

3: University Hospital Southampton, Tremona Road, Southampton, UK

4: Centre for Academic Primary Care, Bristol Medical School, Population Health Sciences, University of Bristol, Bristol, UK

**Corresponding author**
Dr Emily Donovan
Department of Primary Care and Population Sciences, University of Southampton
Aldermoor Health Centre, Aldemoor Close, Southampton, UK
SO16 5ST

Email: e.donovan@soton.ac.uk
Telephone: 02381204956

**How this fits in**
It is widely believed that digital interventions will play an important role in future health care delivery. Parents of children with non-serious self-limiting illnesses have demonstrated they need reassurance and self-care information to help them decide if and when to seek health care. Our findings highlight an absence of evidence of effectiveness for digital interventions, and low levels of satisfaction if developed without involvement of their intended users.

## Abstract

**Background:** Consultations for self-limiting infections in children are increasing. Digital technology has been proposed to enable parents' decision making for self-care and treatment-seeking.

**Aim**: To evaluate the evidence for digital interventions in enabling parents' decisions on self-care and treatment-seeking for acute illnesses in children.

**Design and setting**: Systematic review.

**Method**: MEDLINE and EMBASE searched from inception to January 2019 for studies assessing digital interventions for parents of children with acute illnesses.

**Results**: Three studies involving 4838 participants were included. They assessed 'Children's On Call' (US advice-only app), 'Should I see a doctor?' (Dutch self-triage app for any acute illness) and 'SORT for Kids' (US self-triage website for influenza-like illness). None of these involved parents during intervention development, and many parents did not find the first two apps easy to use. The sensitivity of self-triage interventions was 84% for 'Should I see a doctor?' compared to nurse triage, and 93% for 'Sort for Kids' compared to the need for emergency department intervention, but both had lower specificity (74% and 13% respectively). None demonstrated reduced use of urgent care services. Although 65% of 'Should I see a doctor?' users stated that they intended to follow the app's advice, the proportion who heeded this advice wasn't reported.

**Conclusion**: There is little evidence for the use of digital interventions to support parent/carers looking after children with acute illness. Future research should involve parents during intervention development, and adequately-powered trials are needed to assess impact on health services and the identification of seriously ill children.

**[249 words]**

## Introduction

Acute illnesses in children are a common reason for seeking urgent care, and the rate of acute admissions with self-limiting infections for young children has been increasing year-on-year since 1999 (1, 2). A small number of acute illnesses can become severe, but the vast majority are self-limiting and can be effectively managed in the community if parents feel empowered to provide care at home and to access professional advice when needed.

The UK's National Health Service (NHS) telephone triage helpline "111", introduced in 2013, has been criticised for being very risk averse: the vast majority of recommendations for children aged under 5 are to seek primary care (80%) or urgent review in ED (Emergency Department) (10%), and in only 10% of cases is self-care recommended (3). Although it was hoped that "111" would be part of the solution for what has been labelled a systematic failure of the NHS (2), data suggests that it has had a mixed impact (4, 5). Children with self-limiting acute illnesses presenting to urgent care are highly likely to be prescribed antibiotics (often unnecessarily) (6), thus contributing to the global

crisis in antibiotic resistance, as well as potentially causing unnecessary side effects for the child and encouraging parents to feel it is necessary to seek urgent care next time their child has a self-limiting illness. Access for children with illnesses that do warrant urgent attention may also be delayed.

Alongside the rise in availability of smartphone technology and internet access globally, national surveys have found that more than half of UK adults will research health topics via their mobile phones prior to seeking medical care (7). The NHS long term plan highlights digital and mobile technology as an opportunity to support parents/guardians in making the best decisions when considering accessing healthcare for their children by providing evidence-based advice to prevent inappropriate treatment-seeking for children with minor illnesses, while signposting those with signs of severe illness to urgent care services (8, 9). As such, it is becoming increasingly recognised that optimising the utilisation of health technology is essential to create an effective modern health care system (10).

The aim of this review was to summarise the current evidence for using digital technology as a tool to enable parents to make better decisions on self-care and treatment-seeking for acute illnesses in children.

## Methods

This review follows the Preferred Reporting Items for Systematic Reviews and Meta-analyses (PRISMA) (11) and Cochrane Collaboration guidelines (12) and was registered on the PROSPERO database, registration number CRD42019127125.

### Data sources, search strategy and selection criteria

Literature searching was conducted through MEDLINE and EMBASE for articles published from inception to 19/01/2019. Search terms were developed in collaboration with a librarian and adapted for each database (see Supplementary Figure S1 for search terms). Two authors (ED, CW) independently screened the titles and abstracts of all articles identified. Full-text copies of articles that appeared eligible were assessed for inclusion and their reference lists were screened.

Articles were eligible if they reported on studies which investigated the use of digital interventions by parents of children with acute illnesses. All study designs were eligible, as were articles published in any language. Children could be of any age and recruited from any healthcare setting. Studies that included adults were also eligible for inclusion if children were also included. Acute illnesses may have been either infectious or non-infectious in origin.

Our primary outcome of interest was whether the use of digital interventions reduced use of urgent care services (number of consultations per patient). Secondary outcomes included ease of use, user satisfaction, sensitivity/specificity of triage advice, incidence of adverse events, use of antibiotics, and cost-effectiveness.

### Data extraction & quality assessment

Data extraction and risk of bias assessment were undertaken independently and in duplicate by two authors (CW and ED). The data extraction form was specifically designed and piloted for this review. Risk of bias was assessed using a standardised form according to study type, devised by the National Heart, Blood and Lung Institute (13), see Supplementary Table S2.

## Results

We identified 1766 articles of potential interest after removal of duplicates. Full-text review was undertaken for 20 articles and references were cross-checked (revealing one further relevant article). Excluded articles are listed in Supplementary Table S1. Three met the inclusion criteria: one pilot randomised controlled trial (RCT), one prospective cross-sectional study and one pilot cohort study (Figure 1).

### Study characteristics

The studies reported on 4848 participants (Table 1). On risk of bias assessment, Anhang-Price *et al's* cohort study was rated fair, whilst the other two studies were rated as poor (Table 3, in supplementary information).

