Validation of Search Filters for Identifying Pediatric Studies in PubMed

Edith Leclercq, PhD[1], Mariska M. G. Leeflang, PhD[2], Elvira C. van Dalen, MD, PhD[1], and Leontien C. M. Kremer, MD, PhD[1]

Objective To identify and validate PubMed search filters for retrieving studies including children and to develop a new pediatric search filter for PubMed.

Study design We developed 2 different datasets of studies to evaluate the performance of the identified pediatric search filters, expressed in terms of sensitivity, precision, specificity, accuracy, and number needed to read (NNR). An optimal search filter will have a high sensitivity and high precision with a low NNR.

Results In addition to the PubMed Limits: All Child: 0-18 years filter (in May 2012 renamed to PubMed Filter Child: 0-18 years), 6 search filters for identifying studies including children were identified: 3 developed by Kastner et al, 1 developed by BestBets, one by the Child Health Field, and 1 by the Cochrane Childhood Cancer Group. Three search filters (Cochrane Childhood Cancer Group, Child Health Field, and BestBets) had the highest sensitivity (99.3%, 99.5%, and 99.3%, respectively) but a lower precision (64.5%, 68.4%, and 66.6% respectively) compared with the other search filters. Two Kastner search filters had a high precision (93.0% and 93.7%, respectively) but a low sensitivity (58.5% and 44.8%, respectively). They failed to identify many pediatric studies in our datasets. The search terms responsible for false-positive results in the reference dataset were determined. With these data, we developed a new search filter for identifying studies with children in PubMed with an optimal sensitivity (99.5%) and precision (69.0%).

Conclusion Search filters to identify studies including children either have a low sensitivity or a low precision with a high NNR. A new pediatric search filter with a high sensitivity and a low NNR has been developed. *(J Pediatr 2013;162:629-34)*.

To keep up-to-date with the latest developments in their field and to practice in an evidence-based manner, pediatric health care professionals need to target literature searches in medical databases to search for primary studies and systematic reviews in children. Different search filters for identifying only pediatric studies using PubMed and Medline/Ovid are available to facilitate this.[1-4] They differ with respect to the number of search terms used. The existing search filters for identifying studies of children in PubMed have not been validated and, therefore, it is not clear how well the different search filters are able to identify all studies in PubMed that involve children and how many abstracts need to be screened before relevant papers are identified.

The performance of other PubMed search filters, for example, for identifying systematic reviews or randomized controlled trials (RCTs) or clinical queries have been validated previously.[5,6] The performance of search filters can be expressed in terms of sensitivity, precision, specificity, accuracy, and number needed to read (NNR). These parameters can only be calculated in a database of known dimension, where all records are tagged beforehand according to formulated criteria.

To advise pediatric health care professionals about the usefulness of the different available search filters for identifying studies including children, we developed this study with 3 separate objectives. The first objective was to identify all available search filters. The second objective was to evaluate the performance of the search filters focusing on identifying all relevant studies (sensitivity of the filters) and the effort needed to obtain these results (expressed as NNR to identify 1 relevant paper). The third objective was to develop an improved search filter for identifying studies in PubMed that include children.

Methods

To identify relevant search filters we searched PubMed on April 7, 2008, for "Information Storage and Retrieval/methods [MeSH] AND (pediatric OR paediatric OR child OR children)," where MeSH stands for Medical Subject Heading. In addition, the internet was searched for "pediatric search filter" using Google. The Cochrane Child Health Field (CHF) was contacted for more information

CCG	Cochrane Childhood Cancer Group
CCTs	Clinical controlled studies
CHF	Cochrane Child Health Field
HSSS	Highly Sensitive Search Strategy
MeSH	Medical Subject Heading
NNR	Number needed to read
RCTs	Randomized controlled trials

From the [1]Cochrane Childhood Cancer Group, Department of Pediatric Oncology, Emma Children's Hospital/Academic Medical Center; and [2]Department of Clinical Epidemiology, Biostatistics and Bioinformatics, University of Amsterdam, Amsterdam, The Netherlands

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on pediatric search filters, and finally, the Cochrane Childhood Cancer Group[7] (CCG) filter was included.

