Scientific Foundation SPIROSKI, Skopje, Republic of Macedonia
Open Access Macedonian Journal of Medical Sciences. 2021 Jan 15; 9(E):8-25.
https://doi.org/10.3889/oamjms.2021.3421
eISSN: 1857-9655
Category: *E – Public Health*
Section: *Public Health Legislation*

Investigating Evaluation Frameworks for Electronic Health Record: A Literature Review

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Edited by: Eli Djulejic
Citation: Ebnehoseini Z, Tabesh H, Jangi M, Deldar K, Mostafavi SM, Tara M. Investigating Evaluation Frameworks for Electronic Health Record: A Literature Review. Open Access Maced J Med Sci. 2021 Jan 15; 9(E):8-25. https://doi.org/10.3889/oamjms.2021.3421
Keywords: Electronic medical record; Electronic health record; Evaluation frameworks; Evaluation model; Evaluation theory
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Received: 09-Aug-2020
Revised: 11-Nov-2020
Accepted: 28-Sep-2020

Funding: Current study was fully sponsored by Mashhad University of Medical sciences with grant number 951350
Competing Interests: The authors declare that they have no competing interests.

Abstract

BACKGROUND: There are various electronic health records (EHRs) evaluation frameworks with multiple dimensions and numerous sets of evaluation measures, while the coverage rate of evaluation measures in a common framework varies in different studies.

AIM: This study provides a literature review of the current EHR evaluation frameworks and a model for measuring the coverage rate of evaluation measures in EHR frameworks.

METHODS: The current study was a comprehensive literature review and a critical appraisal study. The study was conducted in three phases. In Phase 1, a literature review of EHR evaluation frameworks was conducted. In Phase 2, a three-level hierarchical structure was developed, which includes three aspects, 12 dimensions, and 110 evaluation measures. Subsequently, evaluation measures in the identified studies were categorized based on the hierarchical structure. In Phase 3, relative frequency (RF) of evaluation measures in different dimensions and aspects for each of the identified studies were determined and categorized as follows: Appropriate, moderate, and low coverage.

RESULTS: Out of a total of 8276 retrieved articles, 62 studies were considered relevant. The RF range in the second and third level of the hierarchical structure was between 8.6%–91.94% and 0.2%–61%, respectively. "Ease of use" and "system quality" were the most frequent evaluation measure and dimension. Our results indicate that identified studies cover at least one and at most nine evaluation dimensions and current evaluation frameworks focus more on the technology aspect. Almost in all identified studies, evaluation measures related to the technology aspect were covered. However, evaluation measures related to human and organization aspects were covered in 68% and 84% of the identified studies, respectively.

CONCLUSION: In this study, we systematically reviewed all literature presenting any type of EHR evaluation framework and analyzed and discussed their aspects and features. We believe that the findings of this study can help researchers to review and adopt the EHR evaluation frameworks for their own particular field of usage.

Introduction

In recent years, electronic health records (EHRs) have been adopted by an ever-increasing number of health-care organizations around the world. Subsequently, assessment of the quality of performance of EHRs is currently the subject of extensive research and debate. Evaluation is defined as the "act of measuring or exploring properties of a health information system (in planning, development, implementation, or operation), the result of which informs a decision to be made concerning that system in a specific context" [1]. The adoption or development of an evaluation framework is the standard method for EHR evaluation. Evaluation frameworks are defined as "methodologies that capture the processes integral to information systems, the users and the world in which the users' function" [2].

Various frameworks have been proposed in different studies for EHR evaluation [3]. Each evaluation framework has unique features and provides a different perspective to assess various aspects of the EHR. The focus of evaluation frameworks may be on the user's behavioral features, organizational aspects, social factors, or technological characteristics. For example, the technology acceptance model (TAM) [3], [4], [5] and the unified theory of acceptance and use of technology (UTAUT) [6] are adopted in many studies for EHR evaluation. TAM was proposed by Davis *et al*. in 1989. It was developed to predict individual adoption and use of new information technologies (IT) [7]. UTAUT was formulated by Venkatesh *et al*. in 2003 [8]. In UTAUT, social influence indicators can measure social factors in EHR adoption [9]. Another famous framework for EHR evaluation is the information system success model (ISSM) [10]. The goal of the ISSM is an evaluation of system quality, service quality, and information quality [11]. The task-technology fit (TTF) framework measures the level of coherence between user tasks and requirements, on the one hand, and system characteristics on the other [12].

Nevertheless, a limited number of studies were performed on the identification and classification of EHR evaluation frameworks. Currie proposed evaluation frameworks for nursing informatics. The frameworks were categorized into four groups: Generic, human behavior, social/organizational relations, and software lifecycle [13]. Yusof *et al*. classified different dimensions of twenty evaluation frameworks for health information systems into three main categories [14]. Nguyen *et al*. classified impact and contingency factors in a systematic review. This study did not present a formal review of the underlying theoretical EHR evaluation frameworks based on the selected reviewed articles. Indeed, this has not been addressed in the current literature reviews of EHR evaluation studies [10]. A literature review covering these studies can be used as a reference for researchers.

As mentioned, the diversity of developed evaluation frameworks reflects the variation in the purpose of evaluation. Various evaluation measures can be utilized to serve each framework. The coverage rate of evaluation measures in a common framework may differ in the studies. For example, Holden and Karsh reviewed 16 studies in healthcare that used TAM. Almost all the studies added variables to TAM and proposed a modified TAM in an attempt to better recognize the antecedents of acceptance or health IT-use behavior. Given the fact that there are many frameworks for EHR evaluation, an inclusive literature review that covers all published studies on EHR evaluation is deemed to be essential. However, a comprehensive literature review itself is not enough. Researchers may wish to conduct a comparative study before adopting or developing EHR evaluation frameworks. Hence, a tailored study is needed when the aim is not just to identify the EHR evaluation frameworks but also to compare the frameworks.

As far as we know, no systematic identification of EHR evaluation frameworks has been conducted. As well, no study has been performed to determine the coverage rate of evaluation measures in EHR evaluation frameworks. The current study addressed these gaps. Accordingly, the objectives of the present study are (1) to undertake a comprehensive literature review of studies of EHR evaluation frameworks; (2) to identify and categorize evaluation measure in EHR evaluation frameworks; (3) to propose a method for measuring the coverage rate of evaluation measures in the frameworks; and (4) to determine the coverage rate of evaluation measures in EHR evaluation frameworks.

Methodology

Acknowledge

The current study was a part of the doctorate thesis (research plan code: 951350) and was performed according to the following steps:

1. A literature review on EHR evaluation frameworks,
2. To develop a hierarchical structure for categorizing extracted items from the EHR evaluation frameworks,
3. To determine the coverage rate of evaluation measures in identified studies.

The literature review on EHR evaluation frameworks

Search strategy

A search of English literature from January 2007 to August 2017 in PubMed, Scopus, ScienceDirect, and Cochrane databases was conducted to identify relevant studies. In the present review, a hybrid protocol and search strategy from Sockolow *et al*. [2], Yusof *et al*. [14], and other EHR literature reviews were implemented [2], [15], [16], [17]. In our study, ISO's EHR definition was applied. The search criteria focused on EHR evaluation frameworks. To achieve a comprehensive search strategy to identify the EHR evaluation frameworks, a large set of search terms were used. The terms related to EHR were derived from ISO's EHR definition and previous systematic literature reviews on EHR [2], [15], [16], [17]. The terms related to the evaluation frameworks were based on the previous literature reviews [2], [14], [15], [17].

Table 1 shows Mesh terms and keywords related to EHR (Group A) and evaluation frameworks (Group B). The "OR" operator was used to combine keywords in Group A and Group B, separately. Then, results from both groups were combined using the "AND" operator. Furthermore, our search was augmented by reviewing bibliographies from identified studies.

Table 1: Groups of keywords used in the search strategy

Group A	Electronic health record and related concept electronic Health records* Medical records systems, computerized* Computerized medical records system Electronic medical records Electronic patient record Hospital information systems*
Group B	Evaluation framework and related concepts evaluation model\ evaluation research\ program evaluation\ measurement practice\ evaluation studies\ program methods\ certification\ measure\ accreditation\ license\ assessment\ cognitive evaluation\ usability testing\ systems analysis\ software evaluation\ qualitative study\ qualitative evaluation\ focus groups\ questionnaires\ health care process assessment\ taxonomy \ classification \ questionnaires\ health services research

*Mesh terms are in bold.

Studies selection criteria

Throughout our study, we focused on evaluation frameworks that were developed or adopted for the summative EHR evaluation.

The articles that did not focus on EHR evaluation, commentary letters, and summary of articles presented at conferences were excluded from the study. Furthermore, the studies whose evaluation dimensions of framework descriptions were not included by their

authors as well as studies that focused on frameworks for formative or lifecycle EHR evaluation.

Preliminary data abstraction

For each studies meeting, the inclusion criteria data were abstracted independently by two researchers (ZE and KD). The researchers kept a list of the reviewed studies that were excluded from the review along with the reasons for their exclusion. Then, full text studies were reviewed and eligible studies were identified and included in the data extraction process. Any disagreement to include an article was resolved by holding a discussion between the two evaluators. Unsolved disagreements were discussed with a third evaluator (MT). The final decision was made after a consensus was reached between all three evaluators. General data abstracted from each study included *the framework name, author(s), location, publication date, EHR evaluation purpose(s)*, *healthcare contexts, evaluation scales, participants, and data collection methods.* These data were selected based on the previous related literature reviews [10], [14], [18].