'Children's On Call' is an advice-only mobile app using information from the Barton Schmidt Paediatric Telephone Advice manual (14) and is derived from paediatric clinical protocols. It also contains answers to commonly asked health questions by parents. Lepley *et al* (17) studied the acceptability of this app, compared with written/video information in a feasibility RCT of 98 parents (of children <11 years) presenting to the paediatric ED with any non-urgent illness in 2014.

'SORT for Kids' is a self-triage website developed by the Centre for Disease Control and the American Academy of Paediatrics. It was originally intended to be made freely available to the public during the 2009 flu season, but it was decided that a pilot study was needed first to assess safety. Anhang-Price *et al* (15) studied its acceptability and accuracy in two paediatric EDs in 2012, involving 294 children (aged 0-18 years), recruited by ED triage nurses, presenting with influenza-like illness.

The self-triage mobile app 'Should I see a doctor?' was developed by a Dutch GP Out-of-Hours (OOH) clinic, based on the Dutch college of GPs' triage system and validated by the Scientific Institute for Quality of Healthcare. Verzantvoort *et al* (16) studied the acceptability and accuracy of this app in 4456 patients in 2014-15 (of which 11.9% were aged 0-12 years).

### Study outcomes

Uptake, acceptability and satisfaction with the intervention

There was low demand for the 'Children's On Call' app, and parents significantly preferred the book (containing written health advice) and video (Table 2a). Of parents allocated to the app, 57.1% and 35.1% downloaded and used it, respectively, whereas 73.0% of parents allocated to the book/video group used the book. Parents/caregivers were also significantly more likely to recommend the book to friends (100% vs 48.7%) and found it easier to understand (94.6% vs 26.0%), and more useful (70.3% vs 37.8%). These findings were reflected in the qualitative analysis of open comments, amongst parents with both low and adequate health literacy. In per-protocol analysis however, comparing groups of those who were followed up at least once, there was no significant difference in use (P = 0.530), understanding (P = 0.222), recommendations (P = 0.517), or usefulness (P = 0.983), of the app compared with the book.

The 'Should I see a doctor?' app was rated very clear/clear by 63.9% of users, and 55.7% were very satisfied/satisfied, however satisfaction was significantly lower amongst younger patients (OR 0.7, 95% CI 0.55-0.89).

Ninety percent of participants found the 'SORT for Kids' website 'very easy' to use, and this result was independent of race, ethnicity or educational attainment. No data was collected on patients' satisfaction with the result of their website triage, as they were blinded to its result.

Accuracy of triage

Two of the apps offered self-triage functionality. Sensitivity and specificity of the 'Should I see a doctor?' app was compared to nurse triage in 126 of the 4456 users (2.8%), who received additional telephone-based nurse triage. In 81% of cases, the app's advice corresponded to the nurse's triage outcome, with sensitivity, specificity, positive- and negative predictive values of 84%, 74%, 88% and 67%, respectively (16). For 8% and 11% respectively, the app over and under estimated symptom risk. However, in no cases of 'under-triage' were the symptoms considered to be 'life-threatening'.

'SORT for Kids' correctly identified 14 of the 15 children in whom an ED visit was deemed necessary by ED clinicians (sensitivity of 93.3%). It also identified all eight children who returned to ED with similar symptoms within seven days as high risk (sensitivity of 100%). However, the algorithm had a very low specificity as it correctly classified as "low/intermediate risk" only 35 of the 271 children whose visit was deemed unnecessary (12.9%, 95% CI 9.2-17.5%) (15).

Use of urgent care services

Lepley *et al* (17) compared non-urgent ED attendance rates between groups over six months following the introduction of 'Children's On Call', using both formal chart review and parental self-report. No significant differences were observed between groups (17).

Sixty-five percent of 'Should I see a doctor?' users intended to follow the app's advice, and intention was significantly higher for those patients aged <13 years (OR 1.8, 95% CI 1.3–2.3), those of male sex (OR 1.2, 95% CI 1.1-11.4), and those who were satisfied with the app (OR 2.5, 95% CI 2.2-2.9). This intention was lower amongst those receiving wait-and-see advice (56%), compared with advice to contact their GP during daytime (75%), self-care advice (67%) or advice to contact out-of-hours services (61%) (16).

Other outcomes

None of the articles reported antibiotic use, incidence of adverse events (hospitalisation, mortality); or cost-effectiveness.

## **Discussion**

### **Summary of main findings**

There is a lack of evidence to support using digital interventions to advise parents on management of acute illness in children. Usability and satisfaction with the self-triage 'Should I see a doctor?' app and the advice-only 'Children's On Call' app was modest to poor, although the usability of the self-triage 'SORT for Kids' website was good. With regards to the accuracy of triage, the sensitivity of both self-triage interventions was good, but at the cost of specificity for "Sort for Kids". None of the apps reported a reduction in use of urgent care services, (a secondary outcome

in one study [Children's On Call]). Although the majority of 'Should I see a doctor?' users stated that they intended to follow the app's advice, the intention was lowest amongst those receiving advice to 'wait and see', and the proportion who actually heeded this advice wasn't reported. A major limitation of the included studies was that none of the digital interventions were developed with input from intended users, and this may explain their poor acceptability. Furthermore, users of 'SORT for Kids' and 'Children's On Call' app were recruited in the ED, meaning the results may not necessarily be generalizable to the general population, and there is no evidence that parents would use these digital interventions for future episodes of illness in the home environment.

## Strengths and limitations

We conducted a comprehensive search using many different terms for acute childhood illnesses, with no restrictions on language or study type. We did not search the grey literature, however, and the lack of standardised keywords and MeSH terms means that a few potentially eligible articles may have been missed. The acute illness listed in our search terms were not exhaustive, and it is possible that some studies may have been missed if they reported on specific illnesses not picked up by our search. We attempted to mitigate this however by enlisting the help of a librarian, using additional broad search terms, and 'exploding' MeSH terms. Finally, the small number of included studies and heterogeneity of study populations, interventions and outcome measures meant that drawing comparisons was difficult.