The performance of a search filter is based on calculations of the sensitivity, precision, specificity, accuracy, and NNR. To evaluate all the measurements of the performance of the different pediatric search filters, we constructed a reference database consisting of RCTs and clinical controlled studies (CCTs) in children identified in PubMed using the existing search filters. To validate the results of the sensitivity of the different search filters, we developed the validation database consisting of RCTs included in Cochrane systematic reviews.

Development of the Reference Dataset

We chose to restrict our research to only RCTs and CCTs to avoid an excessive number of retrieved studies. Therefore, the reference dataset was obtained by combining the Cochrane Highly Sensitive Search Strategy (HSSS) for identifying RCTs and CCTs[8] (**Appendix 1**; available at www.jpeds.com) with the identified child filters with a limit of 1 week in September 2008 in PubMed.

The obtained records were assessed by 2 authors independently (E.L., M.L.) to determine whether a study included children or not. The following inclusion criteria were used: studies which included children (aged 0-18 years), or reviews in which studies with children were evaluated. The following exclusion criteria were used: prenatal, post mortem, and microbiologic studies, which did not present outcomes directly related to children, and reviews or comments in which no studies with children were discussed. When it was not possible to assess the inclusion criteria based only on the abstract and/or the MeSH headings, the full text article was obtained. When no information on the age of the participants could be found in the full text article, the record was excluded, as were records, which could not be obtained as full text. Discrepancies between assessors were resolved by consensus. A third author was consulted in the few cases for which no agreement between the 2 assessors could be obtained. The final reference dataset consisted of relevant studies (RCTs and CCTs including children) and known irrelevant studies (RCTs and CCTs not including children).

Development of the Validation Dataset

To develop the validation dataset (gold standard), we performed a search to identify pediatric RCTs or CCTs, which were included in a Cochrane systematic review (**Appendix 2**; available at www.jpeds.com). From the list of retrieved records, we selected every fifth review. For the selected reviews, it was assessed whether children were included (aged 0-18 years). Reviews with adults only (ie, people aged ≥18 years) were excluded. Reviews that discussed children among adults were included. RCTs or CCTs included in the selected Cochrane reviews were eligible to be included in the validation dataset if children were included in these studies. Furthermore, these publications had to be available in Medline and searchable with the PubMed interface as well. RCTs and CCTs were excluded when participants were adults only, the age of the participants was not clearly defined, the age was not mentioned, or the full text article could not be obtained to verify the age of the participants. Duplicate and triplicate RCTs and CCTs were removed. The validation dataset consisted only of 1357 relevant studies (RCTs and CCTs including children).

Calculation of Sensitivity, Precision, Specificity, Accuracy, and NNR within the Reference Dataset

The sensitivity, precision, specificity, accuracy, and NNR were calculated using the reference dataset in PubMed. The sensitivity is a measure of the proportion of relevant documents retrieved compared with all relevant documents, and the precision indicates the proportion of correctly retrieved articles against all the articles retrieved by the search. The specificity is a measure for the non-retrieval of non-relevant citations,[6] and the accuracy is the proportion of articles of relevant citations retrieved and non-relevant citations not retrieved.[5] The NNR (ie, 1/precision) is defined as the number of relevant and irrelevant articles one has to screen to find one of relevance.[9] The formula in **Table I** were used for calculating these parameters.

Calculation of Sensitivity within the Validation Dataset

To validate the method for calculating the sensitivity of the identified child filters using the reference dataset, the sensitivity of these search filters was also calculated as the proportion of RCTs and CCTs identified by the different search filters against the validation dataset (**Table I**). All

Table I. Formulas for calculating the sensitivity, precision, specificity, accuracy, and NNR of searches for finding pediatric studies

	Relevant	Not relevant	Total
Identified	A (hits, correct inclusion; true positives)	B (noise, incorrect inclusion; false positives)	Total identified
Not identified	C (missed hits, incorrect exclusion; false negatives)	D (correct exclusion; true negatives)	Total not identified
Total	A + C (total relevant hits)	B + D (total not relevant hits)	A + B + C + D (total collection, database)

NNR is defined as 1/precision.
Sensitivity = A/(A + C).
Precision = A/(A + B).
Specificity = D/(B + D).
Accuracy = (A + D)/(A + B + C + D).
NNR = (A + B)/A.

searches for calculating the sensitivity were performed in PubMed in 1 day.

