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Improving the Use of Electronic Medical Records in Primary Health Care: A Systematic Review and Meta-Analysis

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Abstract

Electronic Medical Records were first introduced in the 1970s to organize patient information, improve coordination of care, and improve communication. The purpose of this systematic review was to identify interventions aimed at improving EMR use in primary health care settings. Of 2,098 identified studies twelve were included in the review. Results showed that interventions focused on the use of EMR functions were five times more likely to show improvements in EMR use compared to controls. Interventions focused on data quality were five and a half times more likely to show improvements in EMR use compared to controls. Individuals in primary health care settings aiming to improve EMR use would benefit from implementing interventions focused on EMR feature add-ons, and provisions of educational materials, or financial incentives targeted at improving the use of EMR functions and data quality.

Keywords

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Chapter 1

1   Introduction

In the past few decades technology has taken up a greater role in healthcare. This is reflected in the introduction of information technologies into the health care system. Electronic medical records (EMRs) are one form of information technology which can impact patient health outcomes.[1,2] EMRs are computerized patient records introduced in the early 1970s.[3] However they were not widely accepted by the health care sector until the 1990s and the availability of more affordable technology.[4] Around the turn of the century, EMRs gained attention because of the benefits they could offer the health care system such as: organization of patient health care information, improved coordination of care as well as easier electronic access to medical information and expert opinion.[4,5] This drove organizations and governments to create programs to promote the adoption of EMRs into the health care system.[4] The *Health Information Technology for Economic and Clinical Health Act* (HITECH) enforced in 2009 in the United States, is an example of these attempts to promote EMR adoption.[6]

The distinction between EMR adoption and use is not clearly defined in the literature. However, for the purposes of this review, *adoption* of EMRs is defined as simply the introduction of EMRs into primary health care practice. The *use* of EMRs is the second step following adoption, where practitioners use EMRs and their features to perform daily practice functions. A national survey in 2015 showed that the adoption of EMRs into primary health care practices is on the rise in Canada while EMR use is still low in comparison.[7,8]

Some studies suggest that to achieve noticeable improvements in patient health outcomes following adoption, improving the use of EMRs is necessary.[9,10,11,12] Therefore, improving the use of EMRs to achieve desirable health outcomes has attracted recent attention.[13] Some attempts have already been made to improve EMR use through the development of programs such as the Meaningful Use Criteria developed by The Centers for Medicare and Medicaid Services (CMS) in the US.[14] CMS defined meaningful use as: "Using [EMRs] to: Improve quality, safety, efficiency, and reduce health disparities.

Engage patients and family. Improve care coordination, and population and public health. Maintain privacy and security of patient health information". [15] For the purposes of this review, improved EMR use is defined as using EMRs according to the above definition. The mechanisms to improving EMR use however, have not yet been determined. This systematic review sought to identify interventions focused on improving EMR use.

1.1 Thesis Structure

This thesis was written in a monograph format in accordance with the requirements outlined by Western University School of Graduate and Postdoctoral Studies. It is a systematic review with the goal of identifying interventions aimed at improving EMR use in primary health care. Chapter 2 is a literature review. Inclusion criteria and the process by which the literature was searched to identify relevant studies are described in Chapter 3, along with information on data extraction, the meta-analysis methods and the use of the risk of bias assessment tool. Chapter 4 presents the results of the database search as well as the results of the individual included studies. Following that, the meta-analysis results are presented using forest plots and while the risk of bias assessment results are presented using a bar graph. Chapter 5 is the discussion chapter in which the results are briefly summarized and the main findings of the review are elaborated on. Chapter 5 also lists the strengths and limitations of this study.

Chapter 2

2 Literature Review

This chapter defines important concepts relevant to this review. Research in the area of EMRs and their adoption and use is described, followed by introducing and defining meaningful use. A conceptual model that links EMR use and patient outcomes is also discussed in this chapter. In addition, concepts that support the inclusion and exclusion criteria used in this review (described in the methods section) are discussed.

2.1 Electronic Medical Records

EMRs were introduced in the early 1970s as a way to organize, secure, complete and improve the quality of patient health care records.[3] According to the International Organization of Standardization (IOS) "[An EMR is] … a repository of patient data in digital form, stored and exchanged securely, and accessible by multiple authorized users. It contains retrospective, concurrent, and prospective information and its primary purpose is to support continuing, efficient and quality integrated health care."[16]

The terms electronic health records, electronic medical records and personal health records are used interchangeably depending on the location/country of use.[17] Canada Health Infoway, a federally funded non-for-profit organization, suggests the three terms differ in two main ways: the completeness of the information and the keepers/organizers of the database.[18] EMRs hold a portion of a patient's health record information and are maintained by the health care provider. True to their name, EMRs contain all matters related to a patient's medical visits such as diagnostic, treatment and medication prescription information. Electronic health records are similarly maintained by the health care provider but differ from EMRs in that they hold a complete record of the patient's lifetime health history. This includes information that reaches beyond just medical information to document a full patient history.[19] Finally, personal health record can be a partial or complete record of the patient's lifetime health that is managed by the patient or a family member.[18] Other common ways to refer to EMRs include: Computerized Patient Records, Computerized Medical Records, Computerized Health Records, simply e-

records, in addition to longitudinal health records.[16] For the purposes of this review, any electronic record created with the purpose of storing patient information, which fulfils the definition by the IOS, will be referred to as an electronic medical record or EMR.

EMRs were created to be a secure and efficient way to organize patient information and assist in daily primary health care functions.[3] To enable EMRs to perform these functions, they have been equipped with various features.[20] The storing of organized and secure patient information is made possible through the health templates feature.[21,22] Health templates are used to manage clinically relevant patient information such as medication lists, patient history, diagnostic information and laboratory results.[9] The stored patient information can be used in combination with clinical decision support features to assist health care professionals with treatment and prescription options.[20,23,24,25,26,27] Another way to benefit from health templates is the use of these EMR features for the exchange of patient health care information. This allows for managing the flow of laboratory, diagnostic imaging and prescription patient information by allowing for electronic communication between health care providers.[30,32,13] EMR features also assist primary health care providers with patient referrals through facilitating patient flow between health care sectors.[21,22] Some EMRs are also equipped with features that allow for the creation of alerts and reminders to assist in prescription management and in reviewing screening, laboratory and diagnostic tests.[28,30,32] EMR features could also be used to manage administrative processes through the use of recorded EMR information as feedback.[21,22]

The primary intended users of the EMR are health care providers, however there are some EMR features that allow for patient involvement.[17,33] These features allow patients to access their EMRs to directly communicate with their primary health care providers.[13] According to a review of the literature conducted by Hayrinen et al. (2008), EMR users are primarily general practitioners and nurses but could also include pharmacists, laboratory, radiology and administrative staff as well as patients and, for those underage, their guardians.[17] EMRs can be equipped with features to improve their function. The use of these features can lead to: 1) the complete and safe documentation of patient information leading to improved, timely and unhindered access; 2) improved

coordination of care; 3) reduced errors; 4) more involved patients; 5) smoother administrative processes with the help of tailored feedback.

2.2 Primary Health Care

Primary health care involves one-on-one interaction between patient and health care providers. In this context, primary health care professionals are expected to be the coordinators of health care and when needed, facilitate the use of other health related services. Barbara Starfield defined primary care as "the level of health service system that provides entry into the system for all new needs and problems, provides-person focused care over time, and coordinates or integrates care provided elsewhere by others".[34] In addition, according to the Ontario Ministry of Health and Long-Term Care, primary health care is defined as the first level of care and first point of contact for patients with the health care system. It includes services to promote health care and disease prevention and to perform health assessments. It is also responsible for the diagnosis and treatment of chronic conditions and rehabilitative care.[35] Therefore, primary health care has a great impact on the health of the population. The importance of a strong primary health care system is also reflected in the results of a study by Macinko et al. 2003, which showed a strong inverse relationship between the strength of the primary health care system and mortality in developed countries.[36]

For the purposes of this review, primary health care as defined by Barbara Starfield (1998) and the Ontario Ministry of Health and Long-Term Care is the target setting. It includes community based health care settings that target primary prevention, diagnosis, treatment and management of chronic diseases in addition to rehabilitation support and end of life care. Any health care setting that is considered the first point of contact with the patient providing one-on-one interactions and is responsible for referrals of new patients into the system will be considered a primary health care setting and be included in this review.

2.3 Impact of EMRs

With their creation and introduction into primary health care, EMRs were expected to have a positive impact on the quality of health care.[37] This was expected to be realized through the use of EMRs to improve data quality through the recording of patient information and perform primary health care functions. However, even after the rise in adoption rates, studies continued to show mixed results of the impact of EMRs on patient health outcomes. [10,11,33,37,41] While EMRs have been successfully used as an electronic way to store patient information, the impact of the use of more advanced functionalities is still to be determined. The electronic storing of patient information provides rapid and timely remote access to patient information which could assist in speeding up the provision of care.[9] Studies have found that the use of the EMR decision support feature resulted in improved patient outcomes through decreasing errors related to patient care.[24,25,40] Similarly, studies found that the use of alerts and reminders allowed for on time patient preventative and screening tests.[32,41,42] Some studies found that using the EMR features to exchange patient information allowed for fast and timely patient referrals.[12,28,29] However, even though studies found a positive effect in relation to those EMR features on primary health care center workflow, they were unable to link that improvement to changes in the quality of health care.[9,24,27] Some studies have also linked the use of EMR features to improvements in the management of chronic diseases.[43,44,45] The EMR's ability to help with chronic disease management is achieved through the use of its previously mentioned features, which include: health templates, decision support systems, and alerts and reminders. Therefore, the improved use of EMRs is expected to have an impact on data quality and quality of care, which could lead to improvements in patient health outcomes.[12]

2.4 Levels of EMR Adoption and Use

Even though the difference between EMR *adoption* and *use* has not been clarified in the literature, based on the goals of the HITECH act, adoption of EMRs is defined as simply the introduction of EMRs into primary health care.[6] The use of EMRs follows adoption,

and requires the use of EMRs and its features to perform daily primary health care functions. This review focused on the use of EMRs after their adoption.

Levels of EMR adoption in primary health care have been on the rise in most developed countries.[46] The Commonwealth International Health Survey of Primary Care Physicians (2012), used the availability of EMRs in practice and the use of its most basic features to define *adoption*.[46] Of the eleven countries included in the survey the Netherlands and Norway are the countries with the highest percentage of EMR *adoption* at 98% followed closely by New Zealand at 97% with Switzerland as the lowest at 41%.[46] The United Kingdom, Australia and Sweden fell in the middle with 96%, 95% and 94% respectively.[46] Germany, the United States and France scored on the lower end with 82%,69% and 67% respectively.[46] Canada was the country with the second lowest scores after Switzerland at 56%.[46] All five countries included in the previous Commonwealth International Health Policy Survey of Physicians report in 2000, showed great improvements in adoption in the twelve-year gap period between the two reports.[46,47] The five countries, New Zealand, United Kingdom, Australia, Canada, and United States scored 52%, 59%, 25%, 14%, and 17% respectively on adoption in 2000.[47] Even though EMR adoption has been on the rise for the past decade, levels of improved EMR *use* have not followed the same trend. In the Commonwealth International Health Survey of Primary Care Physicians EMR use was defined as the use of the EMR's more advanced features.[46] Levels of EMR *use* for all eleven countries fall below 70% with the United Kingdom leading at 68% and Norway trailing at 4%.[46] Canada scores near the bottom at 10%.[31] These low percentages of EMR use, and in some cases EMR adoption, are suspected to be due to a number of barriers to adoption and continued use.[48,49] A better understanding of those barriers could assist in creating targeted interventions to eliminate these impediments to the adoption and use of EMRs.

2.5 Barriers to EMR Use

To better understand the reason for the discrepancy between adoption and use, one must consider barriers that prevent the improved use of EMR in primary health care. Those could include technical, technological and financial barriers. A better understanding of

the barriers that affect EMR use is essential to creating interventions targeted at breaking down those impediments to use. Some of the most common challenges include: cost, required computer skills, technical EMR system challenges, knowledge of EMR functions and time.[50,51,52,53] The usability of information technology systems, including EMRs, can be a barrier to their adoption.[54,55,56] However, usability as a barrier was not a focus of this systematic review. Barriers to EMR use fall under the following categories:

2.5.1 Technical

EMRs, as a new software system added into primary health care, require some basic computer skills to operate. Not all primary health care providers or intended users possess those required skills.[51] Therefore, one of the major barriers to use is the skill needed to use basic electronic functions.[50] In addition to basic computer skills, the knowledge of available EMR functions was also found to be lacking in intended users.[20] An important component to increasing EMR use is a good understanding of its features and advanced functions.[51,52] EMRs can assist users in performing the required procedures to allow for the smooth flow of information through primary health care and between health care sectors.[31,38] To allow for the proper use of those features, basic computer skills need to be coupled with knowledge about the availability of those features and guides on how to use them. Concerns have also been raised about the time required to acquire those new skills for those health care providers who are not technologically inclined.[51] Other barriers to EMR use in primary health care include time interruptions and time delays in everyday processes due to the use of EMRs.[52] Therefore, technical barriers to EMR use include: lack of computer skills, time to acquire those skills and, added time to incorporate EMRs into daily functions of primary health care.

2.5.2 Technological

Expanded EMR capability comes from the numerous functional software add-ons that have been developed to widen the use of this technology in the field of health care. Therefore, it is essential for health care practices to constantly upgrade the EMR to incorporate new and improved EMR features.[52,53] Along with that, an EMR as a

computer software program requires constant monitoring and repairs. Interruptions in EMR functioning could affect use and greatly impede workflow in primary health care, delaying the delivery of health care. Therefore, the availability of technological support is key for the continued use of EMRs in primary health care.[52]

2.5.3 Financial

One of the biggest challenges to the continued use of EMRs is on-going costs. These include maintenance costs required to keep the EMR system in working order and up to required standards.[53] Health care practices are required to pay for technical support and additional EMR features after installation.[53] The concerns related to the burden of ongoing costs is in part due to the fact that there is a lack of financial resources and funding incentives to achieve the meaningful use of EMRs.[53] Financial resources are necessary to assist in maintenance and upgrade costs associated with the ongoing use of EMRs.[53]

These three areas group the main barriers to the use and continued use of EMRs which need to be addressed using tailored interventions.[53]

2.6 Improving EMR Use

Improving EMR use through the proper use of its features could have a favorable impact on health care. The adoption of EMRs into primary health care is only the first step to creating a potential positive change. [11,12,20] The Clinical Adoption Meta-Model (CAMM) discusses the steps leading to the improved use of EMRs and its effect on patient health outcomes. The CAMM classified the adoption of EMRs into primary health care in four phases, starting with the availability of the EMR system.[57] The first phase of EMR adoption is not enough to achieve improved health outcomes without being followed by the second phase, which is EMR use. The improved use of EMRs after adoption could lead to the third phase of clinical and health behavioral changes resulting in improvements in clinical outcomes as the fourth and final phase (as shown in Figure 1).