## Comparison with published literature

This is the first systematic review of digital interventions as a tool to enable parents to make better decisions on self-care and treatment-seeking for children with acute illnesses. A previous review investigated the effects of paper-based interventions, demonstrating that parental help seeking behaviour can be modified (18). Online interventions for acute illness have been shown to modify health-seeking behaviour without increasing hospital admissions in adults (19). There is huge scope to empower parents to provide home care for children who have frequent self-limiting acute illnesses. A recent audit of self-triage apps (only one of them specifically for children, 'Healthy Children' [USA]) identified that triage advice from symptom checkers is generally risk averse, prioritising sensitivity over specificity, encouraging users to seek care for conditions where self-care is reasonable (20). Similarly, a recent evidence synthesis of different models of urgent care delivery concluded that telephone triage was safe, at the level of the individual, but at the cost of efficiency, and some studies suggested that nurses were more likely to refer to higher-level care than doctors (21).

Digital interventions aimed at parents and carers of children have been successful at promoting self-care for chronic conditions such as eczema, diabetes and asthma (22) (23), especially when developed using the person-based approach with input from intended users (24). It is recognised that good quality accessible information is key in empowering children and carers to self-manage their long-term conditions (25). However, the clinical utility of such apps (in comparison to simply providing written information) remains uncertain (23) (26), and a recent review found insufficient evidence to support the efficacy of apps directed at older children with chronic mental health problems (27). Written advice has been shown to help parents decide when they can confidently self-care and when they need to seek advice from a health care professional (28) (29) (30) (31).

It has been well documented that parents with lower health literacy are more likely to seek out-of-hours health care unnecessarily for non-urgent complaints (32) (33), and a recent systematic review

has highlighted that mhealth apps may be of particular benefit in this group, and have the potential to reduce disparities in healthcare (34). Lepley *et al* note that the use of jargon and complex sentences in their 'Children's On Call' advice app may have been responsible for its poor acceptability, particularly given that over half their study population had low health literacy. Again, these issues may be improved with the involvement of the intended end-users in the development process, to ensure that the intervention is not only acceptable, usable and effective, but also engaging and persuasive (24). It is also important to consider how and by whom future digital interventions are delivered. If interventions are not delivered effectively, not easy to access, or not supported by empathetic engaging staff at the time of making parents aware of them, they may not end up being effective.

## Implications for future research

Our findings highlight the need for rigorous evaluation of digital interventions, and the need to develop interventions in collaboration with their intended target populations, for example through the person-based approach (24). There are many examples of where the person based approach has resulted in the development of cost-effective digital interventions, such as 'Internet Doctor", an interactive website for the self-management of respiratory infections which was shown to reduce contact with doctors without increasing hospital admissions (19). Self-care advice on mHealth apps (for which acceptability and intention to follow was modest in this review) also needs to be optimised for the target population, and further links given to endorsed websites and educational resources (16) (35).

Another priority for research is to develop triage algorithms which have sensitivity to detect serious illness, yet also have a good specificity, in order to avoid sending patients unnecessarily to urgent care services, while correctly identifying those in need of urgent care. At present, most algorithms are very risk-averse and rarely promote self-care or watchful waiting, resulting in unnecessary consultations, antibiotic overuse, and delays for those for whom urgent care is warranted. Finally, once appropriate self-triage interventions have been developed (which are both user-friendly, sensitive and specific), adequately-powered RCTs should assess their impact on healthcare resource use and patient outcomes.

## <u>Conclusion</u>

Based on current evidence, we are unable to recommend any digital interventions as a support tool to enable parents to make better decisions on self-care and treatment-seeking for acute illnesses in children. Future interventions should be developed in collaboration with their target audience to improve usability and satisfaction, and more specific algorithms should be developed to avoid unnecessary use of urgent care services, while maintaining sensitivity to correctly identifying children with serious illnesses.

## Acknowledgements

## Author contributions

ED, CW, and MW drafted the manuscript. ED, CW, PL, AH, SP, and MW contributed to the protocol design. ED, CW and MW undertook literature searching, data extraction, and data analysis. All authors critically revised the manuscript and approved the final version.

**Conflicts of interest**

We declare that we have no conflicts of interest.

1
2
3
4
5
6
7
8
9
10
11
12
13
14
15
16
17
18
19
20
21
22
23
24
25
26
27
28
29
30
31
32
33
34
35
36
37
38
39
40
41
42
43
44
45
46
47
48
49
50
51
52
53
54
55
56
57
58
59
60

## References

1.      Fake E, Lees A, Tapson K, et al. Parental views on the management of young children with respiratory tract infections in primary care – a pilot study - Selfcare Journal. 2018.

2.      Gill PJ, Goldacre MJ, Mant D, et al. Increase in emergency admissions to hospital for children aged under 15 in England, 1999–2010: national database analysis. Arch Dis Child Educ Pract Ed. 2013;98(5):328-34.

3.      Walton E, Pall K, Shah S, et al. A service evaluation of the pathways of care for children <5 years through the NHS following contact with NHS 111: a pilot evaluation with a focus on children with fever London: Royal College of Paediatrics and Child Health; 2015 [Available from: https://www.rcpch.ac.uk/sites/default/files/Phase_1_Report_-_NHS_111_Service_Pilot_Evaluation.pdf.

4.      Iacobucci G. NHS 111 sends more and more callers to emergency departments, analysis shows. BMJ. 2017;356:j965.

5.      Pope C, Turnbull J, Jones J, et al. Has the NHS 111 urgent care telephone service been a success? Case study and secondary data analysis in England. BMJ Open. 2017;7(5):e014815.

6.      Williams MR, Greene G, Naik G, et al. Antibiotic prescribing quality for children in primary care: an observational study. Br J Gen Pract. 2018;68(667):e90-e6.

7.      Office for National Statistics. Internet access - households and individuals, Great Britain - Office for National Statistics: Office for National Statistics; 2018 [Available from: https://www.ons.gov.uk/peoplepopulationandcommunity/householdcharacteristics/homeinternetandsocialmediausage/bulletins/internetaccesshouseholdsandindividuals/2018.

8.      NHS. The NHS long term plan. 2019 [cited 2019 2nd April]. Available from: https://www.longtermplan.nhs.uk/wp-content/uploads/2019/01/nhs-long-term-plan.pdf.