Development of a New Search Filter

False-positive studies are studies retrieved by the search filters but not assigned in the reference dataset as a study including children. The search terms which resulted in false-positive studies were identified by comparing the text words and MeSH terms of each retrieved study with the search terms of the respective search filter. We investigated why these search terms retrieved these false-positive records.

Based on evaluation of false-positive records, we developed a new improved search filter for identifying studies including children. The existing search filter with the lowest number of search terms and with the highest sensitivity in the validation dataset was used as a starting point. Every search term therein was compared with similar search terms from the next 2 search filters with a high sensitivity. All search terms were evaluated for retrieving studies with children. Search terms retrieving studies, which were already identified with another search term were deleted, and search terms from other child filters which identified new studies were added. Search terms retrieving false-positive studies were deleted or adjusted. The new filter was validated using the reference and validation datasets.

Results

Seven pediatric search filters were identified. The child filters of the CCG[7] and of the CHF[3] were developed for PubMed. The BestBets[1] and Kastner[2] search strategies were originally designed for Medline accessed via Ovid. We adapted these search filters for PubMed. The PubMed search filter is part of the limits option in PubMed.[4] This filter was recently renamed by PubMed as the Child: 0-18 years filter.[4] Details of the search filters can be found in **Appendix 3** (available at www.jpeds.com).

Development of the Reference Dataset

By combining all above mentioned child search filters with the Cochrane HSSS for identifying RCTs and CCTs, 701 references were retrieved in PubMed during one week (**Figure**). Of the 701 retrieved records, 431 references were assigned as studies including children, and 270 references were assigned as studies without children or as studies where the outcome was not directly related to children, for instance prenatal studies, where the outcome of pregnant women was discussed.

Development of the Validation Dataset

A total of 173 Cochrane systematic reviews met our inclusion criteria and were used for retrieving RCTs or CCTs for inclusion in our validation dataset. These reviews included 2808 RCTs and CCTs published as journal articles (N = 2430, including 161 not indexed in PubMed), theses (N = 33), proceedings abstracts (N = 203), and other publications types (N = 142).

After removal of the studies not indexed in PubMed (ie, journals not available in PubMed, theses, proceedings abstracts, and other publication types), studies with adults only or age not clearly specified, and of the double or triple RCTs and CCTs, 1357 unique articles were entered into the validation dataset (**Appendix 4**; available at www.jpeds.com). The validation dataset covered 351 journals, and 46 publications years (1951-2008).

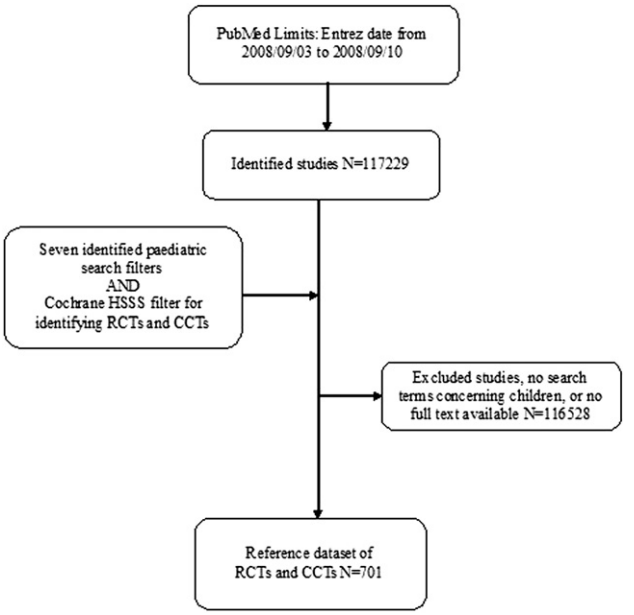

Figure. Flow chart for the development of the reference dataset in PubMed.