To develop a hierarchical structure for categorizing extracted items from the EHR evaluation frameworks

To classify extracted items from EHR evaluation frameworks, a three-level hierarchical structure was developed. The structure included aspects, dimensions, and evaluation measures. Top level of this hierarchical structure comprised aspects. Each aspect encompassed a number of dimensions. Middle and lower levels of the hierarchy contained dimensions and evaluation measures, respectively. Each evaluation dimension contained at least one evaluation measure.

Yusof *et al*. investigated the evaluation frameworks for health information systems and suggested that technology, human, and organization are the essential evaluation aspects of health information systems [14]. This study adopted evaluation aspects used by Yusof *et al*.

The middle level which included eight dimensions was developed in the following two steps. First, a number of literature reviews, related to categorizing evaluation dimensions of EHR, were identified [10], [13], [18]. Evaluation dimensions of three identified literature reviews were extracted independently by two researchers and were mapped in evaluation aspects including, technology, human, and organization. The results were saved in Excel files. An expert panel approach was used to combine the extracted dimensions. The common dimensions were merged by two researchers. Unresolved disagreements were discussed with a third researcher. After this step, eight dimensions were considered as “primary dimensions of the hierarchy structure,” which are as follows:

- Technology: System quality, information quality, service quality
- Human: Satisfaction, system use
- Organization: Characteristics of organization and organizational factors, environment, and, net benefit and EHR impacts.

In the second step, evaluation dimensions of identified studies related to EHR evaluation frameworks were extracted independently by two researchers. The results were saved in Excel files. Each researcher compared evaluation dimensions of EHR in the retrieved studies to “primary dimensions of the hierarchy structure.” Common dimensions were mapped to “primary dimensions of the hierarchy structure.” Some dimensions were added to the hierarchical structure in this step. Then, two Excel files were combined in expert panel meetings that were held by two researchers. In this step, four dimensions were added to the middle level of the hierarchy structure, which includes “computer knowledge and self-efficacy,” “users’ characteristics and personality,” and “positive or negative feeling about EHR.” Furthermore, the dimension of “net benefit and EHR impacts” was divided into two separate dimensions as following “effects on workflow and organization” and “effects on outcome quality of care.”

The lower level of the hierarchy structure was formed by a similar procedure. Evaluation measures of identified studies related to EHR evaluation frameworks were extracted independently by two researchers and were then mapped in various dimensions of evaluation aspects. Unsolved disagreements were discussed by two researchers. Out of a total of 588 evaluation measures that were extracted from the frameworks, 110 remained after combing common evaluation measures. These evaluation measures covered 12 dimensions in three evaluation aspects. 50, 29, and 31 evaluation measures were related to the aspects of technology, human, and organization, respectively. The number of evaluation measures in the three dimensions was as follows:

- Technology: System quality (n = 15), information quality (n = 23), and service quality (n = 12).
- Human: satisfaction (n = 5), system use (n = 9), computer knowledge and self-efficacy (n = 2), users’ characteristics and personality (n=3), and positive or negative feeling about EHR (n = 10)
- Organization: Characteristics of organization and organizational factors (n = 28), “effects on workflow and organization (n = 1), effects on outcome quality of care (n = 1), and environment (n = 1)

Figure 1 shows the hierarchical structure for categorizing extracted items from the EHR evaluation frameworks.

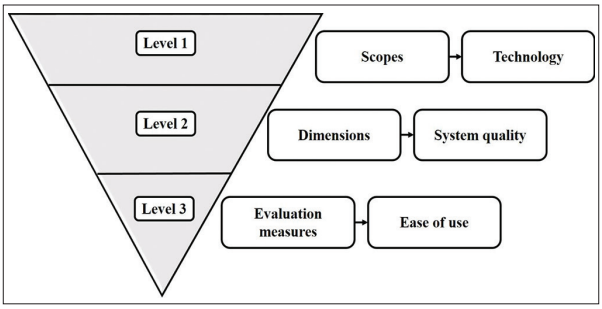

Figure 1: The hierarchical structure for categorizing extracted items from the electronic health records evaluation frameworks

Determining the coverage rate of evaluation measures in identified studies (frameworks)

To determine the coverage rate of evaluation measures in the identified studies, the following six steps were taken:

Step 1- Determination of relative frequency (RF) of evaluation measures in the identified studies:

RF of an evaluation measure= Frequency of an evaluation measure in the identified studies/Total number of identified studies

Example: RF of "usefulness" evaluation measure= the number of studies that contained this evaluation measure divided by the total number of identified studies.

38/62=0.61

Step 2- Determining the sum of RF of the evaluation measures in different dimensions.

Sum of the RF of evaluation measures in each dimension = Total of the RF of evaluation measures in dimensions for all identified studies.

Example: Sum of RF of the "system quality" dimension was equal to the sum of the RF of the following evaluation measures: Ease of use, usefulness, usability, reliability, response time, accessibility, sufficient resources, privacy and security, availability, system function, system interoperability and integration, complexity, flexibility, mobility, and confusion.

0.61+0.52+0.21+0.21+0.13+0.10+0.19+0.11+ 0.08+0.06+0.15+0.03+0.02+0.02+0.02=2.45

Step 3- Determining the sum of RF of the dimensions related to each aspect.

Sum of the RF of the dimensions related to each aspect = Total of the RF of the dimensions related to each aspect for all identified studies.

Example: Sum of RF of the "technology" aspect was equal to the sum of the RF of the following dimensions: system quality, information quality, and service quality.

2.45+1.44+0.73=4.62

Step 4- Determination the sum of RF of the evaluation measures in dimensions and aspects for each identified study

Example: Sum of RF of the dimension of "system quality" for the study by Otieno *et al*. was equal to the sum of RF of the following evaluation measures: ease of use, usefulness, usability, reliability, and availability.

0.61+0.52+0.08=0.90

Example: Sum of RF of the aspect of "technology" for the study by Otieno *et al*. was equal to the sum of RF of the following evaluation dimensions: System quality, information quality, and service quality.

0.90+0.72+0.36=1.98

Step 5- Determination of coverage rate of evaluation measures in dimensions and aspects for the identified studies.

The coverage rate of evaluation measures in dimensions/aspects for each identified studies = Sum of RF of evaluation measures in dimensions and aspects for each of the identified studies (the values obtained in Stage 4)/ sum of RF of evaluation measures in dimensions and aspects for the all identified studies (the values obtained in Stages 2 and 3) × 100

Example: Sum of RF of the dimension of "system quality" for the study by Otieno *et al*. =

(0.90/2.45) × 100 = 37%

Example: Sum of the RF of the "technology" aspect for the study by Otieno *et al*. =

(1.98/4.62) × 100 = 44%

Step 6- Categorization of coverage rate of evaluation measures in dimensions and aspects for the identified studies.

In this step, the determined rates in step 5 above were categorized as follows:

1. Appropriate coverage (50%≤ coverage rate),
2. Moderate coverage (25%≤ coverage rate <50%),
3. Low coverage (coverage rate <25%), and
4. Non-coverage (coverage rate = 0).

After determination of the coverage rate of evaluation measure for the identified studies, the results were plotted on three figures. Using these figures, we can compare different studies.

Results

Literature review

The database search was conducted in 2017. A total of 8276 records were retrieved. Among these, 62 studies met the inclusion criteria (Figure 2).

We conducted a review of the characteristics of the 62 eligible studies. A list of different demographic characteristics and research methods is presented in Table 2.