9.      Department of Health. Matt Hancock launches tech vision to build the most advanced health and care system in the world 2018 [Available from: https://www.gov.uk/government/news/matt-hancock-launches-tech-vision-to-build-the-most-advanced-health-and-care-system-in-the-world.

10.     Singh A, Wilkinson S, Braganza S. Smartphones and pediatric apps to mobilize the medical home. J Pediatr. 2014;165(3):606-10.

11.     Moher D, Shamseer L, Clarke M, et al. Preferred reporting items for systematic review and meta-analysis protocols (PRISMA-P) 2015 statement. Syst Rev. 2015;4:1.

12.     Higgins JPT GS. Cochrane Handbook for Systematic Reviews of Interventions Version 5.1.0 2011 [Available from: www.handbook.cochrane.org.

13.     National Heart L, Blood I. Study Quality Assessment Tools | National Heart, Lung, and Blood Institute (NHLBI) 2019 [Available from: https://www.nhlbi.nih.gov/health-topics/study-quality-assessment-tools.

14.     Schmitt BD. Pediatric Telephone Advice: Lippincott Williams & Wilkins; 2004.

15.     Anhang Price R, Fagbuyi D, Harris R, et al. Feasibility of web-based self-triage by parents of children with influenza-like illness: a cautionary tale. JAMA Pediatr. 2013;167(2):112-8.

16.     Verzantvoort NCM, Teunis T, Verheij TJM, et al. Self-triage for acute primary care via a smartphone application: Practical, safe and efficient? PloS one. 2018;13(6):e0199284.

17.     Lepley BE, Brousseau DC, May MF, et al. Randomized Controlled Trial of Acute Illness Educational Intervention in the Pediatric Emergency Department: Written Versus Application-Based Education. Pediatr Emerg Care. 2019;Publish Ahead of Print.

18.     Andrews T, Thompson M, Buckley DI, et al. Interventions to Influence Consulting and Antibiotic Use for Acute Respiratory Tract Infections in Children: A Systematic Review and Meta-Analysis. PloS one. 2012;7(1):e30334.

19.     Little P, Stuart B, Andreou P, et al. Primary care randomised controlled trial of a tailored interactive website for the self-management of respiratory infections (Internet Doctor). BMJ Open. 2016;6(4):e009769.

20.     Semigran HL, Linder JA, Gidengil C, et al. Evaluation of symptom checkers for self diagnosis and triage: audit study. BMJ. 2015;351:h3480-h.
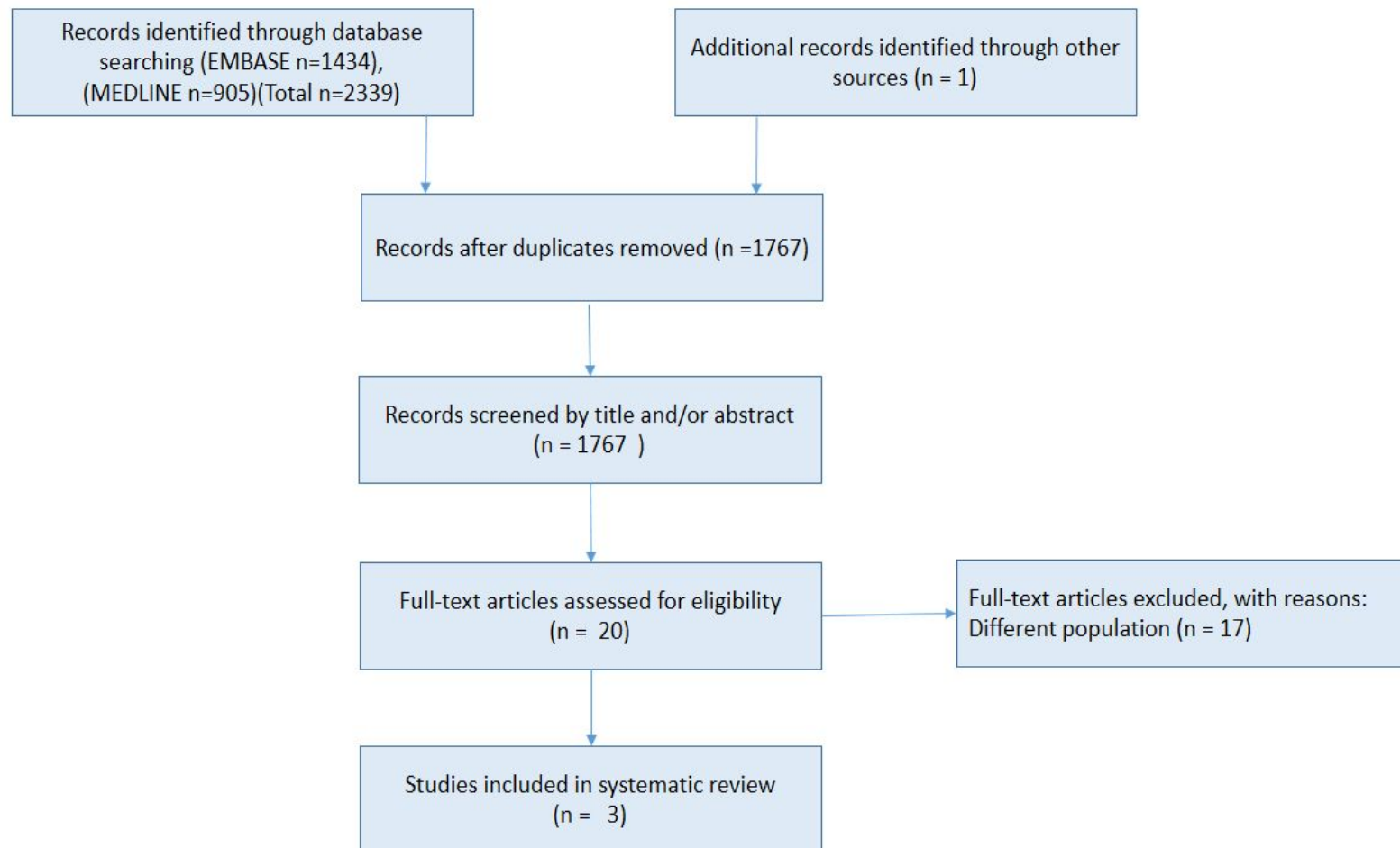
21.     Goyder JT, Joanne C, Duncan C, et al. Telephone triage and advice services. NIHR Journals Library Southampton (UK):. 2015;3.43.