Figure 1: EMR Clinical Adoption Meta-Model
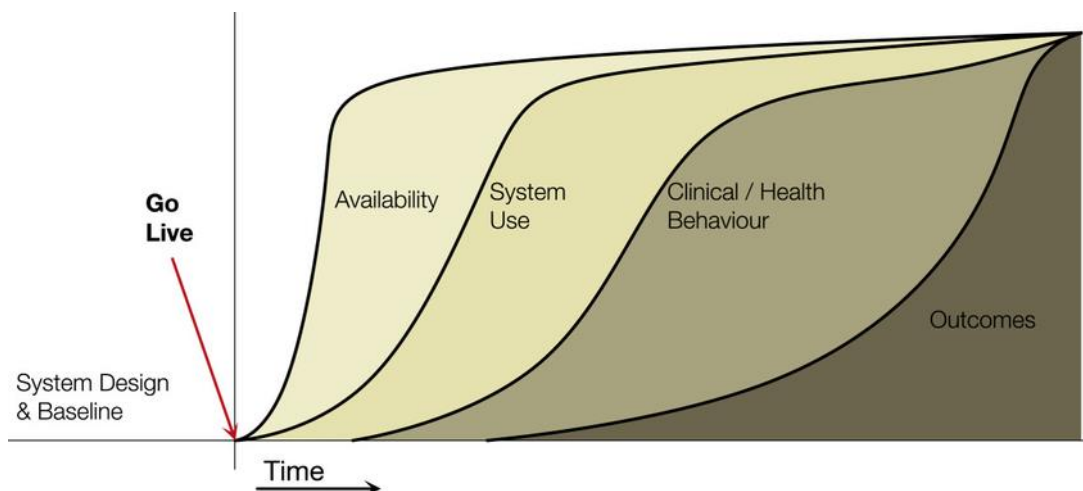
Linking EMR adoption to improvements in clinical outcomes can only be achieved through targeting the missing link, the appropriate use of EMRs. Helping health care providers to improve patient health care may be achieved through improving their EMR use. Improving the use of EMRs refers to using the EMR and all its features in a meaningful way to support achieving desired patient health outcomes. Incentives to maximize EMR use include the establishment of the Meaningful Use criteria which aims to improve EMR use through achieving meaningful use. Meaningful use is defined as, using EMR features to improve the quality of care through capturing and sharing patient health information, improving the coordination of care, and involving patients.[15] The Meaningful Use criteria (updated November 2015) are outlined by CMS of the United States Department of Health and Human Services through two stages[14]:

Stage 1: Promoting Adoption and Documentation–

As mentioned in the CAMM, to benefit from EMR use, primary health care providers must first introduce EMRs. Stage 1 of the Meaningful Use program works to first ensure proper EMR adoption into primary health care. To ensure EMR adoption into primary health care, all paper records are expected to be converted into electronic records stored in an EMR. Following that, the second part of stage 1 includes complete and structured

documentation of patient records electronically.[58]

Stage 2: Quality Improvement-

The link between EMR use and quality improvement is utilizing EMRs and their features in the coordination of care and the exchange of patient health information. This stage targets the implementation and use of EMR features to further the quality of care.[13,58] Stage 2 encompasses 10 objectives that health care practices are required to report on to mark improvements in meaningful use.[58] These objectives are listed along with a detailed description in Table 1. The objectives aim to improve EMR use through promoting the use of its features which include: patient record security and availability, patient information exchange and referrals, as well as the use of clinical decision support systems. In addition, to achieve meaningful use, primary health care providers are expected to use EMR features in laboratory orders, diagnostic imaging orders and medication prescribing and reconciliation.[58] The meaningful use criteria also targets patients as users in the EMR and requires them to access their health information using the provided EMR features. In addition, it encourages patients to use the EMR features to contact their primary health care providers and communicate with them through the EMR.[58] The last objective to achieving meaningful use allows EMR users to contribute to the health care system. This contribution is achieved through allowing for the information collected and stored in the EMR features to be used in reporting on important public health measures.[58] The second stage of meaningful use targets the health care practice's ability to use all the previously mentioned features of an EMR.

Table 1: Description of the Stage 2 Objectives of Meaningful Use Criteria

STAGE 2 OBJECTIVES	DESCRIPTION
Protect Patient Health Information	Ensure updated security measures and identify security downfalls to protect patient health information
Health Information	Electronically documenting referrals to other health care

STAGE 2 OBJECTIVES	DESCRIPTION
Exchange	providers
Clinical Decision Support	Implementing and using CDS in patient diagnosis and drug interactions in relation to medication prescription.
Computerized Provider Order Entry (CPOE)	Using computerized physician order entry (CPOE) to record prescriptions, laboratory orders and diagnostic imaging orders
Electronic Prescribing	Accounting for and electronically transmitting prescriptions
Medication Reconciliation	Performing medication reconciliation for new patients
Patient-Specific Education	Providing patient-specific education resources through the EMR
Patient Electronic Access (VDT)	Providing patients with timely access to the electronic records, to view their health information online as well as download, and transmit to a third party
Secure Messaging	Allowing for sending and receiving secure electronic messages between patients and primary health care providers
Public Health	Active engagement with a public health agency to report on the following: - Syndromic surveillance data. - Immunization data - Specialized registry reporting

Recreated from: Healthit.gov, Step 5: Achieving Meaningful Use Stage 2. 2014. https://www.healthit.gov/providers-professionals/step-5-achieve-meaningful-use-stage-2

Therefore, the meaningful use criteria aims to: 1) improve health outcomes through improving quality, safety and efficiency of health care, 2) improve the coordination of care by increasing the transparency of information storage and exchange, 3) involve patients and patient families in their own health care through improving communication,

and 4) provide public health research information while protecting patient privacy. Ultimately the goal of creating the meaningful use criteria is to improve EMR use in primary health care settings in order to achieve improvements in patient health care.[15]

2.7 Types of interventions

Based on the previously identified barriers, it might be expected that interventions to improve EMR use would focus on these areas. To reduce the effect of technical barriers on EMR use, required interventions would be those that could advance the knowledge of health care providers in computer use and the available EMR features. The advanced knowledge in those areas could reduce the time needed to use EMRs for daily functions.[52] This could be achieved through educational seminars and workshops as well as guidelines to facilitate EMR use.

Technological barriers are another area in which specific and targeted interventions could improve EMR use.[52,53] Technological barriers include lack of up to date EMR features and concerns targeted at interruptions in EMR function due to technological errors.[52,53] Therefore, constant upgrades to the EMR and a technological support team available for troubleshooting could facilitate health care providers' use of the EMR.

Lastly, interventions could target financial barriers to assist with on-going costs of EMR maintenance. Financial interventions could involve government funding or financial incentives and rewards as part of programs that promote improving the use of EMRs. For example, as part of the Medicare and Medicaid EHR Incentive Programs in the United States a financial incentive is provided to those health care practices that can prove meaningful use using the provided criteria.[14] Therefore, interventions in the area of EMR use should work to break down technical, technological and financial barriers to allow for the meaningful use of EMRs as summarized in Figure 2.

Figure 2: The Expected Relationship Between Barriers to EMR Use and Interventions Targeted at EMR Use
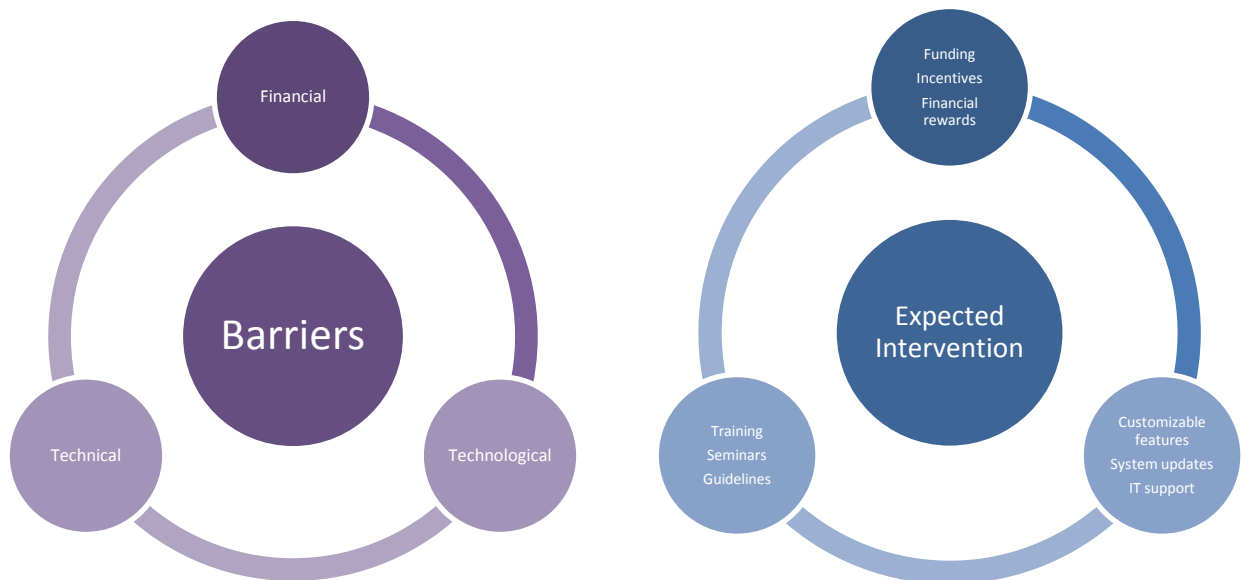
2.8 Target of Interventions

Interventions to improve EMR use can do so through two different paths. The first path includes interventions targeting the earlier identified barriers to EMR use. The second path represents targeting areas of health care center function that were expected to be enhanced by EMR use. For the purposes of this review, these paths will be defined as intervention target areas. Therefore, interventions to improve EMR use can be implemented or observed in two intervention target areas: barriers to EMR use and areas enhanced by EMR use. In addition, a successful intervention needs to target a specific population. EMRs in primary health care are used by a wide variety of personnel.[17] Therefore, in terms of interventions to improve EMR use, the target population would include any possible users. The following section further describes possible intervention target areas to improve EMR use as well as the target population for those interventions.

2.8.1 Intervention Target Area

Barriers to EMR Use: To target barriers to the continued use of EMRs, interventions need to address three different types of barriers. First, technical barriers, which would include the knowledge and skill required to use EMRs. Similarly, interventions can target technological barriers which would include errors in EMR function and technological challenges. The last identified barrier group that could be addressed using interventions, are financial barriers. Those include the on-going costs of maintaining EMR functions and software add-ons.

Areas Enhanced by EMR Use: Equally important as a target to improve EMR use, are areas to be enhanced by the use of EMRs in primary health care practice. Those areas include: 1) data quality, 2) use of EMR functions 3) workflow. 1) When evaluating EMR use, it is important to discuss the quality and efficiency of the inputted data.[59] The quality of data can be measured through its completeness and accuracy.[59] Therefore, data quality is another important target for interventions aimed at improving EMR use due to its ability to affect patients' health.[11] 2) Additionally, EMRs are equipped with features to enhance their functionality and ability to support primary health care practice operations.[21] To maximize EMR use, primary health care providers could use more advanced EMR features to perform specific tasks. Those features would include those that assist in decision making, and allow for patient access. They can also include features that facilitate communication between patients and their health care providers as well as between different sectors of the health care system.[60,61,62,63] Therefore, another area in which EMR use can be influenced is in the use of its features. 3) EMRs also have a great impact on primary care physician and primary health care center workflow.[64,65,66] This includes using EMR software to manage primary health care processes and issue work orders therefore improving the ease at which tasks are performed.

In conclusion, EMR use can be targeted by interventions in areas such as technical, technological and financial support as well as data quality, use of EMR functions and workflow.

2.8.2 Intervention Target Population

The target population for interventions aimed at improving EMR use include primary health care providers such as: family physicians, and registered nurses. It also includes primary health care staff such as administrative assistants and clerks as well as technicians. In some cases, EMR users could also include patients. This is a possibility in primary health care where patients are encouraged to access their EMR to communicate with their primary health care providers. Even though patients as EMR users have recently been accepted as an important aspect of meaningful use, there is still a lack of understanding as to the role they could play in improving the impact of EMRs on health outcomes.[17] The target population could also include EMR vendors for their ability to shape the EMR, thus affecting their usefulness.[13] Interventions aimed at improving EMR use mainly target EMR users as the target population.

2.9 Rationale and Objectives

The EMR system was developed originally in the early 1970's as a means to store patient health information.[3] Over time, and with the improvements in technology, EMRs are now capable of using stored patient health information to assist in the daily care provisions primary health care personnel provide to patients.[67] This is done with the hopes of improving patient health care through creating higher quality patient data and improving primary health care center processes.[28,13] However whether EMR use has been successful in improving the provision of patient care is as yet unclear based on a number of studies with conflicting results on the matter. A possible reason for this variety in results, may be challenges in improving the use of EMRs after their adoption.[29,10,39] Due to the importance of improving the use of EMRs with regard to patient outcomes, there has been recent interest on the part of organizations and governments to provide guidelines to improve EMR use.[13,68] Improving EMR use requires targeted interventions aimed at the areas in which EMRs were created to function. Therefore, the objective of this review was to identify various interventions and their effect on improving EMR use in primary health care settings. A systematic review was conducted. Included studies were those that

observed or implemented an intervention that targeted EMRs or EMR users with the objective of improving EMR use.

Chapter 3

3 Methods

This chapter provides an overview of the steps that were taken in conducting the systematic review and meta-analysis. This systematic review focused on intervention studies designed to improve the use of EMRs in primary health care settings. The Preferred Reporting System for Systematic Reviews and Meta-Analysis (PRISMA) was used as a guide. [69]

3.1 Literature Search

To collect studies for this review, a search strategy was developed with the assistance of a medical sciences research librarian at The University of Western Ontario, Dr. John Costella. The search strategy utilized three components made up of Medical Subject Headings (MeSH) and keyword terms for electronic medical records, primary health care and interventions. To achieve a comprehensive list, the final set of MeSH terms and keywords for the intervention terms were created using a form of "snowballing". Snowballing is known as using references in already identified studies as another source for relevant studies to be included.[70] Relevant intervention terms were collected through preliminary searches and used in combination with EMR and primary health care terms to identify relevant studies. The MeSH terms used to identify those studies were then used to create the final list of intervention terms. After that, limits to only include studies in English with human subjects conducted after 1970 were added to refine the search.

Using the above search strategy, the following databases were searched: MEDLINE (Medical Literature Analysis and Retrieval System Online) Ovid, Excerpta Medica dataBASE (EMBASE) Ovid, Cumulative Index for Nursing and Applied Health Literature (CINAHL), Cochrane Library and Web of Science. In addition to the published literature, the grey literature was also searched through the following databases: Clinical Trials, Networked Digital Library of Thesis and Dissertations (NDLTD), Canadian Agency for Drugs and Technology in Health (CADTH), International Clinical Trials

Registry, Canadian Health Research Collection and the Agency for Healthcare Research and Quality (AHRQ).

Table 2 includes the finalized search strategy with the three search components for Medline. The full search strategy for all databases is listed in Appendix A. Finally, after applying the search strategy to all the mentioned databases and collecting the identified studies, snowballing was used as a supplementary search strategy.