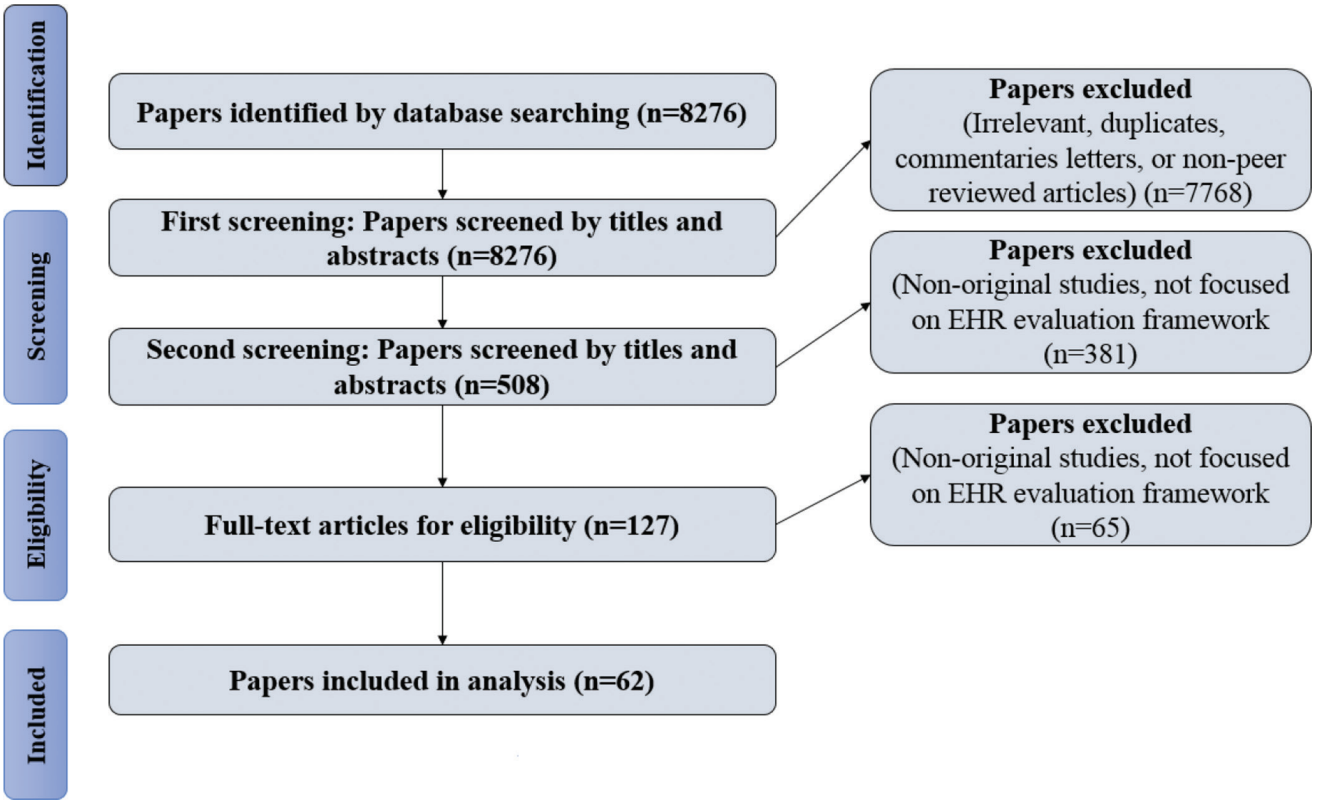

Figure 2: Flow diagram of review

More than half of the studies (n = 32) were from the USA and Taiwan. Fourteen studies were from Iran, the UK, Canada, and the Netherlands. Sixteen studies were conducted in other countries.

Twenty-one EHR evaluation purposes were extracted from the retrieved articles. They were categorized into four groups including, technology, human, organization, and system outcomes (Table 2). "System acceptance" was the most frequent purpose (more than one-third of studies). "Measurement of users' satisfaction" was ranked as the second most frequent purpose (19.3% of studies).

Most EHR evaluations were conducted at hospitals (66%, n = 41) and primary care clinics (16%, n =10). Eighteen percent of evaluations were conducted in other healthcare contexts, including medical centers, physician offices, health and social service organizations, community health centers, long-term residential care facilities, usability laboratories, and social services organizations. In three studies, EHR evaluation was performed in professional associations (such as the association of physicians).

The EHR evaluation scale was divided into three groups: Small, medium, and large (Table 2). The small scale encompassed EHR evaluations that were performed in one to five health-care organizations (64.5%, n = 40). The medium scale included EHR evaluations that were conducted in a geographic region, health-care centers affiliated with a health information system or university, and associations (e.g., association of physicians) (22.5%, n = 14). The large evaluation scale included EHR evaluations that were performed at the national level (13%, n = 8).

EHR evaluation was performed in 56% (n = 35) of the studies with a single group of participants. Physicians and nurses (n = 32) were the most frequent single group of participants. In 39% of the studies (n = 24), multiple groups of participants were involved for EHR evaluation. Similarly, physicians and nurses played an important role in all of these studies. In 5% (n = 3) of the articles, participants were generally reported as users. Participants with a frequency of <5 (n < 5) were considered as clinical and non-clinical participants in Table 2.

Clinician participants included physical and occupational therapists (n = 3), physiotherapists (n = 2), pharmacists (n = 2), social workers (n = 1), laboratory technologists (n = 1), paramedical staff (n = 1), radiology staff (n = 1), medical secretaries (n = 1), and medical technicians (n = 1).

Non-clinical participants included managers (n = 6), IT staff (n = 5), medical record staff (n = 1), health informatics professionals (n = 1), EHR developers (n = 1), financial unit staff (n = 1), and quality improvement personnel (n = 1). Furthermore, physicians with diverse medical specialties, such as dentists and psychiatrists, were generally classified as physicians.

Among the identified studies, seven data collection methods were used. Questionnaire and interview were the most frequently-used data collection methods with prevalence of 89% (n = 55) and 27%

(n = 17), respectively. Other data collection methods, including brainstorming, observation, focus group, log file audit, and scenario were only used along with a questionnaire or interview.

Table 2: Characteristics of the identified studies

Location	US (n=19), Taiwan (n=13), Iran (n=4), Canada (n=4), UK (n=3), Netherlands (n=3), Austria (n=1), Haiti (n=1), Croatia (n=1), Spain (n=1), Greek (n=1), Finland (n=1), Denmark (n=1), Saudi Arabia (n=1), Japan (n=1), Singapore (n=1), Malaysia (n=1), Indonesia (n=1), South Korea (n=1), South Africa (n=1), New Zealand (n=1), and Korea (n=1)
EHR evaluation purposes	Technology: System evaluation (n=3), system quality (n=2), usability (n=2), and system capabilities (n=1), system success (n=1), technical analysis (n=1), functional requirements (n=1), system effectiveness (n=1) Human: System adoption (n=23), user satisfaction (n=11), behavioral intentions to system use (n=4), and users' attitudes (n=1), user perception (n=1), users' experiences (n=1) Organization: Personal analysis (n=1), organizational analysis (n=1), work system challenges (n=1), system effect on outcome quality patient care (n=2), system-costs and benefits (n=1), nurses' perceptions of the system impact on clinical practice (n=1)
Healthcare context	Single: Inpatient: Hospital (n=41), medical center (n=1). Outpatient: Primary care clinic (n=10), physician office (n=2), health and social services organizations (n=1), school of nursing (n=1), community health centers (n=1). Long-term residential care facilities (n=1). Usability laboratory (n=1) Multiple (n=2): Hospital and primary care clinic (n=1), hospital and nursing home (n=1) Special association: (n=3) Not mentioned (n=1)
Evaluation scale	Small scale (n=40): 1 organization (n=28), 2 organizations (n=3), 3 organizations (n=4), 4 organizations (n=2), 5 organizations (n=3) Medium scale (n=14): A certain geographic region (n=5), health care centers affiliated to a health information system or university (n=6), the members of an association (n=3) Large scale (n=8) (national)
Participants	Single participant (n=35): Clinicians: Physicians (n=18) and nurses (n=14). Non-clinical participants: Managers (n=2). Patients (n=1) Multiple participants (n=24): Physicians and nurses (n=7), physicians or nurses with other clinicians (n=8), physicians or nurses with non-clinical participants (n=5), physicians, nurses, clinicians, and non-clinical participants (n=3), and physicians, nurses, non-clinical participants, and patient (n=1). Users (in general): (n=3).
Data collection methods	Single (n=49): Questionnaire (n=44) and interview (n=5). Mixed (n=13): 2 methods: Questionnaire and interview (n=5), interview and observation (n=2), questionnaire and scenario-based (n=1) 3 methods: Questionnaire, interview, and observation (n=2) 4 or 5 methods: Questionnaire, interviews, observation, and focus group (n=1), questionnaire, interviews, brainstorming, and scenario-based (n=1), and questionnaire, interviews, observation, scenario-based, and log file audit (n=1)

RF of the evaluation measures and dimensions in technology, human, and organization aspects

The range of the RF in third-level of hierarchical structure was between 0.2% and 61%. The "ease of use" evaluation measure had the highest RF. Evaluation measures such as flexibility, mobility, and confusion that had the lowest RF were used just in one study. The most frequent evaluation measures in the identified studies as were following,

- Technology: Ease of use (fi: 0.61), usefulness (fi: 0.52), usability (fi: 0.21), reliability (fi: 0.21), and accuracy (fi: 0.21)
- Human: Satisfaction (fi: 0.29), (behavioral) intention of use (fi: 0.34), and computer knowledge and skills (fi: 0.18)
- Organization: Effects on outcome quality of care (fi: 37.1), social context (fi: 0.21), compatibility and fitness with the work process (fi: 0.18), and effects on outcome quality of care (fi: 0.18).

The range of the RF of in second-level of hierarchical structure was between 8.6% and 91.94%. "System quality" (RF: 91.94), "users' satisfaction" (RF: 56.45), "characteristics of the organization and organizational factors" (RF: 53.23), and "service quality" (RF: 53.23) were the most-frequently evaluated dimensions, respectively. "Environment" dimension was the least-frequently evaluated dimensions in the identified studies. Table 3 shows the RF of evaluation measures in the dimensions related to three aspects including technology, human, and organization. Appendix 2–4 demonstrates the detailed list of evaluation measures, dimensions, aspects. Tables 3 and 4 shows the RF of evaluation measures and dimensions and the maximum coverage rate of the evaluation measures in evaluation dimensions and aspects, respectively.