Calculation of Sensitivity, Precision, Specificity, Accuracy, and NNR Within the Reference Dataset

Table II shows the sensitivity, precision, specificity, accuracy, and NNR calculated for each of the 7 child filters applied to the reference dataset. The sensitivity varied between 44.8% for Kastner pediatric 3 filter and more than 99% for the CCG, CHF, and BestBets search filters. The precision varied between 64.5% (CCG filter) and 93.7% (Kastner pediatric filter 3). The specificity varied between 12.6% (CCG filter) and 95.3% (Kastner pediatric filter 3). The accuracy varied between 64.2% (Kastner pediatric filter 3) and 77.3% (PubMed Limits: All Child: 0-18 years). The NNR varied between 1.07 (Kastner pediatric filters 2 and 3) and 1.55 (CCG filter).

Calculation of the Sensitivity Within the Validation Dataset

The sensitivity of the 7 child filters calculated in the validation dataset is comparable with the sensitivity calculated in the reference dataset. The sensitivity varied between 46.4% for Kastner pediatric filter 2 to more than 98% for the CCG, CHF, and BestBets search filters (**Appendix 5**; available at www.jpeds.com). In this validation set, 23 RCTs and CCTs were not identified by either the CCG, CHF, or BestBets child search filters in PubMed (because

Table II. Sensitivity, precision, specificity, accuracy, and NNR for 7 pediatric search filters in the reference dataset

Pediatric search filter	Retrieved references: Total	Correct inclusion	Incorrect inclusion	Correct exclusion	Incorrect exclusion	Sensitivity (%)	Precision (%)	Specificity (%)	Accuracy (%)	NNR
CCG[7]	664	428	236	34	3	99.3	64.5	12.6	65.9	1.55
CHF[3]	625	429	196	74	2	99.5	68.4	27.4	71.8	1.46
BestBets[1]	643	428	215	55	3	99.3	66.6	20.4	68.9	1.50
Kastner pediatric 1[2]	553	408	145	125	23	94.7	73.8	46.3	76.0	1.36
Kastner pediatric 2[2]	271	252	19	251	179	58.5	93.0	93.0	71.8	1.07
Kastner pediatric 3[2]	206	193	13	257	237	44.8	93.7	95.2	64.2	1.07
PubMed Limits: All Child: 0-18 years (in May 2012 renamed as PubMed Filter Child: 0-18 years)[4]	540	406	134	136	25	94.2	75.2	50.4	77.3	1.33
New CCG	622	429	194	76	2	99.5	69.0	28.1	71.9	1.45
Total retrieved records	701	431	270							

Kastner pediatric 1 = Kastner search filter for best sensitivity.
Kastner pediatric 2 = Kastner search filter for best optimization of sensitivity and specificity.
Kastner pediatric 3 = Kastner search filter for best specificity.

they did not contain any words relating to child or pediatric) but were assigned by Cochrane review authors as studies with children.

Development of a New Search Filter

Only these last 3 filters were taken into account because data of the Kastner and PubMed filters were already completely covered by the results of the CCG, CHF, and BestBets filters. The search terms, which resulted in false-positive results in the reference dataset were identified.

False-positive studies (ie, studies retrieved by a search filter but which were not assessed as a study with children) were identified with the search term boy* (CCG, CHF, BestBets), school* (CCG), Adolescent [MeSH] (CCG, CHF), adoles* (CHF) and adolescen* (BestBets), minor* (BestBets), preterm* (CHF), and premature* (CHF), where "*" stands for no character or more characters.

The search term boy* identified 11 false-positive studies because boy* also retrieves author names starting with Boy. The search term school* retrieved 58 false-positive studies, because the affiliation is also searched, and this often holds the term school (eg, School of Medicine). The different search terms for adolescent identified 110 false-positive studies because PubMed has a different definition of this age group. PubMed includes persons aged 18 years in the definition of adolescent and we regarded persons of 18 years old as adults. The false-positive studies identified with the search term minor* (27 studies), preterm* (2 studies), and prematur* (6 studies) were studies where 'minor,' 'preterm,' or 'premature' were used as an adjective (eg, minor myalgias, preterm labor, premature vascular disease).