Table 2: Medical Subject Headings and Keywords used in the Medline Search Strategy

SEARCH TOPICS	MESH TERMS	KEYWORDS
ELECTRONIC MEDICAL RECORDS	exp Medical Records Systems, Computerized/	(electronic or computer* or online) adj2 (medical or health or patient) adj2 (record or records)
PRIMARY HEALTH CARE	Primary Health Care/ or Physicians, Primary Care/ or Family Practice/ or General Practice/ or General Practitioners/ or Nurse Practitioners/	Primary health care or Primary healthcare or Primary medical care or Family practi* or Family medicine or General practi* or Family physician* or Family Doctor* or Nurse Practition*
INTERVENTION	Intervention Studies/ or Feedback/ or Health Knowledge, Attitudes, Practice/ or Computer User Training/ or workflow/ or Office Management/ or Practice Management, Medical/ or Decision Making, Computer-Assisted/ or "quality of health care"/ or exp quality improvement /	Intervention Stud* or Computer user training or Work Flow or Office Management or Medical Practice Management or Computer assisted Decision making or Computer assisted Diagnosis or "meaningful use" or feedback or quality improvement

3.2 Study Eligibility Criteria

The following eligibility criteria were used to identify studies for inclusion:

1. **Study focus:** Included studies were those that specifically focused on the use of EMRs in primary health care, not simply earlier stages of adoption. Therefore, papers that studied the first stages of EMR adoption into primary health care without studying their use were excluded.

2. **Intervention:** The objective of this systematic review was to identify interventions to improve EMR use, therefore only those studies with a clear intervention that was implemented or observed for the purpose of studying use or use patterns of EMRs were included.

3. **Setting:** Included studies were only those conducted in a primary health care setting as described in Chapter 2.

4. **Outcome of interest:** Included studies had to have an outcome of interest related to EMR use to be included in this review. This would include measurements of the use of EMR functions (number of uses, duration of use) as well as outcomes effected by EMR use such as number of referrals and completeness of patient records.

No restrictions based on study design or comparator groups were used. Opinion pieces, editorials and publications without an abstract were excluded, along with conference abstracts.

3.3 Screening

After conducting the database searches, the studies identified were uploaded into EPPI Reviewer 4.0 (by EPPI-Centre, Social Science Research Unit, the Institute of Education, the University of London, UK).[71] EPPI reviewer was used to automatically remove duplicates; subsequently, a manual search was conducted to remove any missed duplicates. Two reviewers, Noura Hamade and Muna Hussain, conducted the screening of the abstracts based on a list of screening questions derived from the eligibility criteria described above (please see Appendix B). Prior to the screening of all abstracts, three

reviewers, Amanda Terry, Noura Hamade, and Muna Hussain, independently reviewed 15 randomly selected abstracts and met to compare and discuss their decisions. This step ensured that all reviewers were using the screening criteria consistently. Following this process, the remainder of the abstracts were screened independently by two reviewers, Noura Hamade and Muna Hussain. The EPPI program was used by the two reviewers to assist in tracking the screening process. Using a software program embedded in EPPI Reviewer, screening questions were programed into EPPI Reviewer allowing for answers to the screening questions to be stored into the program coupled with the title they referred to. Using the results in EPPI Reviewer, the reviewers then met to discuss their decisions; disagreements were resolved by consensus. Two reviewers, Noura Hamade and Amanda Terry, then independently conducted the full text screening of the included studies, using the screening questions listed in Appendix B. These reviewers then met to discuss their decisions; disagreements were resolved by consensus.

3.4 Data extraction

Tables were developed using Microsoft Word 2011 to extract data from the included studies. The tables included basic study identification information and individual study results as well as intervention and outcome characteristics. All information was extracted from the included studies by one reviewer, Noura Hamade.

The first author's name, year of the study, and setting (location and country) were extracted to be used as study citation information. Information on the study population and participant composition were also extracted. Study participant numbers were extracted to calculate the odds ratio to be used in the meta-analysis and allow for identification of studies based on study size. Target population number allowed for power calculations to determine the strength of the study findings as well as providing information on the target population of the intervention. In addition, extracted from each study were: intervention name, intervention type and a brief description of the intervention. In terms of outcomes, the outcome measured and a description of the outcome along with a p-value were also extracted. Lastly, information was extracted to allow for the assessment of individual study bias. This included: information on reported

p-values, type of statistical analysis, completeness of follow up, blinding, appropriateness of outcome assessment, participant representation of the population, and randomization of participant allocation.

Due to the variety of possible interventions that could impact EMR use, studies were placed into three different groups based on intervention type using the EPOC taxonomy of interventions as described in the following sub-section.[72]

3.4.1 Details of Study Interventions

A system was adopted in this review to categorize the wide variety of possible interventions that could be implemented to improve EMR use. Interventions for this systematic review were categorized using the Effective Practice and Organization of Care (EPOC) taxonomy of interventions which was published in the Cochrane Review by the EPOC Group in 2015. Interventions were placed into one of the following categories:[72]

1. **Professional Interventions**: Defined by EPOC as an intervention implemented with the goal of educating or furthering the knowledge of the target group in a specific area with the purpose of creating change. For the purposes of this review, this type of intervention could be categorized in one or more of the following sub-groups:

   a. **Educational**: This incorporated any intervention that included the distribution of education material or meetings such as conferences, lectures and workshops. It also included training sessions with experts aimed at impacting performance or creating changes in the primary health care practice.

   b. **Audit and Feedback**: This sub-group included interventions that provided summary of performance for the primary health care provider. Feedback could be distributed and discussed individually or in groups. In some cases, performance feedback included the comparison of results whether

before and after the intervention or between primary health care providers in the primary health care practice to motivate participants.

c. **Reminders**: This sub-section incorporated interventions which were designed to trigger primary health care providers to recall information. This is usually done to remind participants to take some form of action related to patient care. Also included in this group would be reminders to adhere to an intervention.

d. **Marketing**: This group included the use of focus groups and surveys to promote a service or feature of interest in the study.

2. **Organizational Interventions**: Defined by EPOC as interventions that target workflow, aim to introduce new multidisciplinary teams, expand old roles to include new tasks, or improve communication between team members. Organizational interventions also include those that create structural changes in an organization's framework. Therefore, for the purposes of this review, any interventions that cause changes to the workflow of the primary health care practice through the health care professionals or structurally through physical changes to the clinic itself would be considered an organizational intervention. An intervention that targeted primary health care practice structurally through changes in the facilities used by health care personnel such as changes to the EMRs used through feature add-ons, also belongs to the organizational intervention category.

3. **Financial Interventions**: According to the EPOC definition, interventions were considered to be financial interventions if they provided an incentive for action. In the case of this review, a financial intervention includes any incentive whether given by the primary health care practice or an outside source to any of the health care providers or participants in the study.

A study that focused on the implementation or observation of an intervention that was a combination of two or more of these categories, was classified as a mixed intervention.

Otherwise the study was classified as falling into one of the previously mentioned categories for interventions. A summary of the categorized interventions is presented in Figure 3.

Figure 3: Possible Categories of Interventions Identified in this Review

Intervention	Organizational	Workflow changes
		System Updates
		Staff organization
	Professional	Educational
		Audit and Feedback
		Reminders
		Marketing
	Financial	Grants, Funding
		Incentives, Rewards
		Penalties

Recreated from: Effective Practice and Organisation of Care (EPOC). EPOC Taxonomy; 2015. Available at: https://epoc.cochrane.org/epoc-taxonomy

3.4.2 Intervention Target Areas

Described in Chapter 2 were possible areas of change that could be targeted by interventions intending to improve EMR use. For the purposes of this thesis, the areas targeted for change were called "target areas" and were used to group studies identified in this review. Traditionally studies undergoing a meta-analysis are grouped based on interventions, however for this review the specific target area of an intervention was identified to be just as important as the intervention itself. The target of an intervention points out important areas for change. Therefore, to identify those important areas for change, studies were grouped into intervention target areas for the meta-analysis. Of the target areas described in Chapter 2, only two were identified in the included studies:

1. **Use of EMR functions**: Describes the use of EMR functions discussed in Chapter 2 directly in relation to duration and frequency of use. Examples of the functions include referrals, electronic communication, reminders triggered, use of clinical decision support systems, as well as workflow management support functions.

2. **Data quality**: The main indicator of data quality was the level of completeness of the patient information data. Therefore, studies that described the level of data completeness for basic patient information including diagnostic, laboratory and prescription management information were also included in this group.

The outcomes presented in the included studies were grouped by the target area of the intervention into either: 1) use of EMR functions; or 2) data quality.

3.5 Statistical Analysis

When conducting a meta-analysis, the summary data collected from identified studies are used to obtain an effect size. The effect sizes of the multiple included studies are combined to create a summary effect size which has a higher strength and precision when compared to the outcome measures of individual studies.[73] The summary effect size represents the relationship between two values, including the effect of an intervention on an outcome in the field of study.

To allow for the combination of the effect sizes from the individual studies to create one summary effect size, the chosen effect measure from each study needs to be the same or computable with the available and published information. The chosen effect size should also be compatible with the study design with known sampling distributions to allow for calculations of variances and confidence intervals; representing the precision of the summary effect size.[73] Therefore, it is important to choose the correct effect measure based on the available information and the type of data extracted from the included studies. In addition to choosing the correct effect measure, confidence intervals need to be presented or computable in the included studies to allow for calculations of the variance and standard error of the effect size.[73]

The majority of included studies presented dichotomous data using proportions and 95% confidence intervals. According to the Cochrane Handbook for Systematic Reviews, due to the dichotomous nature of the extracted data from the studies in this review, the summary effect size could only be one of the following three measures: odds ratios, relative risks, or risk ratios.[74] Absolute risks are dependent on the unit of measurement and are less consistent than relative measures and more uncommon in the epidemiological field. In comparison, odds ratios and risk ratios are the two most commonly used measures in the field of epidemiology for binary data. Studies have shown that there is little difference between using odds ratios and risk ratios in terms of statistical significance.[75] However, risk ratios can only be used in studies where the true prevalence can be calculated (not case control studies).[74] Due to the inclusion of some case control studies in this review, where the prevalence was fixed, odds ratios were selected as the appropriate effect measure for this meta-analysis.

The statistical analysis including forest and funnel plots was completed using STATA v. 13.0 (STATA Corporation, College Station, TX).[76] All results were presented in forest plots and expressed in log-odds ratios because of the categorical nature of the outcomes of interest, using 95% confidence intervals. Studies presenting data using proportions and 95% confidence intervals were used to generate 2-by-2 tables to allow for the calculation of odds ratios. Frequencies of outcomes along with the total number of participants were extracted. Some studies presented multiple outcomes using the same population. Those outcomes were combined to create one effect measure to be included in the meta-analysis using the example listed in Appendix C. In addition, the odds ratios of the included studies were presented with their standard errors in funnel plots to assess publication bias. Publication bias can be present when studies are published selectively causing them to be unrepresentative of the population they are drawn from. A visual examination of the funnel plot can indicate publication bias if the clustering of the plotted studies caused the funnel plot to appear asymmetrical.[77]

The random effects model was used to conduct the meta-analysis due to its ability to account for in between study variation that arises from differences in study target

population, study intervention and presentation of outcomes. It does that by assuming the true effect estimate varies between studies. Therefore, the random-effects model using the DerSimonian and Laird methods was used in STATA to create the forest plots.[78]

3.6 Risk of Bias Assessment

As recommended by the Cochrane Handbook for Systematic Reviews a risk of bias assessment was also performed. This is done to assess the methodological quality of the included studies.[72] To evaluate the risk of bias for individual studies, a comprehensive search to identify possible bias assessment tools was first conducted, followed by a comparison of the tools so that the one most suitable to this study could be chosen. A study by Deeks et al. (2003) evaluated 194 quality assessment tools to determine tools for evaluating non-randomized intervention studies and was used to identify possible assessment tools for this systematic review.[79] Of the 194 tools, only six were found by Deeks et al. (2003) to be suitable for systematic reviews, based on their performance score in six specified domains: creation of treatment groups, blinding, soundness of information, follow-up and analysis: comparability and outcome.[79]

Of the six tools deemed appropriate for use in systematic reviews, the best tool for assessment was chosen based the on Agency for Health Research and Quality's (AHRQ) guide for determining the strength of a risk of bias assessment tool.[80] The AHRQ recommends that systematic reviews use tools that were specifically designed for this purpose, and concentrate on methodologic quality and internal validity to assess strength and risk of bias. Another requirement for an appropriate assessment tool is avoiding the use of study design as a proxy for assessment and instead assessing bias using reliability and validity scores. Also preferred are those tools that avoid presentation of risk of bias as a composite score.[80]

The guidelines above were used to determine the usefulness of the assessment tools identified. Of the six tools listed by Deeks et al. as appropriate for use in systematic reviews, five were excluded for the following reasons.[79] The Newcastle-Ottawa tool did not list reliability and validity scores, while the Reisch and colleagues tool was not

developed for use in systematic reviews specifically, and also does not report validity measures.[81,82] The assessment tool developed by Cowley et al., and the one developed by Thomas et al., both listed risk of bias as a composite score and did not report any validity and reliability scores.[83,84] Finally, the tool developed by Zaza similarly did not list validity and reliability scores.[85] Based on the ARHQ requirements listed above, only the Downs and Black risk of bias assessment tool was acceptable for the purposes of this review.[86]

The Downs and Black assessment tool has high levels of reported measures of reliability and validity.[87] It is also specifically designed for use in systematic reviews. It has been found to be a good assessment tool for both randomized and non-randomized studies.[79] The Downs and Black assessment tool was also found to be comprehensive in its ability to report measures of internal validity for assessed studies. This tool also provides an easy-to-interpret numerical score for risk of bias. Therefore, the Downs and Black tool was used to assesses risk of bias for individual studies included in this review.

The Downs and Black scale is made of 27 questions divided into sub-sections based on reporting, external validity, internal validity (bias and confounding) and power. Based on those sub-sections, studies could score a maximum of 31 points for assessing risk of bias of individual studies.[86] The breakdown of the four subsections and a brief explanation of their importance are listed in Appendix D.

The Downs and Black assessment scale was applied to the 12 selected studies to determine the reliability, validity and power of the study. To test the reliability, the reporting strength was examined by extracting information on the reporting of objectives, patient, outcome and intervention characteristics as well as the mention of the confounders and the findings of the study. Both external and internal validity were assessed using this bias assessment tool. External validity was assessed by extracting information about the study participants and location as well as interventions implemented. The assessment of internal validity required the extraction and assessment of information on blinding, recruitment, randomization, statistical analyses and the outcome measures used. Sample sizes were also extracted from the studies to calculate

power. The Downs and Black checklist for bias assessment is presented in Appendix E. Scores were then calculated and combined into a risk of bias bar graph, as suggested by the Cochrane Handbook for Systematic Reviews, used to indicate the level of bias in each study.[74]

Chapter 4

4 Results

This chapter describes the study selection results and the qualitative characteristics of the included studies. Also presented are the results of the meta-analysis and the risk of bias assessment.

4.1 Study Selection

After searching the databases in October of 2015, 2,098 abstracts were identified. From these 2,098 abstracts, 659 duplicates were removed. This left 1,439 titles for abstract screening. Following abstract screening, 19 studies were identified for full text screening.

Full text screening was performed on the 19 retrieved studies. Twelve were identified that fit the previously specified inclusion criteria.[88,89,90,91,92,93,94,95,96,97,98,99] Seven studies were excluded for the following reasons: not a primary health care setting (n=2); no intervention specifically to improve EMR use (n=3); and intervention not integrated into an EMR (n=2). The PRISMA flow chart was used to map out the study selection process and is shown in Figure 4.[69]

All twelve studies identified in this review were identified from initial electronic database screening. Weekly electronic search reminders and supplementary searches did not identify any additional studies for inclusion.