Coverage rate of evaluation measures in identified studies (frameworks)

Almost in all identified studies evaluation measures related to the technology aspect were appropriately, moderately, or poorly covered. However, evaluation measures related to human and organization aspects were covered in 68%, 84% of the identified studies, respectively. About 53% of the identified studies covered evaluation measures related to three aspects. However, none of them covered evaluation measures of all three aspects appropriately. Evaluations measures related to dimensions of "characteristics of the organization and organizational factors," "Users' satisfaction," and "System quality" had the highest appropriately evaluation measure coverage rate (Table 5).

Three-level hierarchical structure contains 12 dimensions which cover three aspects including technology, human, and organization. Identified studies cover at least one and at most nine dimensions.

Two studies [19], [20], four studies [21], [22], [23], [24], and five studies [2], [25], [26], [27], [28] covered 9, 8, and 7 dimensions, respectively.

Nine studies [3], [4], [9], [20], [21], [29], [30], [31], [32] appropriately covered evaluation measures in the technology aspect. In human and organization aspects, the coverage rate of evaluation measures in six [23], [24], [33], [34], [35], [36] and four studies [9], [20], [37], [38] was better than other studies, respectively. Almost 40% of evaluations measures related to the human and organization aspects were covered by these studies. Table 6 [39], [40], [41], [42], [43], [44], [45], [46], [47], [48], [49], [50], [51], [52], [53], [54], [55], [56], [57], [58], [59], [60], [61], [62], [63], [64], [65], [66], [67], [68], [69], [70], [71], [72] shows the coverage of evaluation measures for identified studies. In this table dimensions related to technology, human, and organization aspects were reported as following abbreviation, T1-T3 and TT

for technology aspect, H1-H5 and TH for human aspect, and O1-O4 and TO for organization aspect. In this table, the coverage rate of evaluation measures was represented by color cells. The white, light gray, dark gray, and balk cells show no-coverage, low, moderate, and appropriate coverage, respectively.

Figure 3 shows the coverage rate of evaluation measures in three aspects of technology, human, and organization for the identified studies.

Table 3: The maximum coverage rate of the evaluation measures in evaluation dimensions and aspects

Evaluation aspects (The maximum coverage rate)	Evaluation dimensions (The maximum coverage rate)
Technology (4.62)	System quality (2.45)
	Information quality (1.44)
	Service quality (0.73)
Human (2.06)	Users' satisfaction (0.65)
	System use (0.68)
	Users characteristics and personality (0.31)
	Computer knowledge and self-efficacy (0.16)
	Positive or negative feeling about EHR (0.26)
Organization (1.61)	Characteristics of organization and organizational factors (0.98)
	Net benefit and EHR effects on workflow and organization (0.37)
	EHR effects on outcome quality of care (0.18)
	Environment (0.08)

HER: Electronic health records.

In Figure 3, the horizontal (X) axis shows the coverage rate of the technology aspect and the vertical (Y) axis shows the coverage rate of the organization aspect. Identified studies are plotted as circles of different color and white triangle. The color of each circle in XY coordinates represents the coverage rate of the corresponding identified studies in the human aspect. The white, gray, and balk circles show low, moderate, and appropriate coverage, respectively. White triangle represents no-coverage. The number of each circle was assigned based on the number list of identified studies in Table 6.

There are two thresholds of 25% and 50% on both the horizontal and vertical axes. These thresholds determine the coverage cutoff points of low, moderate, and appropriate coverage in each axis, which creates a total of nine zones (these zones are represented by Z followed by a number between 1 and 9). The minimum and maximum values on the technology (horizontal) axis are zero and 60%, respectively. There is a rising trend of coverage rate in the technology aspect from left to right. Based on the represented coverage rates in Figure 1, it is expected to observe low coverage in

Table 4: The relative frequency of evaluation measures and dimensions

Evaluation aspects	Evaluation dimensions (relative frequency %)	Evaluation measures (relative frequency %)
Technology	System quality (91.9)	Ease of Use (0.61), usefulness (0.52), usability (0.21), reliability (0.21), response time (0.13), accessibility (0.10), sufficient resources (0.19), privacy and security (0.11), availability (0.08), system function (0.06), system interoperability and integration (0.15), complexity (0.03), flexibility (0.02), mobility (0.02), confusion (0.02)
	Information quality (41.9)	Accuracy (0.21), Completeness (0.18), Timeliness (0.13), Format (0.13), Sufficiently (0.11), ease of use (0.10), availability (0.06), up-to-date (0.06), accessibility (0.05), legibility (0.05), reliability (0.05), relevance (0.05), consistency (0.03), compatibility (0.05), clear (0.03), currency (0.03), content (0.02), secure and confidential (0.02), right data (0.02), right level of detail (0.02), Locatability (0.02), meaning (0.02), authorization (0.02)
	Service quality (53.2)	Training (0.16), responsiveness (0.10), assurance (0.13), empathy (0.08), it staffs availability and providing it support (0.10), pay attention to user needs (0.05), system guideline or users' manual (0.03), production timeliness (0.02), assistance (0.02), follow-up service (0.02), reliability (0.02), is performance (0.02)
Human	Users' Satisfaction (56.5)	Satisfaction (0.29), attitude toward system (0.18), system acceptance (0.11), users' expectations (0.05), personality traits (0.02)
	System use (48.4)	(Behavioral) Intention of use (0.34), system use (0.19), frequency of use (0.05), intensity of use (0.02), level of use (0.02), reason to use (0.02), observability (0.02), information about change (0.02), trialability (0.02)
	Computer knowledge and Self-efficacy (14.5)	Computer knowledge and skills (0.18), self-efficacy (0.13)
	Users characteristics and personality (27.4)	General characteristics (0.13), personal identity (0.02), innovativeness (0.02)
	Positive or negative feeling about EHR (19.4)	Concerns for EHR (0.10), perceived threat (0.03), perceived risk (0.02), instructional trust (0.02), optimism (0.02), discomfort (0.02), anxiety (0.02), insecurity (0.02), inequity (0.02), resistance to change (0.02)
Organization	Characteristics of organization and Organizational factors (53.2)	Social context (0.21), compatibility and fitness with the work process (0.18), management support (0.08), physician involvement (0.03), organization characteristics (0.05), physician autonomy (0.03), communication (0.03), organization structure (0.03), coherence (0.02), cognitive participation (0.02), collective action (0.02), reflexive monitoring (0.02), monitoring and feedback (0.02), leadership (0.02), physical proximity (0.02), competition (0.02), employee understanding and support of implementation (0.03), organizational support for implementation (0.02), innovative culture in hospital (0.02), open culture in hospital (0.02), situational normality (0.02), strategy (0.02), supporting best practices (0.02), supportive norms (0.02), task equivocality (0.02), task interdependence (0.02), caseload (0.02), voluntary turnover (0.02)
	Effects on workflow and organization (37.1)	Equal to dimension
	Effects on outcome quality of care (17.7)	Equal to dimension
	Environment (8.1)	Equal to dimension

HER: Electronic health records.

Table 5: The coverage rate in EHR evaluation dimensions

Aspects	Dimensions	Coverage (n= 62)			
		No-coverage	Low	Moderate	Appropriate
		n (%)	n (%)	n (%)	n (%)
Technology	System quality	5 (8.1)	10 (16.1)	28 (45.2)	19 (30.6)
	Information quality	36 (58.1)	9 (14.5)	10 (16.1)	7 (11.3)
	Service quality	29 (46.8)	12 (19.4)	8 (12.9)	13 (21)
Human	Users' satisfaction	27 (43.5)	16 (25.8)	16 (25.8)	3 (4.8)
	System use	32 (51.6)	3 (4.8)	6 (9.7)	21 (33.9)
	Users characteristics and personality	53 (85.5)	1 (1.6)	0 (0)	8 (12.9)
	Computer knowledge and self-efficacy	45 (72.6)	0 (0)	6 (9.7)	11 (17.7)
	Positive or negative feeling about EHR	50 (80.7)	6 (9.7)	6 (9.7)	0 (0)
Organization	Characteristics of organization and organizational factors	29 (46.8)	28 (45.2)	5 (8.1)	0 (0)
	Net benefit and EHR effects on workflow and organization	39 (62.9)	0 (0)	0 (0)	23 (37.1)
	EHR effects on outcome quality of care	51 (82.3)	0 (0)	0 (0)	11 (17.17)
	Environment	57 (91.9)	0 (0)	0 (0)	5 (8.1)

HER: Electronic health records.