22.     Santer M, Muller I, Yardley L, et al. Supporting self-care for families of children with eczema with a Web-based intervention plus health care professional support: pilot randomized controlled trial. J Med Internet Res. 2014;16(3):e70.

23.     Whitehead L, Seaton P. The Effectiveness of Self-Management Mobile Phone and Tablet Apps in Long-term Condition Management: A Systematic Review. J Med Internet Res. 2016;18(5):e97.

24.     Yardley L, Morrison L, Bradbury K, et al. The person-based approach to intervention development: application to digital health-related behavior change interventions. J Med Internet Res.. 2015;17(1):e30-e.

25.     Nightingale R, Hall A, Gelder C, et al. Desirable Components for a Customized, Home-Based, Digital Care-Management App for Children and Young People With Long-Term, Chronic Conditions: A Qualitative Exploration. J Med Internet Res. 2017;19(7):e235-e.

26.     Stukus DR, Farooqui N, Strothman K, et al. Real-world evaluation of a mobile health application in children with asthma. Ann Allergy Asthma Immunol. 2018;120(4):395-400.e1.

27.     Grist R, Porter J, Stallard P. Mental Health Mobile Apps for Preadolescents and Adolescents: A Systematic Review. J Med Internet Res . 2017;19(5):e176.

28.     Francis NA, Butler CC, Hood K, et al. Effect of using an interactive booklet about childhood respiratory tract infections in primary care consultations on reconsulting and antibiotic prescribing: a cluster randomised controlled trial. BMJ. 2009;339:b2885.

29.     Yoffe SJ, Moore RW, Gibson JO, et al. A reduction in emergency department use by children from a parent educational intervention. Fam Med. 2011;43(2):106-11.

30.     Herman A, Jackson P. Empowering low-income parents with skills to reduce excess pediatric emergency room and clinic visits through a tailored low literacy training intervention. J Health Commun 2010;15(8):895-910.

31.     Andrews T, Thompson M, Buckley DI, et al. Interventions to Influence Consulting and Antibiotic Use for Acute Respiratory Tract Infections in Children: A Systematic Review and Meta-Analysis. PloS one. 2012; 7(1). Available from: http://dx.doi.org/10.1371/journal.pone.0030334.

32.     Keeble EKL. Focus on: Emergency hospital care for children and young people. 2017.

33.     Morrison AK, Schapira MM, Gorelick MH, et al. Low caregiver health literacy is associated with higher pediatric emergency department use and nonurgent visits. Acad Pediatr. 2014;14(3):309-14.

34.     Anderson-Lewis C, Anderson-Lewis C, Darville G, et al. mHealth Technology Use and Implications in Historically Underserved and Minority Populations in the United States: Systematic Literature Review. JMIR Mhealth Uhealth 2018;6(6):e128 https://mhealthjmirorg/2018/6/e128/. 2018.

35.     Wyatt JC. Fifty million people use computerised self triage. BMJ. 2015;351:h3727.

1
2
3
4
5
6
7
8
9
10
11
12
13
14
15
16
17
18
19
20
21
22
23
24
25
26
27
28
29
30
31
32
33
34
35
36
37
38
39
40
41
42
43
44
45
46

**Figure 1:  PRISMA Flow Chart**

Moher D, Liberati A, Tetzlaff J, Altman DG, The PRISMA Group (2009). *P*referred *R*eporting *I*tems for *S*ystematic Reviews and *M*eta-*A*nalyses: The PRIS
Statement. PLoS Med 6(7): e1000097. doi:10.1371/journal.pmed1000097 **For more information, visit www.prisma-statement.org.**



Records identified through database searching (EMBASE n=1434), (MEDLINE n=905)(Total n=2339)

Additional records identified through other sources (n = 1)

Records after duplicates removed (n =1767)

Records screened by title and/or abstract (n = 1767  )

Full-text articles assessed for eligibility (n =  20)

Full-text articles excluded, with reasons: Different population (n = 17)

Studies included in systematic review (n =   3)

1
2
3
4
5
6
7
8
9
10
11
12
13
14
15
16
17
18
19
20
21
22
23
24
25
26
27
28
29
30
31
32
33
34
35
36
37
38
39
40
41
42
43
44
45
46

**Table 1. Study Characteristics**

| AUTHOR | INTERVENTION | SETTING | SUBJECTS | N of participants | STUDY DESIGN | COMPARATOR | OUTCOMES |
|---|---|---|---|---|---|---|---|
| Anhang Price 2013 | Website-based self-triage system (SORT for kids) administered to those attending ED | Website was used in two EDs in USA | Care givers of children <18 years with influenza-like illness | 294 (electronic records found for 286) | Pilot cohort study | Clinical necessity for admission (based on requiring ≥1 interventions in ED) | 1) Usability and acceptability of website amongst caregivers 2) Accuracy, sensitivity and specificity of triage compared to need for immediate ED management (as judged by clinicians) |
| Verzant-voort 2018 | Self-triage mobile app (Should I see a doctor?) available for download | Any setting, The Netherlands | Any user of the app (of any age) with acute primary-care symptoms | 4456 app users (of which 12% were parents of children aged 0-12 years) | Prospective cross-sectional cohort | 126 participants also received telephone-based nurse triage | 1) Usability and acceptability of app (5-point Likert scale) 2) Proportion who intended to follow app's advice 3) Accuracy, sensitivity and specificity of triage compared to nurse triage |
| Lepley 2019 | Healthcare advice mobile app (Children's on call) (group 2) provided on discharge from ED | Parents recruited from single paediatric ED in USA | Care givers of children ≤ 12 years presenting with non-urgent complaints. | Total: 98 1: Book/app: 24 2: App: 25 3: Book: 24 4: Control: 25 | Feasibility RCT | Group 1: Written advice booklet with short introductory video Group 3: Both mobile app and written/video Group 4: Control group given booklet on car seat safety | 1) Non-urgent ED visits over following 6 months 2) Usability and acceptability of app amongst caregivers was followed up by researchers at 1, 3 and 6 months by 5-point Likert scale questions or dichotomous questions |