Figure 4: PRISMA Flow Chart of Study Selection

PRISMA 2009 Flow Diagram
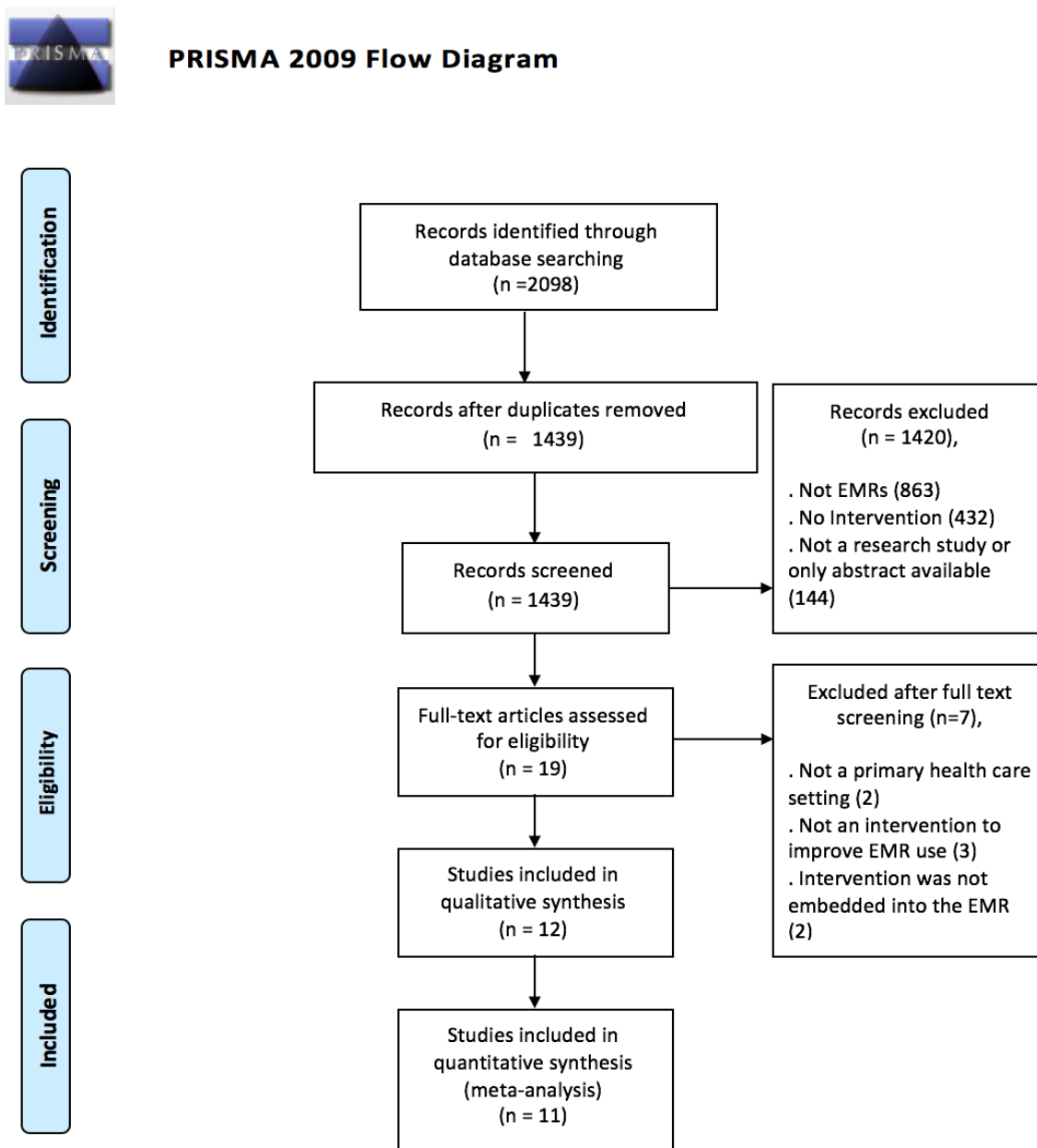
4.2 Study Characteristics

Of the identified studies more than half (n=7) were conducted in the United States.[88,91,92,93,95,96,98] The remaining five were set in the United Kingdom (n=2)[89,90], Finland (n=2)[99,94] and Canada (n=1)[97]. Four of the included studies had a quasi-experimental study design due to lack of randomization, three of the studies were

randomized control trials, two each were retrospective observational and mixed-methods study design while the last one was a prospective observational study design.

All the included studies were conducted in a primary health care setting. Ten of the studies were set in primary health care practices.[88,89,90,92,94,95,96,97,98,99] The last two studies by Pan et al (2009) and Mavigilia et al (2006) were set in family residency medicine training clinics and outpatient clinics respectively.[91,93] Participants in all twelve included studies also had to have access to a certified EMR.

In terms of study population size, the twelve included studies targeted 1,564 primary care providers in 132 primary health care practices. The primary care providers in these studies cared for 578,071 patients. The study by Baer et al. (2013) was the only study to not provide the number of primary care providers however, the number of included primary health care practices and patients cared for at those practices were included.[92] Similarly, another two studies did not provide the number of included patients but listed the number of primary health care providers.[88,89] de Lusignan et al. (2002) did not provide the exact number of primary health care practices. Even though some of the studies were missing one of the three values used to summarize study size (number of health care providers, number of included primary health care practices and patient size) none of the studies were missing all three. The characteristics of the included studies are listed in Table 3.

Table 3: Study Characteristics

Author	Setting	Study Design	Number of PCPs	Composition	Number of Patients
Jerome et al. (2008)	1 Primary health care center Country: United States	Prospective observational	137	Attending and resident physicians	…
de Lusignan et al. (2002)	… Primary health care centers	Retrospective observational	576	…	…

| Author	Setting	Study Design	Number of PCPs	Composition	Number of Patients
	Country: United Kingdom				
de Lusignan et al. (2004)	84 Primary health care centers Country: United Kingdom	Quasi-experimental	252	84 Physicians 84 Nurses 84 Managers	~20,000 19470 pre-intervention 19784 post-intervention
Pan et al. (2009)	2 Family medicine residency training clinics Country: United States	Quasi-experimental	8	4 Certified Medical Assistants 4 Nurses	525 patients 279 pre-intervention 246 post-intervention
Baer et al. (2013)	5 Primary health care centers Country: United States	Quasi-experimental	…	…	15,495
Mavigilia et al. (2006)	18 Outpatient clinics Country: United States	Quasi-experimental	359	187 Physicians 108 Nurses 64 Other	413,417
Kortteisto et al. (2014)	1 Primary health care center Country: Finland	Randomized Controlled Trial	48	15 Physicians 24 Nurses 9 Other	13,588
Nemeth et al. (2012)	8 Primary health care centers Country: United States	Mixed Methods	74	…	66,104
Kruse et al. (2012)	2 Primary health care centers	Mixed Methods	36	21 Physicians	2,894

Author	Setting	Study Design	Number of PCPs	Composition	Number of Patients
	Country: United States			3 Nurses 12 Physician trainees	
Maddocks et al. (2011)	9 Primary health care centers Country: Canada	Randomized Control Trial	24	Physicians	23,688
Davis et al. (2010)	1 Primary health care center Country: United States	Retrospective Observational	36	Residents	360 patients 180 pre-intervention 180 post-intervention
Sweeney et al. (2014)	1 Primary health care center Country: Ireland	Randomized Control Trial	16	10 Physicians 6 Nurses	22,000

… represent missing data

The target populations for all twelve studies included the medical team, staff and/or patients. Of the 1,564 primary health care providers almost half (42%) did not have the composition reported. The other half were comprised of 30% physicians, 15% nurses, 5% managers and 8% other. Others included: residents, physician trainees, certified medical assistants, physiotherapists, psychologists and administration. The composition of primary health care providers targeted by the included studies is listed in Table 3 and presented visually in a pie chart in Figure 5.

Figure 5: Composition of Targeted Primary Health Care Providers
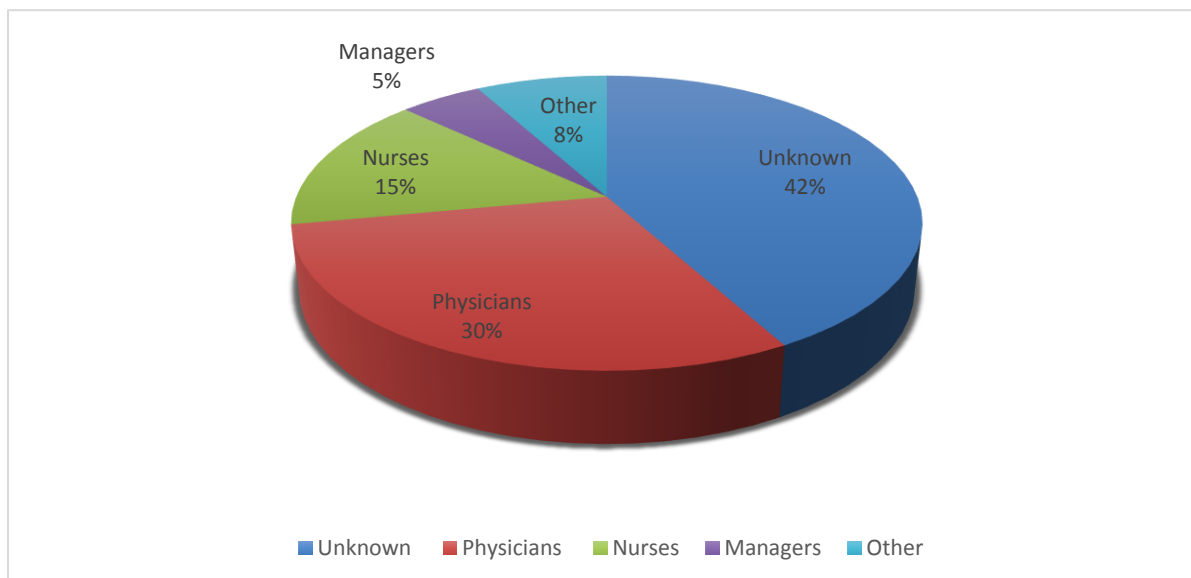
4.3 Intervention Characteristics

The twelve included studies were divided into three categories based on intervention type using the EPOC taxonomy (see Chapter 3). There were no identified studies that explored only financial interventions. However, there was one study that explored financial intervention in combination with a professional intervention; this was therefore identified as a mixed intervention. The three intervention groups that encompassed all the interventions identified were organizational interventions, professional interventions and mixed interventions.

4.3.1 Organizational Interventions

Four studies were classified as purely organizational interventions.[92,93,94,96] All four studies involved the use of a software based intervention that was embedded or connected to the EMR, where no training sessions or guidelines were provided. The first study by Baer et al. (2013) implemented an EMR linked web-based tool called Young Heath Snapshot (YHS). This tool collected family history information that was completed by patients before their visits to the primary health care center. Primary health care providers then reviewed the collected data and accepted it for viewing in the EMR. The collected

data were then used to create reminders for colon and breast cancer screening based on the patient family history.[92] The second study by Mavigilia et al. (2006) used a new function in the EMR called KnowledgeLink, an info look-up button that referred primary health care providers to web-based information resources. KnowledgeLink was designed to assist primary health care providers with decision making and answer any questions pertaining to patients' medication.[93] Third, Kortteisto et al. (2014) studied a computer-based decision support system (Evidence-Based Electronic Decision Support - EBMeDS) integrated into the EMR. The EBMeDS system cross-referenced patient diagnostic information with disease databases to provide primary health care providers with patient treatment options.[94] Finally, Kruse et al. (2012) used the Tobacco Treatment Management system embedded in the EMR to assist with referral of eligible patients to tobacco treatment centers.[96] A more in-depth explanation of the interventions implemented in each of the four studies is provided in Table 4.

Table 4: Organizational Interventions Description

Author	Intervention	Intervention Description
Baer et al. (2013)	Web-based appraisal tool	- Web-based appraisal tool used to generate reminders with the help of an electronic decision support system - Self-administered by patients to collect family history information
Mavigilia et al. (2006)	KnowledgeLink	- A medication "look-up" button - Allowed physicians with questions about a patient's medication to access that information with one click from the EMR
Kortteisto et al. (2014)	Computer based decision support system EBMeDS	- The EBMeDS collects diagnosis information entered in the EMR and runs it against studies done on the base population generating reminders pertaining to treatment triggered by the data - Presented reminders triggered by accessing the EMR
Kruse et al. (2012)	Electronic one-click referral button to tobacco use control center	- Clicking the button sends an automatically generated email to the internal tobacco care coordinator (TTC) center

4.3.2 Professional Interventions

Five of the included studies were classified as professional interventions.[88,90,91,97,99] All
five studies implemented an educational or training program to improve EMR use.
Jerome et al. (2008) studied a recently implemented decision support system (Evidence
Based Medicine (EBM) Literature Request feature). The objective of the study was to
identify the effects of marketing strategies and feedback on the use of the EBM feature.[88]
The second study by de Lusignan et al (2004), used the Primary Care Data Quality
(PCDQ) Program as a resource to produce written guidelines and workshops on coding
patient information.[90] Pan et al., the third study in this group, developed a 5-component
program to improve data entry into the EMR using post intervention motivational
feedback and awards, recognizing primary health care providers with 100% completion
in data entry. The intervention also included educational programs and training to
emphasize the importance of recording patient information.[91] Similarly, Maddocks et al.
implemented an educational intervention coupled with feedback to motivate primary
health care providers to improve preventive care testing.[97] Lastly, Sweeney et al.
implemented a data management strategy to improve data recording. One Clinical Data
Manager (CDM) was appointed to the clinic and provided training, ongoing support and
feedback.[99] Therefore, the five studies classified as professional interventions all
implemented an educational or training program to improve EMR use. A more in-depth
explanation of the interventions implemented in each of the five studies is provided in
Table 5.

Table 5: Professional Interventions Description

Author	Intervention	Intervention Description
Jerome et al. (2008)	Focus groups driven by customized educational strategies	- The EBM worked to directly link evidence expertise to the clinical work flow facilitating easy and direct communication - The EBM was marketed to clinicians at the start of the study. - A focus group was conducted at the midway point of the study to discuss strategies to improve use and visibility of the EMB feature.

Author	Intervention	Intervention Description

de Lusignan et al. (2004)	Primary Care Data Quality (PCDQ) Program	- An educational intervention that targeted primary health care providers to improve data recording while monitoring and assessing data quality.
		- 3 step intervention:
		  1. 1-hour introductory meeting at baseline
		  2. Every 6-months workshops that lasted 2-3 hours were held
		  3. The PCDQ included a Morbidity, Information Query and Export System (MIQUEST) program which extracted data to be used in the workshops and produced guidelines on how to code information in the EMR

Pan et al. (2009)	Feedback and education	- First a focus group to get a better understanding of EMR use to appropriate data entry was conducted
		- Using the focus group data, a 5-component intervention to improve EMR data entry was developed:
		  1. motivational feedback
		  2. academic detailing: a personalized educational programme which highlighted the importance of recording patient information
		  3. improved efficiency of data entry: training on how to correctly use EMR data entry templates
		  4. post-test feedback
		  5. awards based on aggregate improvement in data entry

Maddocks et al. (2011)	Two-hour educational session	- Hands-on training to teach physicians how to manipulate the EMR to generate a list of patients eligible for preventive testing - Provided was also an instructional material tool kit - Feedback on current levels of preventive care in Ontario were provided for comparison
Sweeney et al. (2014)	Data Management Strategy	- Provided information and training on data recording to create protected, logical and unified levels of coded patient information - Coding was then monitored to provide feedback to primary health care providers and management reports

4.3.3 Mixed Interventions

The remaining three studies implemented mixed interventions, including at least two of the following: organizational, professional and financial.[89,95,98] The only study to use a financial intervention was by de Lusignan et al (2002); an incentive of £ 400 was used for those who reached the desired target levels of data quality scores. This study was also classified as a professional intervention due to the use of feedback techniques to motivate participants to improve their data quality.[89] The second study by Nemeth et al. (2012) examined the implementation of Standing Orders (SOs) into EMRs. A Practice Partner Health (PP HM) template was adopted into the EMR system to serve as the SOs source along with guidelines to educate participants on the use of the template.[95] Finally, Davis et al. (2010) used a two-part intervention which involved the use of an asthma template embedded into the EMR along with lectures and posters promoting its use.[98] A more in-depth explanation of the interventions implemented in each of the three studies is provided in Table 6.