Table 6: The coverage rate of evaluation measures in dimensions and aspects for the identified studies

Row	Author(s)	Technology				Human						Organization				
		T.1	T.2	T.3	TT	H.1	H.2	H.3	H.4	H.5	TH	O.1	O.2	O.3	O.4	TO
1	Otieno *et al*. [39]															
2	Otieno *et al*. [30]															
3	Yusof *et al*. [21] (HOT-fit)															
4	Hyun *et al*. [40]															
5	Oroviogoicoechea and Watson [19]															
6	Hennington *et al*. [41]															
7	Sicotte *et al*. [29]															
8	Devine *et al*. [42]															
9	Chisolm *et al*. [43]															
10	Morton *et al*. [44]															
11	Sockolow *et al*. [25]															
12	Hsiao *et al*. [32]															
13	Carayon *et al*. [45]															
14	Holtz and Krein [46]															
15	Aggelidis *et al*. [47]															
16	Schnall *et al*. [48]															
17	Sockolow *et al*. [26]															
18	Chen and Hsiao [5]															
19	Chen and Hsiao [4]															
20	Leblanc *et al*. [35]															
21	Takian *et al*. [37]															
22	Lu *et al*. [3]															
23	Sockolow *et al*. [2]															
24	Lin *et al*. [49]															
25	Dale *et al*. [50]															
26	Bouamrane and Mair [51]															
27	Messeri *et al*. [52]															
28	Hsu *et al*. [53]															
29	Michel-Verkerke *et al*. [54]															
30	Mei *et al*. [55]															
31	Gardner and Pearce [56]															
32	Gagnon *et al*. [27]															
33	Gu and Day [57]															
34	Garcia-Smith and Effken [9]															
35	Kuo *et al*. [58]															
36	Tavakoli *et al*. [59]															
37	Kirkendall *et al*. [60]															
38	Iqbal *et al*. [61]															
39	Bossen *et al*. [62]															
40	Ho *et al*. [63]															
41	Kowitlawakul *et al*. [36]															
42	O'Mahony *et al*. [31]															
43	Hysong *et al*. [64]															
44	Schwarz, and Schwarz [65]															
45	Hsieh (2014)															
46	Abdekhoda *et al*. [12]															
47	Alharthi *et al*.															
48	Tilahun *et al*. [22]															
49	Liu *et al*. [66]															
50	Kralj *et al*. [67]															
51	Wang *et al*. [68]															
52	Steininger *et al*. [23]															
53	Sintonen *et al*. [69]															
54	Gan *et al*. [70]															
55	Michel-Verkerke *et al*. [40]															
56	Erlirianto *et al*. [20]															
57	Salleh *et al*. [71]															
58	Gilani *et al*. [33]															
59	Kim *et al*. [72]															
60	Lambooij *et al*. [38]															
61	Bush *et al*. [28]															
62	Nematollahi *et al*. [34]															

In this table dimensions related to technology, human, and organization aspects were reported as following abbreviation, T1-T3 and TT for technology aspect, H1-H5 and TH for human aspect, and O1-O4 and TO for organization aspect. In this table, the coverage rate of evaluation measures was represented by color cells. The white, light gray, dark gray, and balk cells show no-coverage, low, moderate, and appropriate coverage, respectively.

Z1/Z4 and Z7, moderate coverage in Z2/Z5 and Z8, and appropriate coverage in Z3/Z6 and Z9. The circles on the technology (horizontal) axis also represent the non-coverage of a study in the organization aspect.

The minimum and maximum value of the organization (vertical) dimension was zero and 47%, respectively. There is a rising trend in the coverage rate from bottom to top in the organization dimension. It is expected to observe low coverage in Z7/Z8 and Z9, moderate coverage in Z4/Z5 and Z6, and appropriate coverage in Z1/Z2 and Z3. The circles on the organization (vertical) axis also represent the non-coverage of a study in the technology aspect.

Z3 shows appropriate coverage rate of identified studies based on the two aspects of technology and organization. If the objective of a particular research is to explore the appropriate identified studies in the technology and organization aspects, Z3 is deemed to find the most suitable studies. The identified studies had a low coverage rate in the organization and technology aspects, and a moderate coverage rate in Z7 and Z5, respectively.

The coverage rate of evaluation measures for different studies is a combination of low, moderate, and appropriate coverage in both technology and organization aspects in Z1, Z2, Z4, Z6, and Z8. Z4, for example, shows studies with low and moderate coverage in the technology and organization aspects, respectively. Z8, on the other hand, illustrates studies with moderate and low coverage in the technology and organization aspects, respectively.

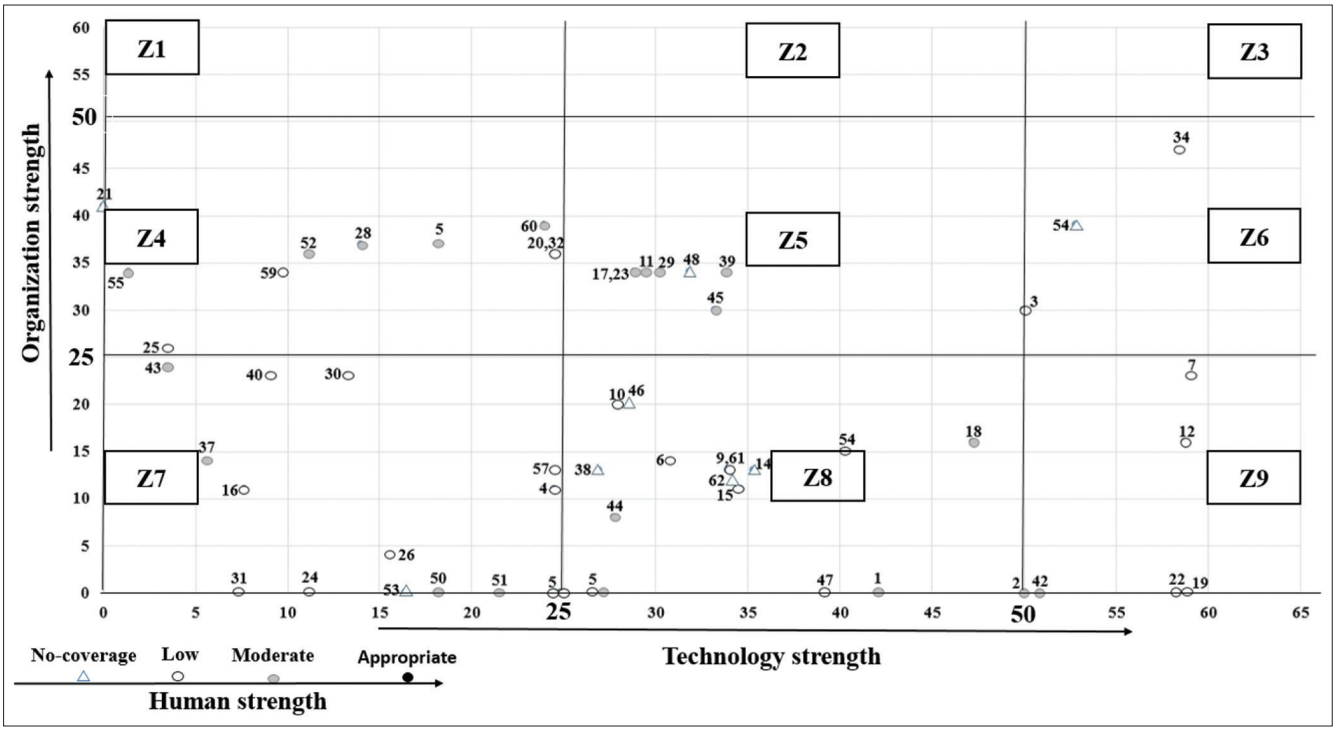

Figure 3: The coverage rate of evaluation measures based on the technology and organization aspects in identified studies

In Figure 4, the horizontal (X) axis shows the coverage rate of the technology aspect and the vertical (Y) axis shows the coverage rate of the human aspect. The color of circles represents the coverage rate of the organization aspect. In Figure 5, the horizontal (X) axis shows the coverage rate of the human aspect and the vertical (Y) axis shows the coverage rate of the organization aspect. The color of circles represents the coverage rate of the technology aspect. The cutoff thresholds depicted in Figures 4 and 5 can be described as the ones in Figure 3. In Figure 4, for example, Z1, Z2, and Z3 show the most appropriate identified studies in the organization aspect. Z7, in Figure 5, includes those studies which possess low coverage rates in both human and organization aspects.

The study by Oroviogoicoechea and Watson [19] is one of the identified studies. The coverage rate of evaluation measures aspects of technology, human, and organization was 18.2% 38%, and 37%, respectively. As shown in Figure 6, this study located in Z4. Hence, the study covered technology and organization aspects poorly and moderately. Gray circle represents moderately the coverage rate of the human aspect.

Discussion

There is no study for determining coverage rate of evaluation measures in the EHR evaluation frameworks presented in the current body of literature. In this study, a comprehensive literature review was performed to identify current EHR evaluation frameworks and extract evaluation measures. Based on our review and frequency analysis of evaluation measures, a model for determining the coverage rate of evaluation measures in EHR evaluation frameworks was suggested. The most significant findings of the present study are discussed in the following paragraphs.

The findings of the study revealed that 53% (n = 33) of studies covered all three evaluation aspects. The rest of the studies only included one or two aspects. Moreover, the findings of our study demonstrate that the coverage rate of evaluation measures differed with respect to various studies. Although some studies covered one aspect or dimension perfectly, they might not cover other aspects or dimensions. In the best case, 67% (n = 8) to 75% (n = 9) of dimensions are covered by a single study. None of the studies covered all evaluation dimensions in all three aspects of technology, human, and organization. Shaw [73] also observes this finding and points out that there is no comprehensive evaluation framework which covers all evaluation dimensions. For example, the framework presented by Otieno *et al*. includes evaluation measures of technology and human aspects, but does not cover evaluation measures of the organization aspect [30]. Likewise, in the studies by Garcia-Smith and Effken [9], Lambooij *et al*. [38], and Takian *et al*. [37], evaluation measures of the organization aspect were moderately covered, but evaluation measures related to the human aspect were very weak.