A new improved search filter for identifying studies with children was developed based on the results of our study, using the BestBets search filter as starting point, as this filter had the highest sensitivity in the validation dataset and the lowest number of search terms. The term infan* was chosen because it retrieves infant, including MeSH, and terms like infancy. Both new-born* and newborn* were chosen, because of the higher amount of retrieved studies. Baby, baby*, and babies were chosen instead of bab*, a search term of the BestBets filter because bab* has more than 600 variations. PubMed can only search the first 600 variations of a truncated search term. Addition of baby* and babies to the search filters gives a higher retrieval. The search term minor* resulted in too many irrelevant studies and was, therefore, replaced by the search terms minors OR minors*, part of the CCG search filter. The search term boy* was replaced by boy OR boys OR boyfriend OR boyhood to avoid retrieval of false-positive studies (ie, author's last name starting with Boy). The search term child* was replaced by child OR child* OR children*, as with child* only the first 600 variations will be searched by PubMed. The search term school*age was replaced by 2 search terms school[tiab] OR school*[tiab] where [tiab] stands for title or abstract. Then, only title and abstract are searched, and also records with school child will be identified, thus, solving the problem associated with searching the affiliation of authors. The search terms prematur* OR preterm* from the CHF search filter identified unique studies, not identified by other search terms. Despite a few false-positive studies they were also added to the new search filter.

The new search filter (**Table III**) was validated within the reference dataset (**Table II**). The sensitivity of this new filter was 99.5% in the reference dataset, which is comparable with those of BestBets and CCG (ie, 99.3%) and similar to that of the CHF filter. The precision of the new search filter was 69.0%, the specificity was 28.1%, and the accuracy was 71.9%. The NNR was 1.45. In the validation dataset, the

Table III. Improved CCG child filter for PubMed

Infan* OR newborn* OR new-born* OR perinat* OR neonat* OR baby OR baby* OR babies OR toddler* OR minors OR minors* OR boy OR boys OR boyfriend OR boyhood OR girl* OR kid OR kids OR child OR child* OR children* OR schoolchild* OR schoolchild OR school child[tiab] OR school child*[tiab] OR adolescen* OR juvenil* OR youth* OR teen* OR under*age* OR pubescen* OR pediatrics[mh] OR pediatric* OR paediatric* OR peadiatric* OR school [tiab] OR school*[tiab] OR prematur* OR preterm*

mh, Medical Subject Heading; *tiab*, title or abstract.

sensitivity of the new search filter was 98.3%, similar to that of the BestBets search filter.

Discussion

PubMed is one of the most widely used medical databases among health care professionals and has reached over 21 million records representing articles in the biomedical literature in 2012.[10] To be able to keep up-to-date with relevant research findings, health care professionals must be able to use search filters that are both sensitive (ie, retrieving as many relevant publications as possible) and precise (ie, identifying as few irrelevant studies as possible). This is the first study in which the performance of all available search filters identifying studies including children has been evaluated.

Three of 7 search filters for identifying studies with children performed similarly with respect to sensitivity, precision and NNR (CCG,[7] CHF,[3] and BestBets,[1] respectively). The likelihood of missing relevant studies with 1 of these filters was low. The other 4 search filters were more specific, having a higher precision and, thus, a lower NNR. However, these 4 filters with the highest precision missed many relevant studies (Kastner[2] pediatric filters 1, 2, and 3, PubMed Limits: All child: 0-18 years[4]).

The accuracy, describing the proportion of correctly included and correctly excluded citations[5] of the 7 child search filters was almost identical, but the performance of these search filters with respect to sensitivity and precision was very different. This suggests that accuracy was not a good measure for validation of these search filters, and may be not for other search filters as well.

The sensitivity of the 7 search filters for identifying studies including children in the validation dataset was comparable with those calculated within the reference dataset. It can be concluded that the method for constructing and using the reference dataset for calculating the sensitivity of search filters was valid.

Our results regarding the Kastner pediatric search filters are comparable with those calculated by Kastner et al,[2] but in a few cases a different result was identified. For instance, Kastner pediatric filter 1 has a high sensitivity (98%) but a low precision (25%). We calculated 94% and 74%, respectively, for those measures in our database. This difference can be explained by the use of a different database. Kastner et al[2] used a database with data from 161 journals, and we used RCTs and CCTs including children published within PubMed in a 1 week period. Boluyt et al[3] showed a sensitivity of 98% for the CHF filter in PubMed, which is in agreement with our findings.