Key : ED = Emergency department; ILI = Influenza like illness, USA = United States of America, RCT = Randomised Controlled Trial

**Table 2a. Outcome 1: Does intervention reduce consultations?**

| Intervention | Group | Outcome |
|---|---|---|
| Paediatric mhealth app (Lepley 2019) (n=25 per group) | | ED re-attendance (Incidence Rate Ratio, 95% CI) |
| | App vs control: | 1.14 (0.6 -2.3) |
| | Book vs control: | 0.78 (0.3–1.7) |
| | Book and app vs control: | 0.60 (0.3–1.4) |
| "Should I see a doctor?" app (Verzantvoort 2018) (n=4456) | App disposition (% of participants) See own GP in hours: 16% | Intention to follow app disposition (% within each disposition group) 75% |
| | See OOH GP: 42% | 61% |
| | Self-care: 34% | 67% |
| | Wait-and-see: 8% | 56% |

Key:    CI = Confidence Interval, n= number of participants, mhealth app = Mobile health application, ED = Emergency Department, OOH = Out of Hours, GP = General Practitioner

**Table 2b. Outcome 2: Accuracy of triage**

| Intervention | Comparator | Sensitivity (95% CI) | Specificity (95% CI) | Comments |
|---|---|---|---|---|
| "SORT for kids" algorithm (Anhang Price 2013) | Documented evidence that the child received 1 or more of the 5 ED-specific interventions (n=100) | 93% (68-100%) | 13% (9-18%) | The algorithm classified many of these children as high risk because of reports that the child had not urinated in the last 8 hours, was "fussy or cranky," was "much sleepier or more tired than usual," or was confused. |
| "Should I see a doctor?" app (Verzantvoort 2018) | nurse triage call outcome (n=126) | 84% (74 – 91%) | 74% (58-86%) | In 81% of (126) participants the app's advice corresponded to the nurse triage call outcome |

Key: SORT = Strategy for Off-site Rapid Triage, ED = Emergency Department, CI = Confidence Interval, n= number of participants

### Table 2c. Outcome 3: Uptake, acceptability and satisfaction with the intervention

| Intervention | Percentage who downloaded app | Clarity (% of parents who found intervention easy/very easy to understand) | % Measures of usefulness / ease of use / satisfaction (To nearest decimal place) |
|---|---|---|---|
| 'Children's on call' app (Lepley 2019) | 57% (35% used the app at least once) | 46% | 37% found app useful |
| "SORT for kids" algorithm (Anhang Price, 2013) | NA (website) | 98% | 91% found app" easy to use" |
| "Should I see a doctor?" app (Verzantvoort 2018) | 200 000 downloads (denominator unknown) | 64% | 56% were "satisfied" or "very satisfied" with the app |

**Supplementary information.**
**Figure S1: Search terms**

**Medline search 25.1.19**

915 refs

1. child/

2. infant/

3. newborn/

4. preschool child/

5. pediatrics/

6. (child or children or infant* or newborn* or baby or babies or toddler*).mp.

7. (pediatric* or paediatric*).mp.

8. (under five* or under 5* or preschool).mp.

9. 1 or 2 or 3 or 4 or 5 or 6 or 7 or 8

10. acute disease/

11. acute.mp.

12. upper respiratory tract infection/ or viral upper respiratory tract infection/

13. exp otitis media/

14. otalgia/

15. urinary tract infection/ or exp kidney infection/

16. coughing/

17. exp meningitis/

18. headache/

19. (cough* or urinary tract infection* or UTI* or meningitis or ear ache or earache or otitis media or headache* or respiratory tract infection*).mp.

20. tonsillitis/

21. lower respiratory tract infection*.mp. [mp=title, abstract, original title, name of substance word, subject heading word, floating sub-heading word, keyword heading word, protocol supplementary concept word, rare disease supplementary concept word, unique identifier, synonyms]

22. (tonsillitis or pharyngitis or pharyngotonsillitis or rhinopharyngitis or nasopharyngitis or (sore adj3 throat*)).mp.

23. exp diarrhea/

24. "nausea and vomiting"/ or exp newborn vomiting/ or vomiting/

25. gastroenteritis/

26. allerg*.mp.

27. hypersensitivity/

28. childhood injury/ or childhood disease/ or injury/

29. head injury/

30. accidental ingestion.mp.

31. (diarrhoea or diarrhea).mp. [mp=title, abstract, original title, name of substance word, subject heading word, floating sub-heading word, keyword heading word, protocol supplementary concept word, rare disease supplementary concept word, unique identifier, synonyms]

32. (vomit* or gastroenteritis or nausea).mp. [mp=title, abstract, original title, name of substance word, subject heading word, floating sub-heading word, keyword heading word, protocol supplementary concept word, rare disease supplementary concept word, unique identifier, synonyms]

33. injur*.mp. [mp=title, abstract, original title, name of substance word, subject heading word, floating sub-heading word, keyword heading word, protocol supplementary concept word, rare disease supplementary concept word, unique identifier, synonyms]

34. (intoxicat* or poison*).mp. [mp=title, abstract, original title, name of substance word, subject heading word, floating sub-heading word, keyword heading word, protocol supplementary concept word, rare disease supplementary concept word, unique identifier, synonyms]

35. 10 or 11 or 12 or 13 or 14 or 15 or 16 or 17 or 18 or 19 or 20 or 21 or 22 or 23 or 24 or 25 or 26 or 27 or 28 or 29 or 30 or 31 or 32 or 33 or 34

36. 9 and 35

37. mobile application/

38. app.mp.

39. (digital intervention or mhealth or m-health).mp.

40. ((mobile or phone or smartphone or cell) adj3 app*).mp.

41. 37 or 38 or 39 or 40

42. 36 and 41


**Embase search 25.1.19. Total 1448**

1. child/

2. infant/

3. newborn/

4. preschool child/

5. pediatrics/

6. (child or children or infant* or newborn* or baby or babies or toddler*).mp.