Yosef *et al*. highlight the fact that evaluation measures are not complete by themselves, and rather,

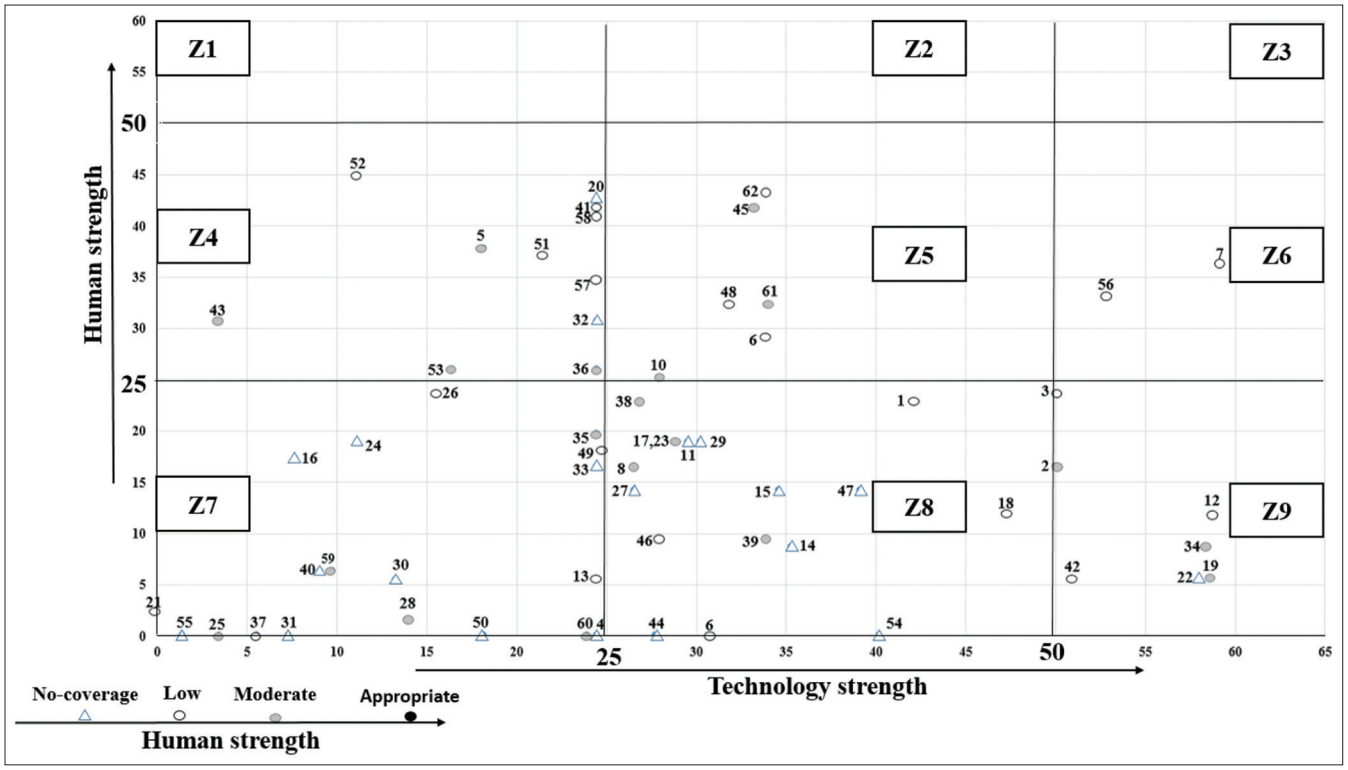

Figure 4: The coverage rate of evaluation measures based on the technology and human aspects in identified studies

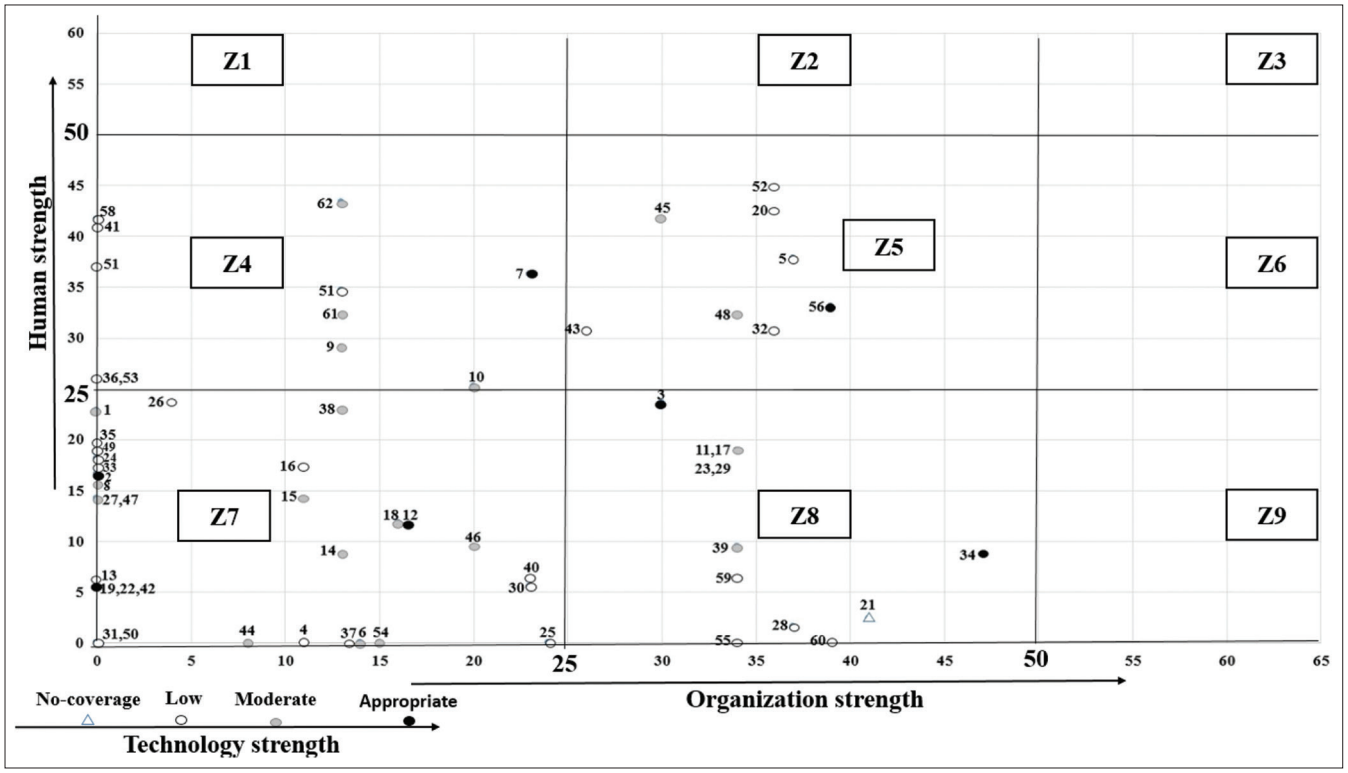

Figure 5: The coverage rate of evaluation measures based on the organization and human aspects in identified studies

they complement each other [14] .The findings of the present study also confirm this fact. Evaluation frameworks can potentially cover the shortcomings of other frameworks. This underscores the importance of a model for determining the coverage rate of evaluation measures in the EHR evaluation frameworks. Results of the present study enable users to observe the coverage rate of different evaluation measures in identified frameworks in the three aspects of technology, human, and organization. The users can understand the strengths and limitations of EHR evaluation frameworks. Furthermore, they can explore the focuses