In this study, we used both a reference and validation dataset, so we could confirm our results in a new set of data. Development of a small reference dataset in PubMed as described in this study is easy and less time consuming than constructing a closed database, as for instance, Kastner et al[2] have used. However, our reference dataset only consisted of RCTs and CCTs. This was chosen for practical reasons to keep the amount of data manageable. We do not expect that this will have affected the results of our study, as the child search filters are independent from the design of the original studies.

In the validation dataset 23 RCTs and CCTs were not identified by the CCG,[7] CHF,[3] and BestBets[1] child search filters, as no words relating to child or pediatric were available in the title or abstract of the PubMed records, and they were not indexed in PubMed as studies including children. However, they were assigned by authors of Cochrane reviews as such. New research should be performed to clarify this matter.

We evaluated the retrieval of false-positive results in the reference dataset. Based on these results, we developed a new child search filter. This improved search filter (new CCG search filter) was also validated using both the reference and validation datasets. The sensitivity of the new CCG search filter in the reference dataset was similar to the 3 search filters with the highest value for this measure (CCG,[7] CHF,[3] BestBets[1]), and a higher precision was obtained compared with these 3e search filters.

Based on the results of our study, we recommend using this new improved child CCG search filter for retrieving studies with children in PubMed. In addition to high sensitivity, this search filter also has high precision with a low NNR. As a result, few studies will be missed while eliminating the need to read excessive irrelevant data. Use of this search filter likely would save time for pediatric health care professionals who want to keep up to date with all relevant pediatric studies. ■

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Reprint requests: Edith Leclercq, PhD, Cochrane Childhood Cancer Group, Department of Paediatric Oncology, Emma Children's Hospital/ Academic Medical Center, Meibergdreef 9, 1105 AZ Amsterdam, The Netherlands. E-mail: e.leclercq@amc.uva.nl

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Appendix 1. Cochrane HSSS for identifying RCTs and CCTs filter for PubMed, update February 2008

((randomized controlled trial[pt]) OR (controlled clinical trial[pt]) OR (randomized[tiab]) OR (placebo[tiab]) OR (drug therapy[sh]) OR (randomly[tiab]) OR (trial[tiab]) OR (groups[tiab])) AND (humans[mh])

Appendix 2. Cochrane Library search strategy for identifying systematic reviews including children as participants

#1. (child* OR infant*) in Title, Abstract, or Keywords
#2. (1994 OR 1995 OR 1996 OR 1997 OR 1998 OR 1999 OR 2000 OR 2001 OR 2002 OR 2003 OR 2004 OR 2005 OR 2006 OR 2007 OR 2008) in Source
3. #1 AND #2

Issue 2, 2008 of the Cochrane Database of Systematic Reviews of the Cochrane Library (via www.thecochranelibrary.com) was searched.

Appendix 3. Child search filters for PubMed

CCG[7]:
Infant OR infan* OR newborn OR newborn* OR new-born* OR baby OR baby* OR babies OR neonat* OR perinat* OR postnat* OR child OR child* OR schoolchild* OR schoolchild OR school child OR school child* OR kid OR kids OR toddler* OR adolescent OR adoles* OR teen* OR boy* OR girl* OR minors OR minors* OR underag* OR under ag* OR juvenil* OR youth* OR kindergar* OR puberty OR puber* OR pubescen* OR prepubescen* OR prepuberty* OR pediatrics OR pediatric* OR paediatric* OR peadiatric* OR schools OR nursery school* OR preschool* OR pre school* OR primary school* OR secondary school* OR elementary school* OR elementary school OR high school* OR highschool* OR school age OR schoolage OR school age* OR schoolage* OR infancy OR schools, nursery OR infant, newborn

CHF[3]:
Infant[MeSH] OR Infant* OR infancy OR Newborn* OR Baby* OR Babies OR Neonat* OR Preterm* OR Prematur* OR Postmatur* OR Child[MeSH] OR Child* OR Schoolchild* OR School age* OR Preschool* OR Kid OR kids OR Toddler* OR Adolescent[MeSH] OR Adoles* OR Teen* OR Boy* OR Girl* OR Minors[MeSH] OR Minors* OR Puberty[MeSH] OR Pubert* OR Pubescen* OR Prepubescen* OR Pediatrics[MeSH] OR Pediatric* OR Paediatric* OR Peadiatric* OR Schools[MeSH] OR Nursery school* OR Kindergar* OR Primary school* OR Secondary school* OR Elementary school* OR High school* OR Highschool*