7. (pediatric* or paediatric*).mp.

8. (under five* or under 5* or preschool).mp.

9. 1 or 2 or 3 or 4 or 5 or 6 or 7 or 8

10. acute disease/

11. acute.mp.

12. upper respiratory tract infection/ or viral upper respiratory tract infection/

13. exp otitis media/

14. otalgia/

15. urinary tract infection/ or exp kidney infection/

16. coughing/

17. exp meningitis/

18. headache/

19. (cough* or urinary tract infection* or UTI* or meningitis or ear ache or earache or otitis media or headache* or respiratory tract infection*).mp.

20. tonsillitis/

21. lower respiratory tract infection*.mp. [mp=title, abstract, heading word, drug trade name, original title, device manufacturer, drug manufacturer, device trade name, keyword, floating subheading word, candidate term word]

22. (tonsillitis or pharyngitis or pharyngotonsillitis or rhinopharyngitis or nasopharyngitis or (sore adj3 throat*)).mp.

23. exp diarrhea/

24. "nausea and vomiting"/ or exp newborn vomiting/ or vomiting/

25. gastroenteritis/

26. allergic rash/

27. allergic reaction/

28. childhood injury/ or childhood disease/ or injury/

29. head injury/

30. accidental ingestion.mp.

31. (diarrhoea or diarrhea).mp. [mp=title, abstract, heading word, drug trade name, original title, device manufacturer, drug manufacturer, device trade name, keyword, floating subheading word, candidate term word]

32. (vomit* or gastroenteritis or nausea or allerg*).mp. [mp=title, abstract, heading word, drug trade name, original title, device manufacturer, drug manufacturer, device trade name, keyword, floating subheading word, candidate term word]

33. injur*.mp. [mp=title, abstract, heading word, drug trade name, original title, device manufacturer, drug manufacturer, device trade name, keyword, floating subheading word, candidate term word]

34. (intoxicat* or poison*).mp. [mp=title, abstract, heading word, drug trade name, original title, device manufacturer, drug manufacturer, device trade name, keyword, floating subheading word, candidate term word]

35. 10 or 11 or 12 or 13 or 14 or 15 or 16 or 17 or 18 or 19 or 20 or 21 or 22 or 23 or 24 or 25 or 26 or 27 or 28 or 29 or 30 or 31 or 32 or 33 or 336. 9 and 35

36. 9 and 35

37. mobile application/

38. app.mp.

39. (digital intervention or mhealth or m-health).mp.

40. ((mobile or phone or smartphone or cell) adj3 app*).mp.

41. 37 or 38 or 39 or 40

42. 36 and 41

**Table S1: Excluded articles after reading full text.**

| **Article excluded** | **Reason** |
|---|---|
| 1.Consumerism, Innovation, and the Future of Pediatric Primary Care | Viewpoint article |
| 2.Smart technologies to improve health outcomes in juvenile idiopathic arthritis | Review article |
| 3.Computer-Based and Online Therapy for Depression and Anxiety in Children and Adolescents | Population was not acutely ill children. |
| 4.Formative evaluation of a proposed mHealth program for childhood illness management in a resource-limited setting in Peru | Text messaging |
| 5.A model for predicting utilization of mHealth interventions in low-resource settings: case of maternal and newborn care in Kenya | Theoretical study |
| 6.. A randomized controlled trial to evaluate the Make Safe Happen app-a mobile technology-based safety behaviour change intervention for increasing parents' safety knowledge and actions | Evaluation study |
| 7. Smartphones and pediatric apps to mobilize the medical home | General article |
| 8.Behaviour change communication using mobile phones: Implications for infant and young child feeding interventions | Scoping review/Wrong population (young child feeding) |
| 9. Cool Runnings - an app-based intervention for reducing hot drink scalds: Study protocol for a randomised controlled trial | Study protocol |
| 10.Development and Evaluation of a Mobile Oral Health Application for Preschoolers Campos, Lfxa | Population was not acutely ill children. |
| 11.The Health-e Babies App for antenatal education: Feasibility for socially disadvantaged women | Population was not acutely ill children. |
| 12.The Paediatric Risk Assessment (PARA) Mobile App to Reduce Post discharge Child Mortality: Design, Usability, and Feasibility for Health Care Workers in Uganda | Population was not acutely ill children. |

| 13. Assessing the Effect of mHealth Interventions in Improving Maternal and Neonatal Care in Low- and Middle-Income Countries: A Systematic Review | Text messaging |
|---|---|
| 14Utilization and Content Evaluation of Mobile Applications for Pregnancy, Birth, and Child Care | Population was not acutely ill children. |
| 15Construct validity and reliability of a real-time multidimensional smartphone app to assess pain in children and adolescents with cancer | Population was not acutely ill children. |
| 16Pediatric Telehealth: Opportunities and Challenges | Review article |
| 17The role of mHealth intervention on maternal and child health service delivery: findings from a randomized controlled field trial in rural Ethiopia | Text messaging |

**References of excluded articles.**

1. Fiks AG, Friesen R, Biggs L. Consumerism, Innovation, and the Future of Pediatric Primary Care. *JAMA Pediatrics* 2018;172(9):797-98.

2. Coda A, Sculley D, Santos D, et al. Harnessing interactive technologies to improve health outcomes in juvenile idiopathic arthritis. *Pediatric Rheumatology* 2017;15(1):40.

3. Stasiak K, Fleming T, Lucassen MF, et al. Computer-Based and Online Therapy for Depression and Anxiety in Children and Adolescents. *J Child Adolesc Psychopharmacol* 2016;26(3):235-45.

4. Calderon TA, Martin H, Volpicelli K, et al. Formative evaluation of a proposed mHealth program for childhood illness management in a resource-limited setting in Peru. *Rev Panam Salud Publica* 2015;38(2):144-51.

5. Mburu S, Oboko R. A model for predicting utilization of mHealth interventions in low-resource settings: case of maternal and newborn care in Kenya. *BMC medical informatics and decision making* 2018;18(1):67-67.