Table 6: Mixed Interventions Description

Author	Intervention	Intervention Description
de Lusignan et al. (2002)	Feedback of data quality markers and financial incentives	- 10 data quality markers were examined for completion, calculated and fed back to the physicians every three months to determine if feedback caused an improvement in data quality - A small financial incentive was also given to physicians to reach intended levels of quality scores.
Nemeth et al. (2012)	Electronic standing orders provided by a customized health template	- Customized health maintenance template that provided authorization to healthcare personnel to carry out medical orders for screening, immunization and diabetes measures - An introductory meeting was conducted explaining the project and guiding participates in using the electronic SOs in their primary health care practices
Davis et al. (2010)	Asthma template along with lectures and tutorials	- Mandatory lecture guidelines for use of the asthma template for proper documentation - Reminders to stress the importance of the template use were also posted in patient care areas and on PowerPoint slides before meetings

4.4 Study Outcome Characteristics

Outcomes in the twelve studies were categorized based on the target area of the intervention: use of EMR functions and data quality. The studies in each of the two categories were further classified into subsections based on the EMR feature and the data quality area targeted. Some studies presented results for both of those categories, and therefore some studies were presented in both. Of the twelve studies, five reported on the use of EMR functions, and four on data quality, while the last three reported on both those categories. The following section presents more information on the use of EMR functions and data quality.

4.4.1 Use of EMR Functions

Eight of the included studies reported on the use of EMR functions using percentages and frequency measures along with p-values.[88,92,93,96,95,97,94,98] Three studies, conducted by Jerome et al. (2008), Bear et al. (2013) and Mavigilia et al. (2006), reported on the use of EMR functions in the area of decision support. Kruse et al. (2012) and Maddocks et al. (2011), as well as Nemeth et al. (2012) and Davis et al. (2010), reported on the use of EMR functions in the areas of patient health care information exchange and in health template use respectively. The last study in this category by Kortteisto et al. (2014) examined the use of EMR functions in relation to alerts and reminders. A more in depth description of the EMR function and the outcome reported, along with an outcome measurement description is presented in Table 7.

Table 7: Outcome Measurement Description of Studies Reporting on the Use of EMR Functions

Author	Outcome	EMR feature	Outcome Measurement Description
Jerome et al. (2008)	Percent change in use of EBM literature request	Decision support	- Change was measured by obtaining number of literature requests by health care providers
Baer et al. (2013)	Percent of new EMR generated	Decision support	- Data entered into the EMR was saved in a firewall-protected server to be used in the study

Author	Outcome	EMR feature	Outcome Measurement Description
	reminders on colon and breast cancer screening		- Participants were also contacted by phone for an interview
Mavigilia et al. (2006)	Frequency of use of KnowledgeLink	Decision Support	- Participants were emailed an online questionnaire after every incident of use of the KnowledgeLink feature along with a more extensive questionnaire at the end of the study - Data on use was collected by analyzing search logs or through patient consent
Kortteisto et al. (2014)	Change in number of reminders triggered	Alerts and reminders	- Reminders were triggered automatically upon use - The EMR system was used to calculate the number of reminders triggered
Nemeth et al. (2012)	Percent of nurses and nursing staff using the health maintenance template	Health template	- Primary health care practices submitted the EMR data electronically on a quarterly basis to the Practice Partner Net - Data were then used to measure the use of the Health Maintenance Template
Kruse et al. (2012)	Percent of referrals through EMR to tobacco use control center	Exchange of patient health care information	- Measured through access to EMR records and Tobacco Treatment Coordinator centers
Maddocks et al. (2011)	Change in provided preventive care testing	Exchange of patient health care information	- The rate of patients tested was calculated by dividing the number of patients that visit the primary health care centers by the number of patients tested per year
Davis et al. (2010)	Percent use of asthma template	Health template	- Pre-intervention data were collected by retrospectively reviewing patient records, while post intervention data were collected through a chart review of the patients with asthma seen by residents

4.4.2 Data Quality

All studies in the data quality group studied the effect of an intervention on improving the recorded data using an EMR. The completeness and accuracy of patient information are some of the markers used to measure data quality and were the areas most targeted by the included studies.[100] The majority of the seven studies grouped into the data quality category reported outcomes in percentages with percent differences or p-values while one reported outcomes using R-squared values. [89,90,91,92,95,98,99] de Lusignan et al. (2002) reported on data quality using ten standard data quality markers which focus on the completeness of patient EMR data. Five of the seven studies, de Lusignan et al. (2004), Pan et al. (2009), Baer et al. (2013), Nemeth et al. (2012) and Davis et al. (2010), reported the completeness of patient records and basic patient information. The last study by Sweeney et al. (2014) used patient information coded in International Classification of Primary Care (ICPC-2) coding system to measure and present data quality. A more in depth description of the data quality area reported on and the outcome along with an outcome measurement description is presented in Table 8.

Table 8: Outcome Measurement Description of Studies Reporting on Data Quality

Author	Outcome	Data Quality Area	Outcome Measurement Description
de Lusignan et al. (2002)	Change over time in the score of 10 data quality markers	10 data quality markers	- Mean quality marker scores were calculated for each general practitioner by year in which they joined the Mediplus Database
de Lusignan et al. (2004)	Percent change of completed patient records in blood pressure, cholesterol, smoking habits and patients asked to stop smoking	Completeness of patient information	- Data on coding were collected at review meetings throughout the study
Pan et al. (2009)	Percent of new patient height, weight and blood	Completeness of patient information	- Data were collecting through the examination of the EMR of all patients included in the study

Author	Outcome	Data Quality Area	Outcome Measurement Description
	pressure records that were complete		
Baer et al. (2013)	Percent of new coded patient data of family history of cancer	Completeness of patient information	- Data entered into the EMR were saved in a firewall-protected server to be used in the study - Participants were also contacted by phone for an interview
Nemeth et al. (2012)	Percent of new coded patient data	Completeness of patient information	- Primary health care practices submitted the EMR data electronically on a quarterly basis to the Practice Partner Net - Data was then used to calculate performance measures
Davis et al. (2010)	Percent documentation of asthma severity	Completeness of patient information	- Pre-intervention data was collected through retrospectively reviewing patient records, - While post-intervention data was collected through a chart review of the patients with asthma seen by residents in the primary health care practices
Sweeney et al. (2014)	Proportion of primary health care provider notes that were coded using the ICPC-02 system	International Classification of Primary Care (ICPC-2) coding system	- Data extraction on physician and nurse coding levels was done through the GP coding software system at 4 times points in the 18-month period

4.5 Meta-analysis Results

A meta-analysis was conducted on the reported outcomes of the individual studies. The outcome measures in each individual study were transformed into odds ratios to be

included in the analysis. Studies with multiple outcomes related to the same intervention focus area were combined to be included into the analysis. Following that, the studies were separated by intervention focus area into two different forest plots to create a meaningful meta-analysis. The individual study results are presented in percent pre and post intervention measures, and are listed in Table 9.

Table 9: Extracted Outcome Measures Used to Calculate Odds Ratios

Author	*Intervention Focus Area*	*Outcome*		*Pre-intervention (%)*	*Post-intervention (%)*
Jerome et al. (2008)	Use of EMR Functions	Percent change in use of EBM literature request		11	11
de Lusignan et al. (2004)	Data Quality	Percent change of completed patient records	Blood Pressure	13	62
			Cholesterol	74	84
			Smoking habit	46	55
			Asked to quit smoking	92	92
Pan et al. (2009)	Data Quality	Percent of new patient information	Blood Pressure	46.6	96.7
			Weight	97.1	98.8
			Height	96.8	99.2
Baer et al. (2013)	Use of EMR Functions	Percent of new EMR generated reminders on colon and breast cancer screening	Breast screening	0.08	0.3
			Colon Screening	1.1	1.4
Baer et al. (2013)	Data Quality	Percent of new coded patient data of family history of cancer		2	11

Author	Intervention Focus Area	Outcome		Pre-intervention (%)	Post-intervention (%)
Mavigilia et al. (2006)	Use of EMR Functions	Percent use of KnowledgeLink		1.5	89
Kortteisto et al. (2014)	Use of EMR Functions	Change in number of reminders triggered		65	64
Nemeth et al. (2012)	Use of EMR Functions	Percent of nurses and nursing staff using the health maintenance template	Cholesterol	41	56
			HDL Cholesterol	16	52
			Mammography	35	60
			Osteoporosis	9	21
Nemeth et al. (2012)	Data Quality	Percent of new coded patient data	Cholesterol	92	97
			HDL Cholesterol	21	95
			Mammography	92	99
			Osteoporosis	94	100
Kruse et al. (2012)	Use of EMR Functions	Percent use of Tobacco Referral Button		…	92
Maddocks et al. (2011)	Use of EMR Functions	Change in provided preventative care testing	Mammography	47	67
			Pap tests	64	69
			FOBT	52	76
			Albumin Creatinine	61	79
Davis et al. (2010)	Data Quality	Percent documentation of asthma severity		24	44

Author	Intervention Focus Area	Outcome		Pre-intervention (%)	Post-intervention (%)
Davis et al. (2010)	Use of EMR Functions	Percent use of asthma template		13	63
Sweeney et al. (2014)	Data Quality	Proportion of primary health care provider notes that were coded using the ICPC-02 system	General Practitioners	71	92
			Nurses	91	92

… represent missing data

The study by de Lusignan (2002) was excluded from Table 9 because the results of the study were presented using regression coefficients and were not consistent with the other included studies. Therefore, it is presented separately in Table 10 along with the p-values.

Table 10: Extracted Outcome Measures and p-values Used to Calculate Odds Ratios

Author	Intervention Focus Area	Outcome	R^2	P-value
de Lusignan et al. (2002)	Data Quality	Percentage of active Patients seen in the last 12 months	15.9	0.33
		Percent of patients with birth year and sex recorded	13.1	0.38
		No. of prescriptions per 1,000 patients	10.51	0.46
		Percent of notes linked to diagnosis	9.6	0.43
		Percent acute prescription linked to diagnosis	54.7	0.04

Percent of repeat prescription linked to diagnosis	58.7	0.03
Percent with dose details recorded	2.9	0.69
Ratio of repeat to acute prescription	17.2	0.31
Percent of notes in which Read Code is Level 3 or Lower	38.8	0.10
Percent of problems with Read Code of Level 3 or Lower	78.2	0.004

The values in Tables 9 were used to calculate the odds ratios to be used in the meta-analysis. Kruse et al. (2012) did not present pre-intervention scores, as shown in Table 9, and was therefore excluded from the meta-analysis. The values in Table 10 representing the study by de Lusignan et al. (2002) was also excluded from the meta-analysis since the author used different method to present results.

Two forest plots were generated by STATA using the odds ratios. The first forest plot represents studies focused on the *use of EMR functions* as the intervention target area, displayed in Figure 6. This forest plot shows that the study by Jerome et al. (2008) was the only study with a log-odds of zero, which indicated that the intervention had no effect on the outcome. The rest of the studies presented log-odds that favored the intervention shown through reporting positive log-odds values. Those values ranged from 0.04 (Krotteisto et al. 2014) to 6.35 (Mavigilia et al. 2006). The overall effect estimate was a log-odds of 1.66 [95% confidence interval: 1.43 to 1.88]. Since the confidence interval does not include zero and the overall log-odds do not cross the line of no effect on the forest plot, it is considered to be significant. Therefore, personal, organizational and financial interventions directed at the use of EMR functions had a significant and favorable effect on improving EMR use. More specifically, interventions targeted at the use of EMR functions were five times more likely to show improvements in EMR use compared to the controls (see Figure 6).

Figure 6: Log Odds With Associated 95% Confidence Intervals Showing the Effect of Interventions on Use of EMR Functions
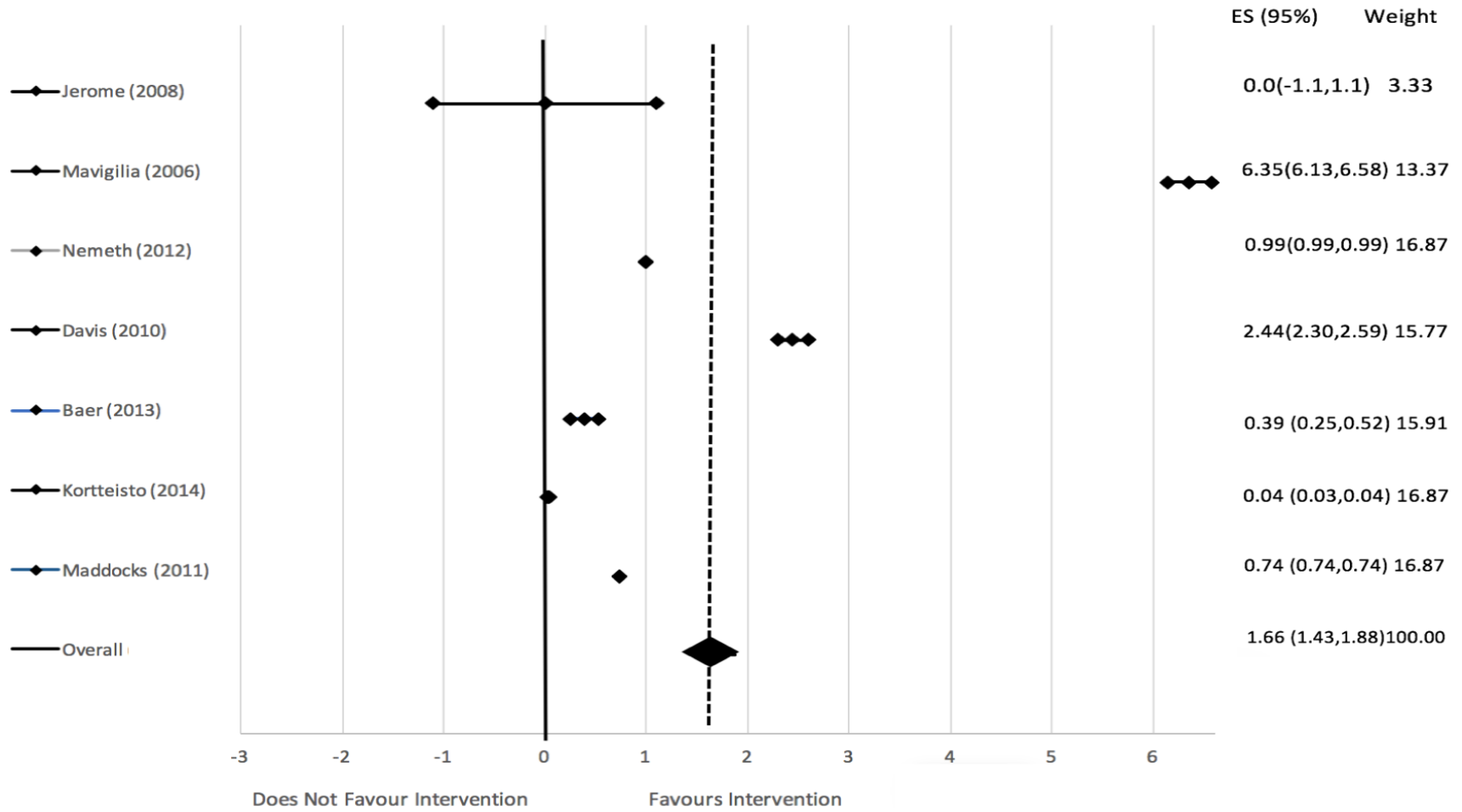
The second forest plot represents studies focused on *data quality* as the intervention target area and is presented in Figure 7. All the studies depicted in this forest plot favored the intervention. However, the study by Sweeney et al. 2014 was the only study to cross the line of no effect (0.85 [95% confidence interval: -0.93 to 2.62]). This means that the study by Sweeney et al. 2014 presented a nonsignificant log-odds value favoring the intervention. The other studies presented significant log-odds that favored the intervention with values ranging from 0.76 (de Lusignan et al. 2004) to 3.79 (Nemeth et al. 2012). The overall effect estimate was a log-odds of 1.71 [95% confidence interval: 0.01 to 3.41]. Since the confidence interval does not include zero and the overall log-odds does not cross the line of no effect on the forest plot, it is considered to be significant. Therefore, personal, organizational and financial interventions directed at data quality had a significant and favorable effect on improving EMR use.