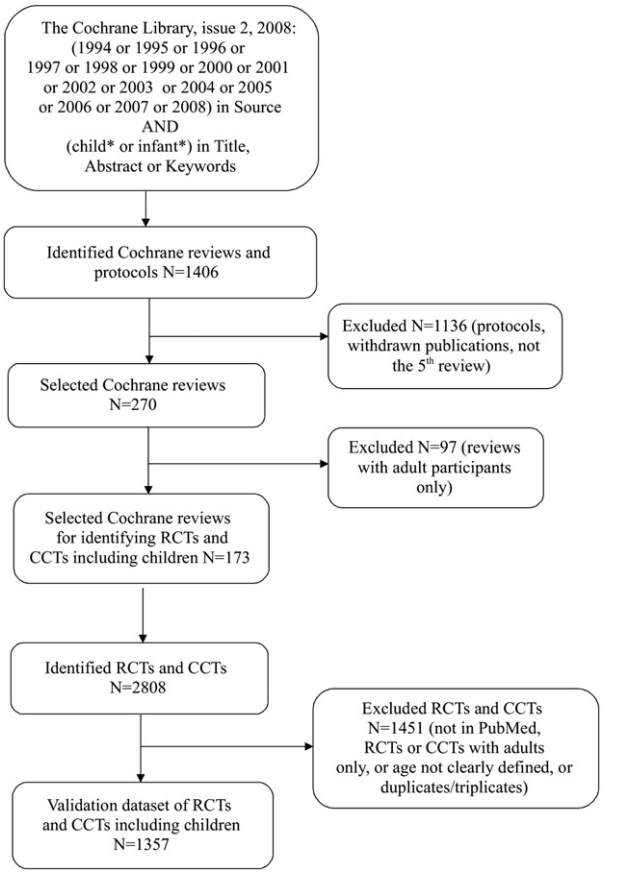
Best Bets[1] (without journals names) adapted for PubMed:
Perinat* OR neonat* OR newborn* OR infan* OR bab* OR toddler* OR boy* OR girl* OR kid* OR school*age OR juvenil* OR under*age* OR teen* OR minor* OR pubescen* OR adolescen* OR child[mh] OR child* OR pediatrics[mh] OR pediatric* OR paediatric*

Kastner[2] pediatric 1 (best sensitivity), adapted for PubMed:
Child OR infan* OR adolescent.

Kastner[2] pediatric 2 (best optimization of sensitivity and specificity), adapted for PubMed:
Adolescent[tiab] OR children[tiab] OR child, preschool[mh]

Kastner[2] pediatric 3 (best specificity), adapted for PubMed:
Children[tiab]

PubMed[4] Limit All Child: 0-18 years
"Infant"[MeSH Terms] OR "child"[MeSH Terms] OR "adolescent"[MeSH Terms]



Appendix 4. Flow chart for developing the validation dataset of RCTs and CCTs.

Appendix 5. Sensitivity of child search filters in PubMed using the validation dataset date of searching June 24, 2009

Pediatric search filter	Retrieved references			Sensitivity (%)	95% CI
	Total	Correct inclusion	Incorrect exclusion		
GS	1357	NA	NA	NA	NA
CCG[7]	1333	1333	24	98.23	0.97-0.99
CHF[3]	1332	1332	25	98.16	0.97-0.99
BestBets[1]	1334	1334	23	98.31	0.97-0.99
Kastner pediatric 1[2]	1325	1325	32	97.64	0.97-0.98
Kastner pediatric 2[2]	630	630	727	46.43	0.44-0.49
Kastner pediatric 3[2]	736	736	621	54.24	0.52-0.57
PubMed Limits: All Child: 0-18 years[4]	1321	1321	36	97.35	0.96-0.98
New CCG	1334	1334	23	98.31	0.97-0.99

GS, gold standard; *NA*, not applicable.
Kastner pediatric 1 = Kastner search filter for best sensitivity.
Kastner pediatric 2 = Kastner search filter for best optimization of sensitivity and specificity.
Kastner pediatric 3 = Kastner search filter for best specificity.