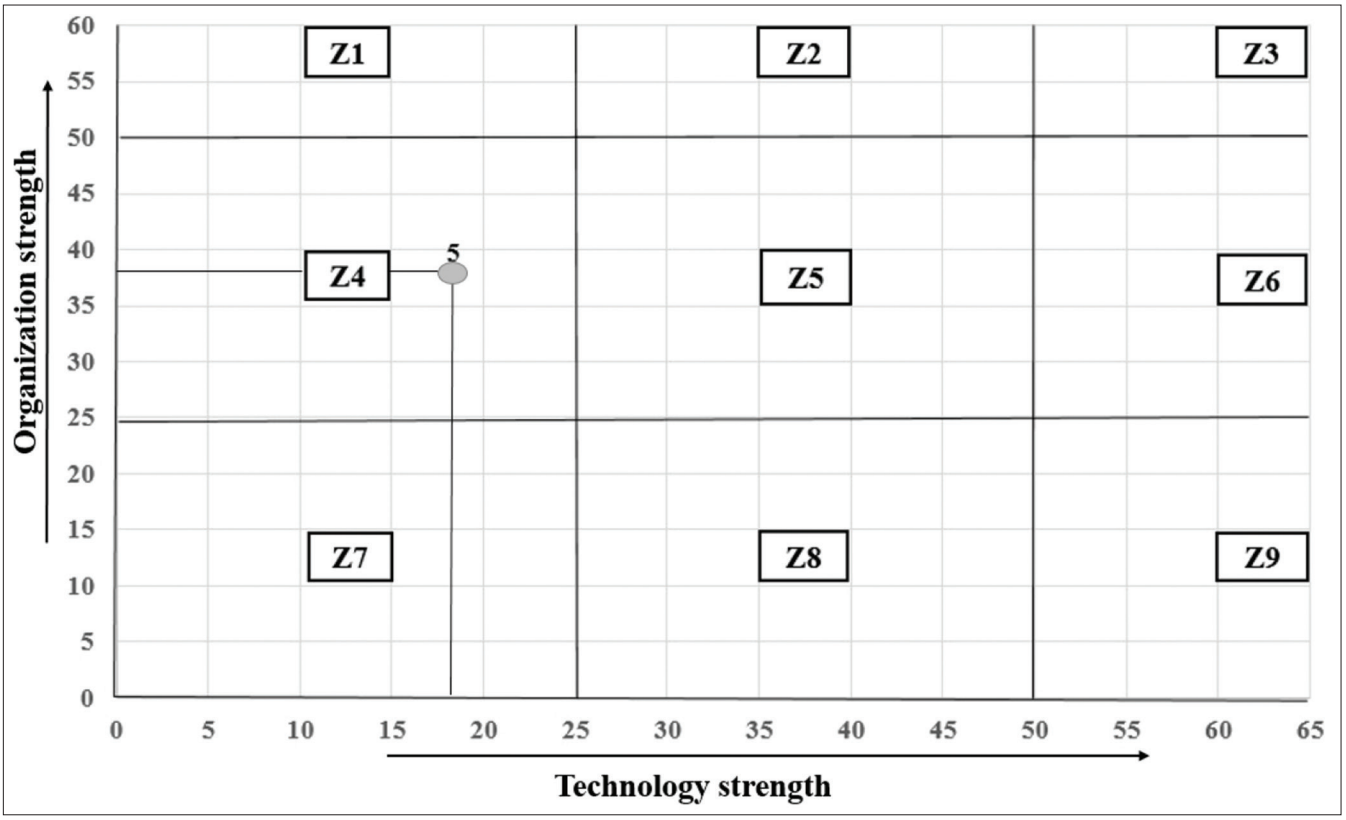

Figure 6: The coverage rate of evaluation measures aspects of technology, organization, and human in the study by Oroviogoicoechea and Watson

of identified frameworks. For example, we elaborate on three frameworks with different characteristics in terms of coverage rate in the three aspects above.

Hsiao *et al*.'s framework [32] appropriately covers the technology aspect and weakly covers the dimensions of organization and human aspects. CISSM [9] like Hsiao *et al*.'s framework appropriately covers the technology aspect. In addition, this framework moderately covers organization. Unlike CISSM, Steiniger *et al*.'s framework [23] covers the human aspect moderately, but weakly covers the evaluation measures of the technology aspect. Therefore, the users can compare the coverage rate of evaluation measures in the EHR evaluation frameworks and choose the most suitable framework based on the focus of their study.

As well, our results show that the coverage rate of evaluation measures differs in various dimensions of the three aspects. Hsiao *et al*.'s framework [32] appropriately covers the three dimensions of technology aspect. In the technology aspect, CISSM [9] mostly focuses on the system quality dimension and moderately covers the two dimensions of service quality and information quality. CISSM and Takian *et al*.'s framework [37] both moderately covers the evaluation measures in the organization aspect. However, CISSM focuses on dimensions of "characteristics of the organization and organizational factors" and "effects on workflow and organization" and does not cover the two dimensions of "effects on outcome quality of care" and environment. Takian *et al*.'s framework puts its emphasis on the dimension of "effects on workflow and organization," "effects on outcome quality of care", and "environment."

In most of the identified studies, researchers developed an EHR evaluation framework. This is mostly due to the gaps and shortcomings of the current framework for the context of use or purpose, which has led to an original framework. For example, ISSM does not cover organizational factors. Therefore, Yusof *et al*. developed the HOT-fit framework based on the ISSM and the IT-Organization fit frameworks and added those dimensions to the ISSM. Similarly, Garcia *et al*. realized that satisfaction indicators in the ISSM did not show why users were satisfied or dissatisfied with an information system and, thus, could not measure the success of an information system. They used the TAM2 and UTAUT, which included user satisfaction factors for the CISSM development [9]. Furthermore, Chen *et al*. found out one limitation of the TAM to be the lack of influence of external variables and barriers to technology acceptance. They proposed a modified TAM derived from TAM and HOT-fit to explore factors affecting physicians' acceptance of a HIS [5].

Most of the original EHR evaluation frameworks were using a common basis. The UTAUT, TAM, TIB,

and theory of planned behavior (TPB) are based on user-acceptance theory. The ISSM was also used in approximately twenty percent of the identified articles. For example, hybrid evaluation frameworks from ISSM and TAM were used in some studies [3], [5], [29], [42]. Kim *et al*. [72] and Iqbal *et al*. [61] developed original frameworks with UTAUT and TAM. Hybrid evaluation frameworks based on ISSM were used in a number of studies [9], [21], [22], [29], [30], [39], [47], [52], [62], [71], [74]. TAM with others framework was implemented in some studies [5], [27], [40], [44], [49], [58], [66], [69]. In a number of studies frameworks based on UTAUT were used [28], [31], [43], [61], [72].

We found out that the primary purpose of several frameworks was not EHR evaluation. Rather, the authors made several modifications and enhancements to turn them into a usable EHR evaluation framework. For example, the TPB was suggested in 1991 by Ajzen and Icek. TPB provided an effective conceptual framework for dealing with the complexities of human social behavior [75]. Hsieh modified TPB to account for the evaluation of physicians' acceptance of electronic medical records exchange [24]. Demerouti *et al*. developed the Job Demands Resource Model (JDRM) in 2001. JDRM proved that job demands require sustained physical or mental effort. Hysong *et al*. combined JDRM and UTAUT for the user acceptance assessment [64]. Burt provided social contagion theory (SCT) in 1987. SCT describes how ideas or opinions spread in a social network [76], [77]. Gan *et al*. created a hybrid framework with SCT and TTF for evaluation of EHR adoption [70].

One of the limitations of this study was that it was based only on articles written in English. Thus, it may not have covered those frameworks that might have been published in non-English-language studies. In addition, in the current study, dimensions of EHR evaluation frameworks were not reported and classified. This can be conducted in future studies.

In future studied an expert team can review identified evaluation measures in the technology, human, and organization aspects and provide a comprehensive EHR evaluation framework.

Conclusion

In this study, we systematically reviewed all literature presenting any type of EHR evaluation framework and analyzed and discussed their aspects and features. We believe that the findings of this study can help researchers to review and adopt the EHR evaluation frameworks for their own particular field of usage.

Acknowledgment

The current study was a part of the doctorate thesis (research plan code: 951350) and supported by Mashhad University of Medical Sciences.

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Appendix 1: Literature review search strategies to identify studies from electronic databases

Search strategy of PubMed

((((Hospital Information Systems [MAJR] OR "Hospital Information System*" [TIAB] OR Electronic Health Records [MAJR] OR "Electronic Health Record*" [TIAB] OR Medical Records Systems, Computerized [MAJR] OR "Computerized Medical Records System*" [TIAB] OR "Electronic Medical Record*" [TIAB] OR "Electronic Patient Record*" [TIAB]) AND (Evaluation framework [TIAB] OR measurement practice [TIAB] OR evaluation model [TIAB] OR evaluation research [TIAB] OR evaluation studies [TIAB] OR program evaluation [TIAB] OR program methods [TIAB] OR assessment [TIAB] OR accreditation [TIAB] OR certification [TIAB] OR license [TIAB] OR cognitive evaluation [TIAB] OR usability testing [TIAB] OR systems analysis [TIAB] OR software evaluation [TIAB] OR qualitative study [TIAB] OR qualitative evaluation [TIAB] OR focus groups [TIAB] OR questionnaires [TIAB] OR questionnaires [TIAB] OR interviews [TIAB] OR taxonomy [TIAB] OR classification [TIAB] OR balanced scorecard health care outcome [TIAB] OR health care process assessment [TIAB] OR cost-benefit analysis [TIAB] OR health services research))) AND ("last 10 years"[PDat] AND Humans [Mesh] AND English[lang])

Search strategy of ScienceDirect

TITLE-ABSTR-KEY (Electronic Health Records OR Electronic Medical Record OR Hospital information systems OR Electronic Patient Records) and TITLE-ABSTR-KEY (Evaluation framework OR measurement practice OR evaluation model OR evaluation research OR evaluation studies OR program evaluation OR program methods OR assessment OR accreditation OR measure OR certification OR license OR cognitive evaluation OR systems analysis OR software evaluation OR qualitative study OR qualitative evaluation OR focus groups OR questionnaires OR questionnaires OR interviews OR taxonomy OR classification OR balanced scorecard health care outcome OR health care process assessment) (All Sources[Computer Science, Medicine, and Dentistry]).