Figure 7: Log Odds With Associated 95% Confidence Intervals Showing the Effect of Interventions on Data Quality
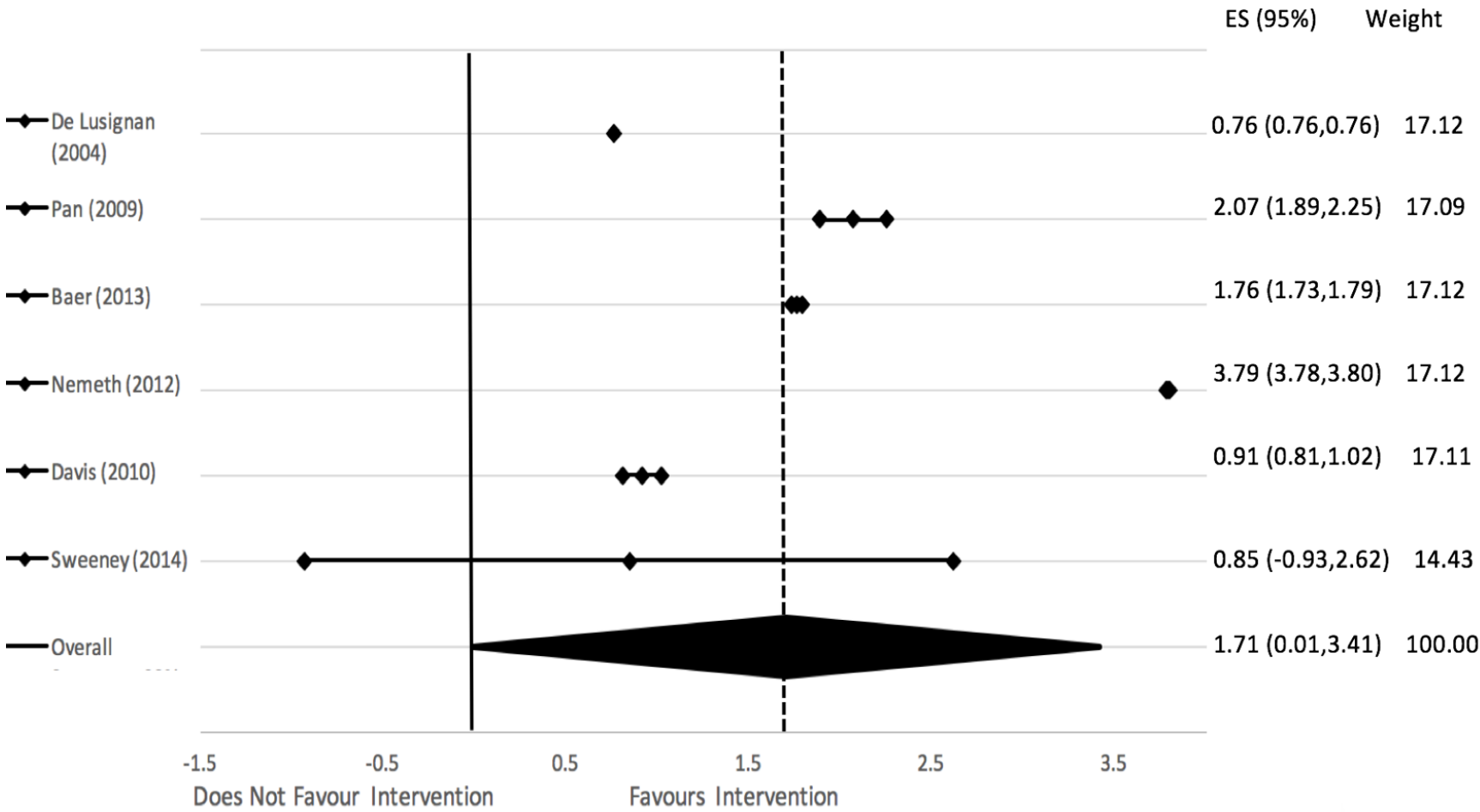
To evaluate the publication bias, two separate funnel plots for the use of EMR functions and data quality were produced using STATA (see Figure 8 and Figure 9, respectively) and then visually assessed for symmetry. Both funnel plots showed that studies were clustered at the top with only one each at the base of the funnel plot. This asymmetry in the funnel plot could be the result of publication bias. However, due to the small number of studies it is difficult to confidently conclude the presence of publication bias.

Figure 8: Funnel Plot Showing the Spread of Included Studies Targeted at Use of EMR Functions
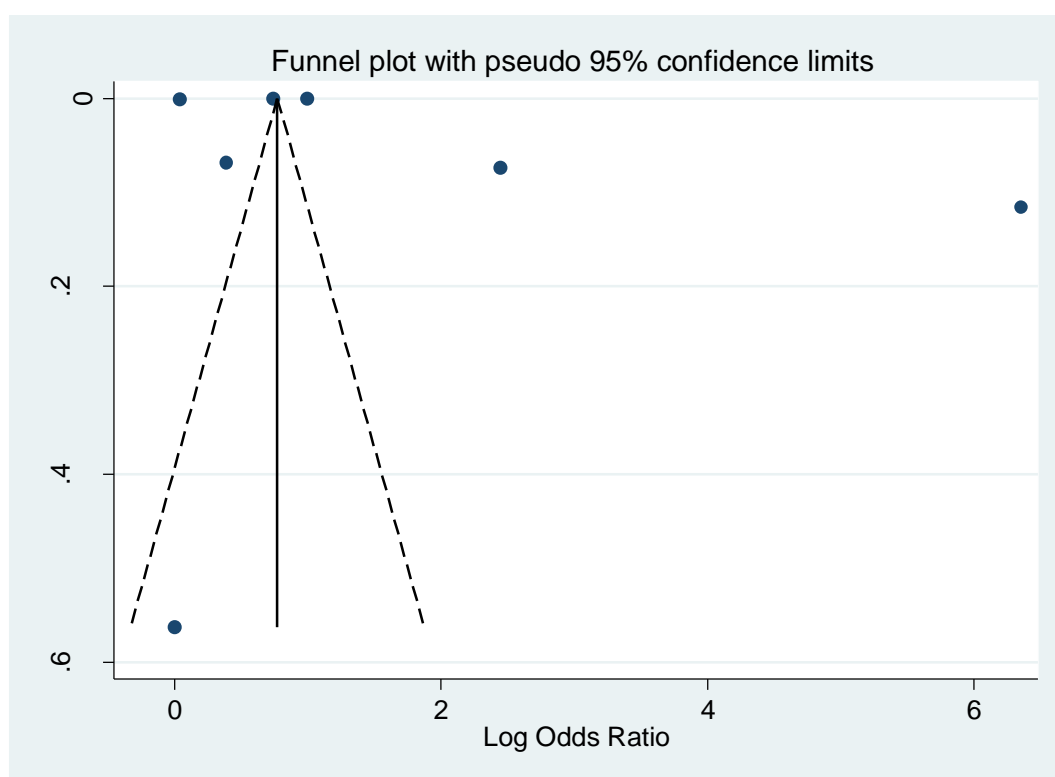
Figure 9: Funnel Plot Showing the Spread of Included Studies Targeted at Data Quality
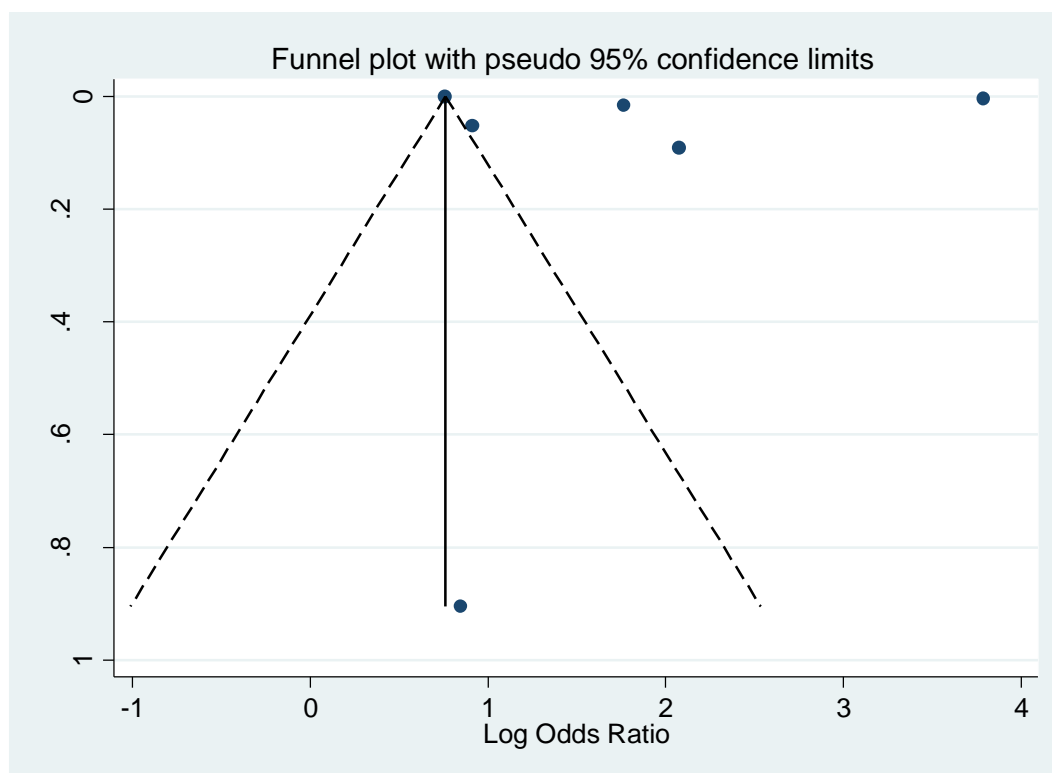
4.6 Risk of Bias Assessment Results

The risk of bias for individual studies was assessed using the Downs and Black assessment tool. It is represented in Figure 10 using a bar graph. All studies reported on six of the twenty-seven questions. Those included clearly described main outcomes and interventions of interest as well as appropriate statistical tests used and representative participants. In contrast, only one study each reported on the following three questions: randomization concealment, blinding those measuring outcomes and blinding study subjects. Therefore, most studies had high reporting of results scores and low internal validity scores. The mean score for risk of bias in individual studies is 64% with an interquartile range of 60%. This shows a moderate risk of bias in the included studies.

Figure 10: Risk of Bias Assessment of Individual Studies

Figure 10: Risk of Bias Assessment of Individual Studies
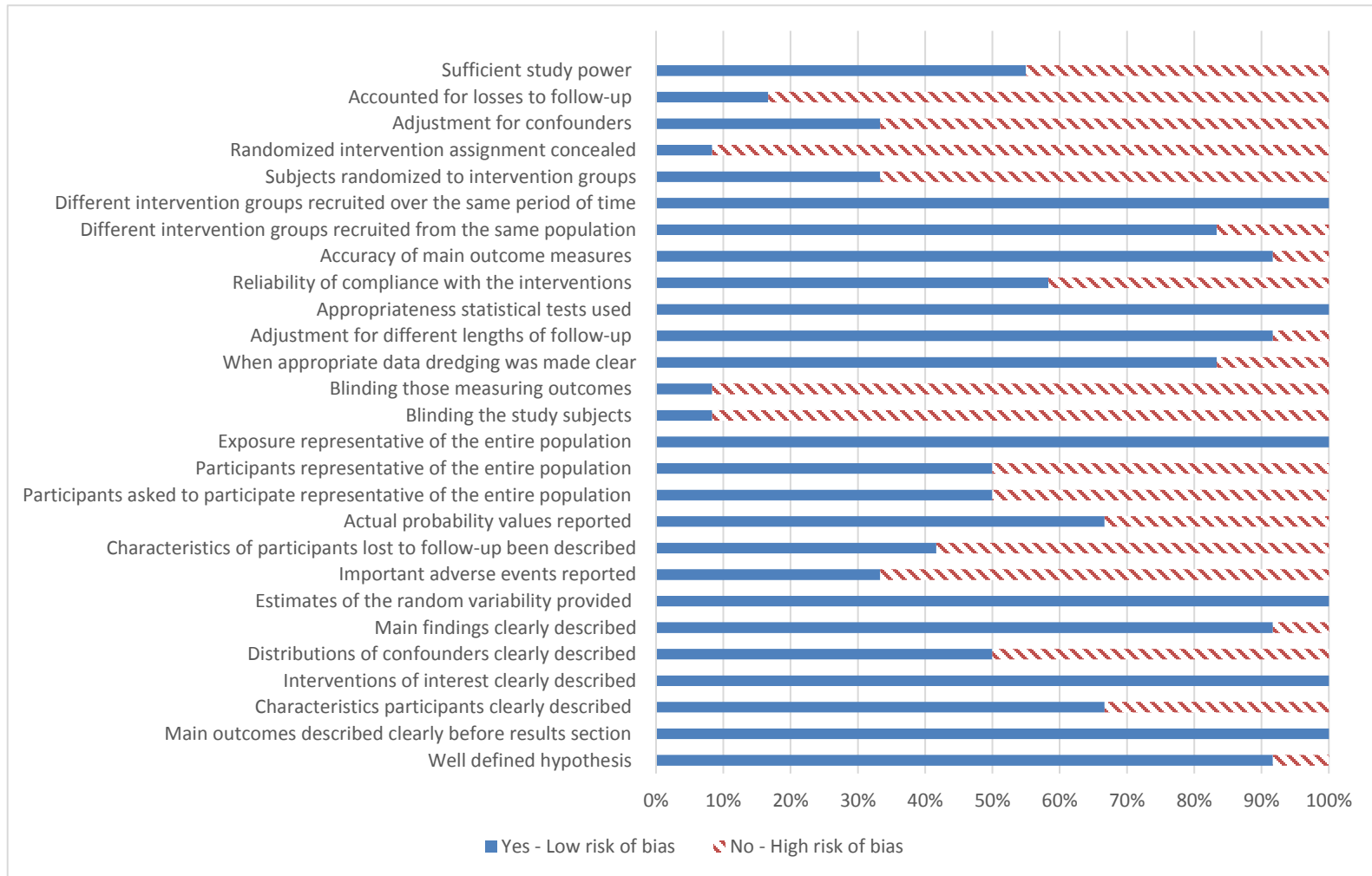
4.7 Conclusion of Results

Twelve studies were identified to be included in this review. The studies were focused on three different interventions (organizational, professional and financial) targeted at two different areas of EMR use (use of EMR functions and data quality). Interventions directed at the use of EMR functions and data quality in primary health care settings produced favorable and significant results compared to controls. The meta-analysis revealed that interventions targeted at the use of EMR functions were five times more likely to yield improvements in EMR use, while those targeted at data quality were five and half times more likely to indicate improvements in EMR use. However, the results need to be approached with care due to the possibility of publication bias. More studies in this area are required to make concrete conclusions.