6. McKenzie LB, Roberts KJ, Clark R, et al. A randomized controlled trial to evaluate the Make Safe Happen® app-a mobile technology-based safety behavior change intervention for increasing parents' safety knowledge and actions. *Injury epidemiology* 2018;5(1):5-5.

7. Singh A, Wilkinson S, Braganza S. Smartphones and pediatric apps to mobilize the medical home. *J Pediatr* 2014;165(3):606-10.

8.  Mildon A, Sellen D. Behaviour Change Communication Using Mobile Phones: Implications for Infant and Young Child Feeding Interventions. *The FASEB Journal* 2017;31(1_supplement):640.9-40.9.

9.  Burgess JD, Cameron CM, Watt K, et al. Cool Runnings - an app-based intervention for reducing hot drink scalds: study protocol for a randomised controlled trial. *Trials* 2016;17(1):388.

10. Campos L, Cavalcante JP, Machado DP, et al. Development and Evaluation of a Mobile Oral Health Application for Preschoolers. *Telemed J E Health* 2018.

11.  Dalton JA, Rodger D, Wilmore M, et al. The Health-e Babies App for antenatal education: Feasibility for socially disadvantaged women. *PloS one* 2018;13(5):e0194337-e37.

12. English LL, Dunsmuir D, Kumbakumba E, et al. The PAediatric Risk Assessment (PARA) Mobile App to Reduce Postdischarge Child Mortality: Design, Usability, and Feasibility for Health Care Workers in Uganda. *JMIR mHealth and uHealth* 2016;4(1):e16-e16.

13. Sondaal SFV, Browne JL, Amoakoh-Coleman M, et al. Assessing the Effect of mHealth Interventions in Improving Maternal and Neonatal Care in Low- and Middle-Income Countries: A Systematic Review. *PloS one* 2016;11(5):e0154664-e64.

14. Lee Y, Moon M. Utilization and Content Evaluation of Mobile Applications for Pregnancy, Birth, and Child Care. *Healthcare informatics research* 2016;22(2):73-80.

15. Stinson JN, Jibb LA, Nguyen C, et al. Construct validity and reliability of a real-time multidimensional smartphone app to assess pain in children and adolescents with cancer. *Pain* 2015;156(12):2607-15.

16. Utidjian L, Abramson E. Pediatric Telehealth: Opportunities and Challenges. *Pediatr Clin North Am* 2016;63(2):367-78.

17. Atnafu A, Otto K, Herbst CH. The role of mHealth intervention on maternal and child health service delivery: findings from a randomized controlled field trial in rural Ethiopia. *mHealth* 2017;3:39-39.

**Table S2:** Risk of Bias Assessments

| **Anhang Price 2013** | |
| --- | --- |
| Study question or objective clearly stated? | Yes |
| Eligibility criteria pre-specified and clearly described? | Yes |
| Participants in study representative of those who would be eligible for the test/service/intervention in the general population of interest? | No |
| All eligible participants that met the prespecified entry criteria enrolled? | No |
| Sample size sufficiently large to provide confidence in the findings? | No |
| Intervention clearly described and delivered consistently across the study population? | No |
| Outcome measures prespecified, clearly defined, valid, reliable, and assessed consistently across all study participants? | Yes |
| People assessing the outcomes blinded to the participants' exposures/interventions? | Yes |
| Loss to follow-up after baseline 20% or less? Those lost to follow-up accounted for in the analysis? | Yes |
| Did statistical methods examine changes in outcome measures from before to after the intervention? | No |
| Outcome measures of interest taken multiple times before and after intervention | No |
| Did statistical analysis take into account the use of individual-level data to determine effects at the group level? | N/A |
| Overall rating | **FAIR** |
| **Verzantvoort 2018** | |
| Was the research question or objective in this paper clearly stated? | Yes |
| Was the study population clearly specified and defined? | No |
| Was the participation rate of eligible persons at least 50%? | No |
| Were subjects recruited from the same populations in same time period. Were inclusion and exclusion criteria for being in the study prespecified and applied uniformly to all participants? | Yes |
| Was a sample size justification, power description, or variance and effect estimates provided? | No |
| For the analyses in this paper, were the exposure(s) of interest measured prior to the outcome(s) being measured? | No |
| Was the timeframe sufficient so that one could reasonably expect to see an association between exposure and outcome if it existed? | No |
| For exposures that can vary in amount or level, did the study examine different levels of the exposure as related to the outcome (e.g., categories of exposure, or exposure measured as continuous variable)? | N/A |
| Were the exposure measures (independent variables) clearly defined, valid, reliable, and implemented consistently across all study participants? | Yes |
| Was the exposure(s) assessed more than once over time? | No |

| | |
|---|---|
| Were the outcome measures (dependent variables) clearly defined, valid, reliable, and implemented consistently across all study participants? | N/A |
| Were the outcome assessors blinded to the exposure status of participants? | N/A |
| Was loss to follow-up after baseline 20% or less? | No |
| Were key potential confounding variables measured and adjusted statistically for their impact on the relationship between exposure(s) and outcome(s)? | No |
| Overall rating | **POOR** |
| **Lepley 2019** | |
| Was the study described as a RCT? | Yes |
| Method of randomization adequate? | No |
| Was treatment allocation concealed? | No |
| Were study participants and providers blinded to treatment group assignment? | No |
| Were people assessing outcomes blinded to participants' group assignments? | CD |
| Were groups similar at baseline on characteristics that could affect outcomes? | No |
| Was overall drop-out rate from study at endpoint 20% or lower of the number allocated to treatment? | No |
| Was the differential drop-out rate at endpoint 15 percentage points or lower? | NR |
| High adherence to the intervention protocols for each treatment group? | No |
| Were other interventions avoided or similar in the groups? | No |
| Were outcomes assessed using valid and reliable measures, implemented consistently across all study participants? | No |
| Did authors report the sample size was sufficiently large to be able to detect a difference in main outcome between groups with at least 80% power? | No |
| Were outcomes reported or subgroups analysed prespecified? | Yes |
| All randomized participants analysed in the group to which they were originally assigned? | Yes |
| Overall rating | **POOR** |

CD = Cannot determine, NR = Not relevant N/A = Not applicable