Search strategy of Cochran

1# (Electronic patient record OR Electronic Health Record OR Hospital Information System OR Electronic medical Record):ti,ab

2# Assess OR Evaluation OR Measure OR accredit OR license OR certify

3# #1 and #2

Search strategy of Scopus

Title, abstract, keywords: ([Hospital Information Systems OR Electronic Health Record OR Electronic Patient Record OR Electronic Medical Record] AND [Evaluation framework OR measurement practice OR evaluation model OR evaluation research OR evaluation studies OR program evaluation OR program methods OR assessment OR accreditation OR measure OR certification OR license OR cognitive evaluation OR systems analysis OR software evaluation OR qualitative study OR qualitative evaluation OR focus groups OR questionnaires OR questionnaires OR interviews OR taxonomy OR classification OR balanced scorecard health care outcome OR health care process assessment])

Appendix 2: The relative frequency of evaluation measures in technology aspect

System quality	References	Information quality	References	Service quality	References
Ease of Use (0.61),	[3], [4], [5], [12], [24], [27], [28], [31], [32], [33], [34], [36], [38], [40], [41], [43], [46], [52], [54], [57], [58], [59], [61], [66], [70], [72]	Accuracy (0.21)	[3], [4], [5], [9], [20], [22], [25], [31], [39], [47], [60], [70], [74]	Training (0.16)	[9], [12], [41], [44], [46], [47], [48], [64], [70], [74]
Usefulness (0.52)	[3], [4], [5], [9], [20], [24], [27], [28], [29], [31], [32], [33], [34], [35], [36], [38], [39], [40], [41], [43], [43], [43], [44], [45], [46], [47], [52], [53], [54], [55], [57], [58], [59], [61], [62], [66], [70], [71], [72], [74]	Completeness (0.18)	[2], [3], [5], [9], [19], [20], [22], [26], [29], [31], [74]	Responsiveness (0.10)	[4], [19], [22], [29], [52], [70]
Usability (0.21)	[2], [19], [20], [25], [26], [29], [31], [47], [54], [56], [67]	Timeliness (0.13)	[3], [4], [5], [20], [31], [38], [39], [47]	Assurance (0.13)	[4], [19], [20], [22], [29], [41], [52], [63]
Reliability (0.21)	[2], [4], [5], [9], [25], [26], [29], [39], [52], [54], [67], [69], [70]	Format (0.13)	[4], [5], [9], [22], [29], [39], [47], [74]	Empathy (0.08)	[4], [9], [19], [20], [70]
Response time (0.13)	[20], [22], [29], [47], [56], [62], [63], [74]	Sufficiently (0.11)	[4], [9], [22], [39], [52], [62], [70]	IT staffs availability and providing IT support (0.10)	[24], [28], [29], [34], [43], [74]
Accessibility (0.10)	[4], [9], [29], [50], [63], [67]	Ease of use (0.10)	[2], [4], [25], [26], [62], [70]	Pay attention to user needs (0.05)	[9], [19], [29]
Sufficient resources (0.19)	[2], [9], [22], [24], [25], [26], [28], [34], [43], [46], [48], [71]	Availability (0.06)	[20], [29], [52], [74]	System guideline or users' manual (0.03)	[22], [62]
Privacy and security (0.11)	[5], [20], [24], [61], [67], [71], [74]	Up-to-date (0.06)	[4], [39], [62], [74]	Production timeliness (0.02)	[70]
Availability (0.08)	[2], [25], [26], [39], [65]	Accessibility (0.05)	[19], [22], [70], [77]	Assistance (0.02)	[70]
System function (0.06)	[50], [63], [67], [68]	Legibility (0.05)	[3], [31], [60]	Follow-up service (0.02)	[32]
System interoperability and integration (0.15)	[4], [9], [28], [29], [34], [43], [46], [67], [71]	Reliability (0.05)	[3], [19], [29]	Reliability (0.02)	[4]
Complexity (0.03)	[53], [69]	Relevance (0.05)	[3], [31], [74]	IS performance (0.02)	[70]
Flexibility (0.02)	[4]	Consistency (0.03)	[3], [31]		
Mobility (0.02)	[66]	Compatibility (0.05)	[5], [20], [70]		
Confusion (0.02)	[70]	Clear (0.03)	[4], [39]		
		Currency (0.03)	[5], [70]		
		Content (0.02)	[47]		
		Secure and confidential (0.02)	[29]		
		Right data (0.02)	[70]		
		Right level of detail (0.02)	[70]		
		Locatability (0.02)	[70]		
		Meaning (0.02)	[70]		
		Authorization (0.02)	[70]		

RF: Relative frequency.

Appendix 3: The relative frequency of evaluation measures in human aspect

Users' Satisfaction	RF (%)*	References	Users characteristics and personality	RF (%)*	References
Satisfaction	0.29	[2], [19], [20], [21], [22], [25], [26], [29], [30], [33], [39], [43], [47], [51], [52], [54], [59], [64]	General characteristics	0.13	[3], [19], [23], [35], [39], [68], [71]
Attitude toward system	0.18	[19], [23], [24], [28], [33], [34], [35], [36], [44], [48], [72]	Personal identity	0.02	[27]
System acceptance	0.11	[3], [4], [5], [31], [32], [45], [55]	Innovativeness	0.02	[58]
Users expectations	0.05	[29], [33], [37]	Maximum Coverage	0.16	
Personality traits	0.02	[35]	Positive or negative feeling about EHR		
Maximum coverage	0.65		Concerns for EHR	0.10	[2], [23], [25], [26], [54], [68]
System use	RF (%)*	References	Perceived threat	0.03	[49], [66]
(Behavioral) Intention of use	0.34	[23], [24], [27], [28], [29], [33], [34], [35], [36], [42], [49], [53], [57], [58], [59], [61], [64], [66], [68], [69], [72]	Perceived risk	0.02	[24]
System use	0.19	[12], [20], [21], [22], [34], [35], [36], [51], [59], [62], [69], [72]	Instructional trust (n=1)	0.02	[24]
Frequency of use	0.05	[29], [30], [39]	Optimism	0.02	[58]
Intensity of use	0.02	[29]	Discomfort	0.02	[58]
Level of use	0.02	[20]	Anxiety	0.02	[28]
Reason to use	0.02	[68]	Insecurity	0.02	[58]
Observability	0.02	[53]	Inequity	0.02	[49]
Information about change	0.02	[27]	Resistance to change	0.02	[27]
Trialability	0.02	[53]			
Computer knowledge and Self-efficacy	RF (%)*	References			
Computer knowledge and skills	0.18	[9], [19], [20], [22], [23], [24], [34], [43], [46], [48], [68]			
Self-efficacy	0.13	[5], [24], [27], [28], [32], [36], [43], [61]			

RF: Relative frequency.

Appendix 4: The relative frequency of evaluation measures in organization aspect

Characteristics of organization and Organizational factors	RF (%)*	References	Effects on workflow and organization	RF (%)*	References	Effects on outcome quality of care RF (%)*	References
Social context	0.21	[9], [23], [24], [27], [28], [34], [35], [41], [43], [46], [61], [70], [72]	Team communication	0.08	[2], [19], [25], [26], [50]	Patient safety	0.08	[2], [25], [26], [37], [60]
Compatibility and fitness with the work process	0.18	[5], [9], [24], [32], [38], [40], [47], [48], [53], [54], [71]	Unintended consequences, barriers	0.08	[2], [25], [26], [35], [37]	Doctor–patient relationship	0.04	[2], [25], [26]
Management support	0.08	[5], [12], [20], [32], [44]	Appropriate patient care orders	0.04	[2], [26], [47]	Costs	0.04	[12], [44], [60]
Physician involvement	0.03	[12], [44]	Department involvement	0.04	[2], [26], [47]	Patient knowledge	0.04	[2], [25], [26]
Organization characteristics	0.05	[19], [53], [65]	Users' productivity\provider performance	0.03	[29], [71]	Patient outcomes	0.04	[2], [25], [26]
Physician autonomy	0.03	[12], [44]	Research and hospital image	0.03	[19], [77]	Impact on patient care	0.02	[19], [37]
Communication	0.03	[20], [38]	Individual impact	0.03	[51], [52]	Self-management	0.01	[77]
Organization Structure	0.03	[20], [21]	Clinician involvement	0.03	[2], [26]	Communication	0.01	[77]
Coherence	0.02	[51]	Product effectiveness	0.03	[20], [63]	Privacy	0.01	[77]
Cognitive participation	0.02	[51]	Demonstrability of results	0.01	[27]	Maximum coverage	0.37	
Collective action	0.02	[51]	Efficiency	0.01	[20]	Environment	0.08	[20], [21], [24], [37], [65]
Reflexive monitoring	0.02	[51]	Relative advantage	0.01	[53]			
Monitoring and feedback	0.02	[64]	Provider perceptions of value	0.01	[64]			
Leadership	0.02	[38]	Global outcome	0.01	[19]			
Physical proximity	0.02	[70]	Hospital profile	0.01	[19]			
Competition	0.02	[20]	Stakeholder benefit	0.01	[23]			
Employee understanding and support of implementation	0.03	[37], [60]	Inter-hospital access	0.01	[29]			
Organizational support for implementation	0.02	[60]	Documentation quality standards	0.01	[9]			
Innovative culture in hospital	0.02	[38]	Quality of patient data in EMR	0.01	[38]			
Open culture in hospital	0.02	[38]	Inter-hospital access	0.01	[29]			
Situational normality	0.02	[24]						
Strategy	0.02	[20]						
Supporting best practices	0.02	[50]						
Supportive norms	0.02	[64]						
Task equivocality	0.02	[70]						
Task interdependence	0.02	[41]						
Caseload	0.02	[70]						
Voluntary turnover	0.02	[64]						

RF: Relative frequency.