Chapter 5

5 Discussion

This chapter summarizes the results drawn from the meta-analysis and discusses important themes that arose from the synthesis of the individual studies in the meta-analysis. The strengths and limitations of this study are outlined and future areas of research are suggested. The chapter ends with the conclusions drawn from this review.

5.1 Summary

The systematic review and meta-analysis were conducted to identify possible interventions focused on improving EMR use in primary health care settings. A comprehensive search of the literature led to the identification of over 2,000 studies. After applying screening questions, twelve studies were included in this review. The twelve studies were focused primarily on professional interventions (42%) compared to organizational (33%) and mixed interventions (25%). This review indicates that significant improvements in EMR use can be realized in primary health care settings where interventions targeting the use of EMR functions or data quality have been implemented. However, due to the possibility of publication bias, these results should be interpreted with caution.

This is the first systematic review and meta-analysis on this topic. Other systematic reviews concentrate on the barriers to EMR adoption and acceptance in primary health care, or the opinions of EMR users in relation to those barriers. [53,101,102,103,104] A review by Gagnon et al. 2014 studied the effect of interventions on Information Health Technologies adoption in the health care system. However, it focused on EMR adoption as opposed to long term EMR use following adoption.[104] One systematic review studied the effect of interventions on EMR use; however, this was restricted to one type of intervention (educational) implemented in a wide variety of settings.[105]

The findings of this review draw attention to four main themes in this area of study. Those themes are listed and discussed below.

5.2 Number of Identified Studies

In this review, only twelve studies of interventions focused on improving EMR use in primary health care were identified. Primary health care settings directly influence the majority of Canadians' health outcomes.[104] The vast majority of Canadians have a consistent relationship with their primary health care provider.[108] The importance of a well-functioning primary health care system was not reflected in the literature. Compared to the impact of this area on the health of the general population, the number of identified studies is surprisingly lacking. The deficiency in studies in the area of EMR use is possibly due to the focus in the field being on the adoption of EMRs.

The past decade has seen a rise in adoption rates of EMRs especially in developed countries.[31] Most studies in the field of EMRs discuss barriers to improving adoption but have yet to move on to exploring the long term use of EMRs in primary health care. Even though studies have shown that adoption alone is not enough to access the EMR's full potential, the shift to focus on improving EMR use is slow.[9,37,11,12] In conclusion, one of the main hopes of this review is to draw attention to this gap in the literature. There should be a greater focus in the area of studies that can connect EMR availability to positive patient outcomes through improving EMR use with targeted interventions.

5.3 Lack of Consistency

The area of EMR use is not only deficient in terms of available literature, but also in the usability of this literature due to its lack of consistency in the information provided. Studies on the topic of EMR use vary in terms of interventions and approaches to assessing EMR use. Due to this being a relatively new field of study, there has been no standardization of implementing interventions to improve EMR use established. This creates difficulties in synthesizing those studies to create a useful meta-analysis.[105] A standardized form of testing interventions to improve EMR use could create studies that are homogeneous enough to provide conclusions with greater power.

In addition, there is no generally accepted evaluation method when discussing EMR use. The ultimate objective shared by the studies was improving EMR use, however each of

the studies in this field defined and evaluated use differently. For example, the United States created the Meaningful Use Criteria to measure and define EMR use, however the Meaningful Use Criteria was not fully defined until 2010 and has since been changed multiple times to keep up with this growing field.[68] While other countries created ways to improve adoption of EMRs, they have yet to move on to the next stage which is improving the use of EMR.

The heterogeneous nature of the studies identified created a unique challenge to this review. Due to this being a relatively new area of research, the identified studies varied by location, intervention, intervention target (population and area) and assessment of EMR use. The differences in location create a unique challenge to this topic because of differences in policies on EMR use, available functions to be added to the EMR as well as the definition of meaningful use. All those factors contribute to the unique nature of every different location which creates difficulty in the generalizability of the results. There was also a lack of standardization of interventions that targeted EMR use. The differences were also obvious in the intervention targets, the target population and target areas which varied between studies based on the intervention. In the future, studies would benefit from standardized interventions and a clearly defined way of evaluating meaningful use of EMRs.

5.4 Nature of the Interventions

The predominant intervention type identified in this review used educational material, seminars and guidelines to target EMR use (professional interventions) which were identified in eight of the twelve studies. This focus on professional interventions was found to be consistent with the literature given that the only other systematic review in this area, Goviea et al. 2013, only included studies with educational interventions.[105] In addition, previous studies aimed at understanding impediments to EMR use have cited lack of knowledge and computer skills as the main barriers to EMR adoption and use.[17,101] To break down those barriers, educational interventions were theorized as being a viable method to improving EMR use.

However, other perceived barriers to EMR use include lack of both financial incentives and useful EMR features.[101,104] To address those barriers, the implementation of financial and organizational interventions is required. While organizational interventions did receive some attention in the studies included in this review (six studies) financial interventions were only implemented in one study (de Lusignan 2002) in combination with a professional intervention.[89] Even though The Medicare and Medicaid EHR Incentive Program used in the United States to promote meaningful use provides financial incentives as a way to promote improving the use of EMRs, the use of financial interventions was not reflected in in this review. [109] Therefore, there is a need for future studies to consider the other categories of interventions (organizational and financial) in the area of improving EMR use.

5.5 Focus of Interventions

Both use of EMR functions and data quality received equal attention as target areas for interventions to improve EMR use. Even though the studies collected for this review represent two important areas for interventions to target in order to improve EMR use, the literature was found to be lacking in other areas that could be targeted to improve use areas such as: communication, workflow, knowledge/skills and technological support. Communication as a target area would cover interactions between primary care providers as well as between primary care providers and patients through the EMR. Some studies have shown that using EMRs when communicating with patients could have a positive impact on patient/physician interactions when used appropriately.[61,110] Therefore, interventions targeted at communications using EMRs are expected to assist in improving EMR use.

In comparison, interventions targeted at the ability of EMRs to affect workflow could assist in improving administrative processes at primary health care practices, as well as the flow of patients (referrals), and patient information exchange between EMR users. EMRs can assist in improving physicians' workflow through presenting tasks in an organized and sequential manner and assisting in the completion of these tasks.[64] One of the ways EMRs can effect workflow is through workflow chart generation software used

to organize tasks. Therefore, interventions targeted at improving the use of EMRs through targeting practice workflow could help improve patient outcomes by enhancing the ease and speed at which primary health care providers perform important patient related tasks.

Two other important areas for interventions to target include the level of knowledge and computer skills users possess and technological barriers, such as the availability of technological support.[48,51] Alternatively, interventions could target EMR vendors to create more user friendly EMRs.[13] The availability of ongoing technological support and troubleshooting options is also essential for improving the use of EMRs.[48,51] Interventions could be aimed at providing on-going or on-site technical support to prevent any work interruptions due to failure in EMR function. In conclusion, the field of interventions and intervention target areas aimed at improving EMR use is still lacking in well-designed studies that cover all areas that effect EMR function and use.

5.6 Strengths

This review and meta-analysis used a comprehensive and inclusive search strategy that was developed with the help of experts in the area to collect relevant studies. This review is aimed at a new and developing field. With higher levels of EMR adoption throughout most developed countries, the next important step is to ensure proper use of this information health technology.[5] This is one of only two systematic reviews conducted in the area of improving EMR use.[105] However, due to high heterogeneity in this area, previous reviews were unable to conduct a meaningful meta-analysis.[105] In this review, a synthesis of the results was possible through: the categorization of interventions using the EPOC taxonomy of interventions and the identification of possible intervention target areas to improve EMR use. This allowed for the meaningful grouping of the studies resulting in the ability to conduct a meta-analysis. This increases the power of the results and the conclusions drawn from those results. Additionally, in accordance with the PRISMA Guidelines for Systematic Reviews the methodological quality of the evidence was assessed using an appropriate tool. [86]

5.7 Limitations

Due to the new and wide geographic spread of information technology use in the health field, EMRs are identified differently in different countries, making it impossible to identify all the studies with one search term. In an attempt to learn all the possible terms that are used to refer to an EMR, a search was performed prior to the creation of the search strategies. Using those newly found terms a search strategy was then created to be as inclusive as possible without straying from the inclusion/exclusion criteria.

Only titles available in the English language were included in this review. A language limitation has been found to create selection bias in systematic reviews.[111,112] However, three separate studies regarding EMR related publications by country found that the top four of the five countries in number of EMR-related publications were English speaking: United States, United Kingdom, Australia and Canada.[113,114,115] Therefore, in this case, it was concluded that the limitation of including English only studies would not have a great impact on the pool of identified studies.

In addition, there was no generally accepted EMR use evaluation method. The ultimate objective shared by the studies in this review was improving EMR use, however each of the studies defined and evaluated use differently. This also included different measurement of outcomes which created the need for the conversion of some outcome measures to be included in the meta-analysis. This heterogeneity between studies created a difficult environment to synthesize the identified studies into one effect estimate. Traditionally studies included in a meta-analysis are grouped based on the intervention. However, as previously mentioned, the intervention target area was found to be just as important and more appropriate for the grouping of studies in this field compared to the intervention. Therefore, in an attempt to address the heterogeneity of the studies, they were grouped into intervention target area categories. This allowed for the synthesis of results, creating a meaningful meta-analysis. In addition, the possibility of publication bias as shown by the examination of the funnel plot and the moderate risk of bias of the included studies require caution in the interpretation of the meta-analysis results. The results of this meta-analysis could also be affected by the clustering of patients based on

the primary health care provider. However, all the measurements were taken at the level of the primary health care provider and were therefore not expected to have a great impact on the results.

5.8 Future Research

With the rise of EMR adoption in primary health care, the next step is to improve EMR use through the proper use of EMRs and their features. To achieve this, guidelines for intervention studies focused on EMR use should be created. However, the first step would be to create a standardized EMR use definition and evaluation method which would allow for the conducting of more meaningful studies in the area of improving EMR use. Standardized interventions and EMR use evaluation methods would go a long way in establishing studies that would assist in creating recognizable and generalizable interventions to improve EMR use. Future research would also benefit from exploring other options for intervention target areas when attempting to improve EMR use. Those would include the effect of EMRs on workflow, the need for on-going technological support, and patient access to the EMR.

5.9 Conclusion

This review reveals a lack of attention given to interventions aimed at improving EMR use in primary health care. This is also reflected in the absence of a generalized method to evaluate EMR use, as well as guidelines to implement interventions to improve this use. After an intensive and inclusive search of the literature, this systematic review found a relatively small number of included studies with high heterogeneity. However, it is still worth noting that the results of this meta-analysis indicate that it is beneficial for primary health care practice to implement organizational, professional and financial interventions. This can be achieved through investing in EMR feature add-ons, educational materials and financial incentives to improving EMR use.

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Appendix A: Complete Search Strategies

Medline- Ovid

#	Search	Results
1	exp Medical Records Systems, Computerized/	29129
2	((electronic or computer* or online) adj2 (medical or health or patient) adj2 (record or records)).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]	22037
3	1 or 2	37459
4	Primary Health Care/ or Physicians, Primary Care/ or Family Practice/ or General Practice/ or General Practitioners/ or Nurse Practitioners/	135663
5	(Primary health care or Primary healthcare or Primary medical care or Family practi* or Family medicine or General practi* or Family physician* or Family Doctor* or Nurse Practition*).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]	207800
6	4 or 5	208329
7	Intervention Studies/ or Feedback/ or Health Knowledge, Attitudes, Practice/ or Computer User Training/ or workflow/ or Office Management/ or Practice Management, Medical/ or Decision Making, Computer-Assisted/ or "quality of health care"/ or exp quality improvement /	200385
8	(Intervention Stud* or Computer user training or Work Flow or Office Management or Medical Practice Management or Computer assisted Decision making or Computer assisted Diagnosis or "meaningful use" or feedback or quality improvement).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]	162119
9	7 or 8	309976
10	3 and 6 and 9	823

#	Search	Results
11	limit 10 to (english language and yr="1970 -Current")	709

EMBASE

#	Search	Results
1	exp electronic medical record/	32147
2	((electronic or computer* or online) adj2 (medical or health or patient) adj2 (record or records)).mp. [mp=title, abstract, heading word, drug trade name, original title, device manufacturer, drug manufacturer, device trade name, keyword]	40575
3	1 or 2	40738
4	primary health care/ or general practice/ or general practitioner/ or nurse practitioner/ or family nurse practitioner/	188427
5	(Primary health care or Primary healthcare or Primary medical care or Family practi* or Family medicine or General practi* or Family physician* or Primary care physician* or Family Doctor* or Nurse Practition*).mp. [mp=title, abstract, heading word, drug trade name, original title, device manufacturer, drug manufacturer, device trade name, keyword]	295406
6	4 or 5	295406
7	intervention study/ or attitude to health/ or exp knowledge management/ or "meaningful use criteria"/ or workflow/ or computer assisted diagnosis/	158262
8	(Intervention Stud* or Computer user training or Work Flow or Office Management or Medical Practice Management or Computer assisted Decision making or Computer assisted Diagnosis or "meaningful use" or feedback or quality improvement).mp. [mp=title, abstract, heading word, drug trade name, original title, device manufacturer, drug manufacturer, device trade name, keyword]	243833
9	7 or 8	336743
10	3 and 6 and 9	887

#	Search	Results
11	limit 10 to (english language and yr="1970 -Current")	791

CINAHL

#	Search	Results
1	(MH "Medical Records, Personal") OR (MH "Computerized Patient Record")	11,234
2	(electronic OR computer* OR online) N2 (medical OR health OR patient) N2 (record OR records)	13,390
3	(S1 OR S2)	13,719
4	(MH "Family Nurse Practitioners") OR (MH "Nurse Practitioners") OR (MH "Family Practice") OR (MH "Physicians, Family") OR (MH "Primary Health Care")	57,922
5	Primary health care or Primary healthcare or Primary medical care or Family practi* or Family medicine or General practi* or Family physician* or Family Doctor* or Nurse Practition*	82,062
6	(S4 OR S5)	82,062
7	(MH "Knowledge Management+") OR (MH "Meaningful Use") OR (MH "Computer User Training")OR (MH "Decision Support Systems, Clinical") OR (MH "Decision Making, Computer Assisted") OR (MH "Attitude to Health")	1,688
8	Intervention Stud* or Computer user training or Work Flow or Office Management or Medical Practice Management or Computer assisted Decision making or Computer assisted Diagnosis or "meaningful use" or feedback or quality improvement	61,868
9	(S7 OR S8)	63,268
10	(S3 AND S6 AND S9)	322

Web of Science

#	Search	Results
1	TS=("Electronic medical record*") OR TS=("Electronic health record*") OR TS=("Computerized patient record*") *Indexes=SCI-EXPANDED, SSCI, A&HCI, CPCI-S, CPCI-SSH Timespan=All years*	12,811
2	TS=("Primary Health Care") or TS=("Primary Care Physicians") or TS=("Family Practice") or TS=("General Practice") or TS=("General Practitioners") or TS=("Nurse Practitioners") *Indexes=SCI-EXPANDED, SSCI, A&HCI, CPCI-S, CPCI-SSH Timespan=All years*	79,091
3	TS=("Intervention Studies") or TS=(Feedback) or TS=("Computer User Training") or TS=(workflow) or TS=("Office Management") or TS=("Practice Management") or TS=("Computer Assisted Decision Making") or TS=("meaningful use") or TS=("quality improvement") or TS=("Computer assisted Diagnosis") *Indexes=SCI-EXPANDED, SSCI, A&HCI, CPCI-S, CPCI-SSH Timespan=All years*	350,825
4	#3 AND #2 AND #1 *Indexes=SCI-EXPANDED, SSCI, A&HCI, CPCI-S, CPCI-SSH Timespan=All years*	141
5	(#4) *AND* LANGUAGE: (English) *Indexes=SCI-EXPANDED, SSCI, A&HCI, CPCI-S, CPCI-SSH Timespan=1970-2015*	140

Cochrane Library

#	Search	Results
1	MeSH descriptor: [Medical Records Systems, Computerized] explode all trees	439
2	MeSH descriptor: [Primary Health Care] explode all trees	4022
3	MeSH descriptor: [General Practice] this term only	209
4	MeSH descriptor: [General Practitioners] explode all trees	95
5	MeSH descriptor: [Nurse Practitioners] this term only	316
6	MeSH descriptor: [Intervention Studies] this term only	2306

#	Search	Results
7	MeSH descriptor: [Feedback] this term only	979
8	MeSH descriptor: [Health Knowledge, Attitudes, Practice] this term only	3916
9	MeSH descriptor: [Computer User Training] explode all trees	47
10	MeSH descriptor: [Workflow] explode all trees	13
11	MeSH descriptor: [Office Management] explode all trees	70
12	MeSH descriptor: [Decision Making, Computer-Assisted] explode all trees	3751
13	MeSH descriptor: [Quality Improvement] 1 tree(s) exploded	49
14	Enter terms for search #2 or #3 or #4 or #5	4485
15	Enter terms for search #6 or #7 or #8 or #9 or #10 or #11 or #12 or #13	10975
16	Enter terms for search "electronic medical records"	183
17	Enter terms for search "electronic health records"	213
18	Enter terms for search "computerized medical records"	21
19	Enter terms for search "electronic patient records"	28
20	Enter terms for search "primary health care"	4725
21	Enter terms for search "primary healthcare"	341
22	Enter terms for search "Primary medical care"	1879
23	Enter terms for search "Family practice"	3579
24	Enter terms for search "Family medicine"	1807
25	Enter terms for search "General practice"	5345
26	Enter terms for search "Family physician"	612
27	Enter terms for search "Family Doctor"	179
28	Enter terms for search "Nurse Practitioner"	544
29	Enter terms for search "Intervention Study"	5584
30	Enter terms for search "Computer user training"	48
31	Enter terms for search "Work Flow"	25
32	Enter terms for search "Office Management"	16
33	Enter terms for search "Medical Practice Management"	3
34	Enter terms for search "Computer assisted Decision making"	5
35	Enter terms for search "Computer assisted Diagnosis"	108
36	Enter terms for search "meaningful use"	21
37	Enter terms for search "feedback"	8445
38	Enter terms for search "quality improvement"	1287
39	Enter terms for search #1 or #16 or #17 or #18 or #19	417
40	Enter terms for search #14 or #20 or #21 or #22 or #23 or #24 or #25 or #26 or #27 or #28	15661
41	Enter terms for search #15 or #29 or #30 or #31 or #32 or #33 or	23975

#	Search	Results
	#34 or #35 or #36 or #37 or #38	
42	Enter terms for search #40 and #41 and #42	80

Appendix B: Screening Questions

Level 1 Screening Questions

1. Is the study focused on Information Technologies (IT) in relation to electronic or computerized patient records and not just as a data source? (could include but is not limited to Electronic Health Records, Electronic Patient Records, Computerized Patient Records, Computerized Medical Records, Computerized Health Records along with proper names for programs being used)
   a. Yes
   b. No
   c. Don't know
2. Does the study focus on EMR use (not the adoption or implementation of EMRs)?
   a. Yes
   b. No
   c. Don't know
3. Is it a study that either implements or observes an intervention with the intent of observing its effect on EMR use? (interventions could include but are not limited to: Educational Interventions, Computer Training, feedback, Work Flow, Practice Management, Office Management, Computer Assisted Diagnosis, Practice Guidelines, Guideline adherence or Training Support)
   a. Yes
   b. No
   c. Don't know
4. Was the study conducted in a primary health care setting? (such as patients' homes, physicians' clinics, physicians' offices, chronic health and primary health units)
   a. Yes
   b. No
   c. Don't know
5. Is it a research study (not an editorial, opinion, case report)?
   a. Yes
   b. No
   c. Don't know

Level 2 Screening Questions

1. Does the study target primary health care settings or personnel?
   a. Yes
   b. No
   c. Don't know
2. Is there a planned intervention implemented or observed with the intention of improving EMR use?
   a. Yes

    b. No
    c. Don't know

3. Does the study report measurements of use (the frequency of use, level of use or variety of use) of EMRs?
    a. Yes
    b. No
    c. Don't know

Appendix C: Example of How Odds Ratios Were Calculated with Combined Outcomes from Nemeth (2012)

In this study Standing Orders (SOs) health templates were implemented into a pre-existing EMR at primary health care practices. Changes in quality indicators were then measured in relation to the presence and use of the health templates for diabetes and screening measures. More specifically those measures included: cholesterol, HDL cholesterol, mammography and osteoporosis. Results were presented on the completion of those measures and the use of the health templates. Below is an example of how the odds ratio were calculated and the outcomes combined using results reported on the use of the previously mentioned templates (use of EMR functions) before and after the intervention.

Outcome	Intervention Event	Intervention No-Event	Control Event	Control No-Event
Cholesterol	3606	2833	3217	4629
HDL Cholesterol	3357	3099	892	4683
Mammography	1359	906	1453	2698
Osteoporosis	473	1779	361	3650
Total	8795	8617	5923	15660

$$\text{OR}_{\text{(Nemeth Total)}} = \frac{(8795) \; x \; (15660)}{(5923) \; x \; (8617)}$$

$$= 2.699$$

$$\text{Log OR}_{\text{(Nemeth Total)}} = 0.99$$

Appendix D: Further Explanation of the Downs and Black Bias Assessment Tool

The Downs and Black scale is made of 27 questions divided in to sub-sections:

1. **Reporting:** Assess whether the information provided allows for an unbiased assessment of the study outcomes. Consists of nine items all scored from 0 to 1 except for the question on listing confounding variables which scored from 0 to 2 contributing a maximum of ten points to the final score.

2. **External Validity:** Examines whether the findings of the study can be generalized to the intended population. Consists of three items all scored from 0 to 1 contributing a maximum of three points to the final score.

3. **Internal Validity:**

   a. **Bias:** Examines the presence of any bias in the measurements of the intervention and outcome. Consists of seven items all scored from 0 to 1 contributing a maximum of seven points to the final score.

   b. **Confounding:** Asses the bias of studies in the selection of study participants. Consists of six items all scored from 0 to 1 contributing a maximum of six points to the final score.

4. **Power**: Examines the possibility that the study findings could be due to chance. Consists of one item and is scored from 0 to 5 contributing a maximum of five points to the final score.

Therefore, studies could score a maximum of 31 points for assessing risk of bias of individual studies.[86]

Appendix E: The Downs and Black Checklist for Risk of Bias Assessment

Reporting

1. *Is the hypothesis/aim/objective of the study clearly described?*

yes 1

no 0

2. *Are the main outcomes to be measured clearly described in the Introduction or Methods section?* If the main outcomes are first mentioned in the Results section, the question should be answered no.

yes 1

no 0

3. *Are the characteristics of the patients included in the study clearly described?* In cohort studies and trials, inclusion and/or exclusion criteria should be given. In case-control studies, a case-definition and the source for controls should be given.

yes 1

no 0

4. *Are the interventions of interest clearly described?* Treatments and placebo (where relevant) that are to be compared should be clearly described.

yes 1

no 0

5. *Are the distributions of principal confounders in each group of subjects to be compared clearly described?* A list of principal confounders is provided.

yes 2

partially 1

no 0

6. *Are the main findings of the study clearly described?* Simple outcome data (including denominators and numerators) should be reported for all major findings so that the reader can check the major analyses and conclusions.

yes 1

no 0

7. *Does the study provide estimates of the random variability in the data for the main outcomes?* In non-normally distributed data the inter-quartile range of results should be reported. In normally distributed data the standard error, standard deviation or confidence intervals should be reported. If the distribution of the data is not described, it must be assumed that the estimates used were appropriate and the question should be answered yes.

yes 1

no 0

8. *Have all important adverse events that may be a consequence of the intervention been reported?* This should be answered yes if the study demonstrates that there was a comprehensive attempt to measure adverse events.

yes 1

no 0

9. *Have the characteristics of patients lost to follow-up been described?* This should be answered yes where there were no losses to follow-up or where losses to follow-up were so small that findings would be unaffected by their inclusion. This should be answered 'no' where a study does not report the number of patients lost to follow-up.

yes 1

no 0

10. *Have actual probability values been reported (e.g. 0.035 rather than <0.05) for the main outcomes except where the probability value is less than 0.001?*

yes 1

no 0

External validity

All the following criteria attempt to address the representativeness of the findings of the study and whether they may be generalized to the population from which the study subjects were derived.

11. *Were the subjects asked to participate in the study representative of the entire population from which they were recruited?* The study must identify the source population for patients and describe how the patients were selected. Patients would be representative if they comprised the entire source population, an unselected sample of consecutive patients, or a random sample. Random sampling is only feasible where a list of all members of the relevant population exists. Where a study does not report the proportion of the source population from which the patients are derived, the question should be answered as unable to determine.

yes 1

no 0

unable to determine 0

12. *Were those subjects who were prepared to participate representative of the entire population from which they were recruited?* The proportion of those asked who agreed should be stated. Validation that the sample was representative would include demonstrating that the distribution of the main confounding factors was the same in the study sample and the source population.

yes

no 0

unable to determine 0

13. *Were the staff, places, and facilities where the patients were treated, representative of the treatment the majority of patients receive?* For the question to be answered yes the study should demonstrate that the intervention was representative of that in use in the

source population. The question should be answered no if, for example, the intervention was undertaken in a specialist center unrepresentative of the hospitals most of the source population would attend.

yes

no 0

unable to determine 0

Internal validity - bias

14. *Was an attempt made to blind study subjects to the intervention they have received ?* For studies where the patients would have no way of knowing which intervention they received, this should be answered yes.

yes 1

no 0

unable to determine 0

15. *Was an attempt made to blind those measuring the main outcomes of the intervention?*

yes 1

no 0

unable to determine 0

16. *If any of the results of the study were based on "data dredging", was this made clear?* Any analyses that had not been planned at the outset of the study should be clearly indicated. If no retrospective unplanned subgroup analyses were reported, then answer yes.

yes 1

no 0

unable to determine 0

17. *In trials and cohort studies, do the analyses adjust for different lengths of follow-up of patients, or in case-control studies, is the time period between the intervention and*

outcome the same for cases and controls? Where follow-up was the same for all study patients the answer should yes. If different lengths of follow-up were adjusted for by, for example, survival analysis the answer should be yes. (Studies where differences in follow-up are ignored should be answered no).

yes 1

no 0

unable to determine 0

18. *Were the statistical tests used to assess the main outcomes appropriate?* The statistical techniques used must be appropriate to the data. For example, non- parametric methods should be used for small sample sizes. Where little statistical analysis has been undertaken but where there is no evidence of bias, the question should be answered yes. If the distribution of the data (normal or not) is not described it must be assumed that the estimates used were appropriate and the question should be answered yes.

yes 1

no 0

unable to determine 0

19. Was compliance with the interventions reliable? Where there was noncompliance with the allocated treatment or where there was contamination of one group, the question should be answered no. For studies where the effect of any misclassification was likely to bias any association to the null, the question should be answered yes.

yes 1

no 0

unable to determine 0

20. *Were the main outcome measures used accurate (valid and reliable)?* For studies where the outcome measures are clearly described, the question should be answered yes. For studies which refer to other work or that demonstrates the outcome measures are accurate, the question should be answered as yes.

yes 1

no 0

unable to determine 0

Internal validity - confounding (selection bias)

21. *Were the patients in different intervention groups (trials and cohort studies) or were the cases and controls (case-control studies) recruited from the same population?*

For example, patients for all comparison groups should be selected from the same hospital. The question should be answered unable to determine for cohort and case-control studies where there is no information concerning the source of patients included in the study.

yes 1

no 0

unable to determine 0

22. *Were study subjects in different intervention groups (trials and cohort studies) or were the cases and controls (case-control studies) recruited over the same period of time?* For a study which does not specify the time period over which patients were recruited, the question should be answered as unable to determine.

yes 1

no 0

unable to determine 0

23. *Were study subjects randomized to intervention groups?*

Studies which state that subjects were randomized should be answered yes except where method of randomization would not ensure random allocation. For example, alternate allocation would score no because it is predictable.

yes 1

no 0

unable to determine 0

24. *Was the randomized intervention assignment concealed from both patients and health care staff until recruitment was complete and irrevocable?* All non-randomized studies should be answered no. If assignment was concealed from patients but not from staff, it should be answered no.

yes 1

no 0

unable to determine 0

25. *Was there adequate adjustment for confounding in the analyses from which the main findings were drawn?* This question should be answered no for trials if: the main conclusions of the study were based on analyses of treatment rather than intention to treat; the distribution of known confounders in the different treatment groups was not described; or the distribution of known confounders differed between the treatment groups but was not taken into account in the analyses. In non-randomized studies if the effect of the main confounders was not investigated or confounding was demonstrated but no adjustment was made in the final analyses the question should be answered as no.

yes 1

no 0

unable to determine 0

26. *Were losses of patients to follow-up taken into account?* If the numbers of patients lost to follow-up are not reported, the question should be answered as unable to determine. If the proportion lost to follow-up was too small to affect the main findings, the question should be answered yes.

yes 1

no 0

unable to determine 0

Power

27. *Did the study have sufficient power to detect a clinically important effect where the*

probability value for a difference being due to chance is less than 5%? Sample sizes have been calculated to detect a difference of x% and y%.

	Size of *smallest* intervention group	
A	$<n_1$	0
B	n_1-n_2	1
C	n_3-n_4	2
D	n_5-n_6	3
E	n_7-n_8	4
F	n_8+	5

Source: Downs SH, Black N. The feasibility of creating a checklist for the assessment of the methodological quality both of randomised and non-randomised studies of health care interventions. *J Epidemiol Community Health*. 1998;52(6):377-384.

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