Enhancing patient understanding of laboratory test results: a systematic review of presentation formats and their impact on perception, decision, action, and memory

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Submitted to: Journal of Medical Internet Research
on: October 26, 2023

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Abstract

Background: Direct access of patients to their electronic health records, including laboratory test results, has become increasingly common. Laboratory results can be challenging to interpret by patients, which may lead to anxiety, confusion, and unnecessary doctor consultations. Laboratory results can be presented in different formats, but there is limited evidence about the effect of presentation formats on patient outcomes.

Objective: To synthesize the evidence on effective formats for presenting laboratory test results with a focus on patient outcomes, including affective perception, perceived magnitude, cognitive perception, perception of communication, decision, action, and memory.

Methods: The search was conducted in three databases (PubMed, Web of Science, and EMBASE), until May 31st, 2023. We included quantitative, qualitative, and mixed methods articles describing or comparing formats for presenting diagnostic laboratory test results to patients. Two reviewers independently extracted and synthesized characteristics of the articles and presentation formats used. Quality of the included articles was assessed by two independent reviewers by using the Mixed Methods Appraisal Tool.

Results: Eighteen studies were included, which were heterogeneous in terms of study design and primary outcomes used. Quality of the articles ranged from poor to excellent. Most studies (n = 16/18) used mock test results. The most frequently used presentation formats were numerical values with reference ranges (n = 12/18), horizontal line bars with colored blocks (n = 12/18), or a combination of horizontal line bars with numerical values (n = 8/18). All studies examined perception as a patient outcome, while action and memory were studied in one and three articles, respectively. In general, participants' satisfaction and usability were highest when test results were presented using horizontal line bars with colored blocks. Adding reference ranges or personalized information (e.g. goal ranges) further increased participants' perception. Additionally, horizontal line bars significantly decreased participants' tendency to search for information or to contact their physician, compared to numerical values with reference ranges.

Conclusions: In this review, we synthesized available evidence on effective presentation formats for laboratory test results. The use of horizontal line bars with reference ranges or personalized goal ranges increased participants' cognitive perception and perception of communication, while decreasing participants' tendency to contact their physician. Action and memory were less frequently studied, so no conclusion could be drawn about a single preferred format regarding these outcomes. Further research should focus on real-life settings, diverse presentation formats and patient outcomes. Eventually, the overarching objective is to facilitate the development of tools to effectively communicate laboratory test results to patients in clinical practice.

(JMIR Preprints 26/10/2023:53993)
DOI: https://doi.org/10.2196/preprints.53993

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Abstract

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Keywords: electronic health record; patient access to records; patient portal; laboratory test results; clinical laboratory information systems; health communication; health informatics; patient engagement; patient involvement

Introduction

An increasing number of patients have direct access to their own electronic health record (EHR). This includes diagnostic test results ordered by their health care professional, such as laboratory test results [1, 2]. Providing patients online access to EHRs aims to increase patient involvement in their health management. Improving patients' knowledge and self-efficacy may enhance disease self-management, interactions with health care providers and ultimately lead to better health outcomes and increased satisfaction with care [3-6].

However, patient access to EHRs also has potentially negative consequences. For example, misinterpretation or inaccurate knowledge could lead to underestimation of test results and promote a false sense of security [7]. Similarly, gaining insight into medical test results might trigger feelings of insecurity, anxiety, and confusion [8-12]. Previous studies have shown that poor understanding of test results can lead to an increase in telephone calls or doctor consultations, emergency department visits, and even hospitalizations [13-15]. As a result, the overall utility or benefit of providing lab results directly to patients may depend how these data are presented to and interpreted by the patient [16, 17].

Basic EHRs typically present laboratory test results in a numerical format, often accompanied by a reference range (i.e. the range that represents normal values for a particular test) [10, 18, 19]. Additional information, such as textual explanations or visual cues, is usually not provided. Limited health literacy and numeracy skills are significant barriers to the effective use of EHRs and understanding of laboratory test results [20, 21]. Although patient understanding can be improved to some extent by avoiding medical jargon and using plain language, overcoming the problem of incomprehension in its entirety remains an ongoing challenge [21-23]. As noted above, one of the key issues is the numerical presentation of test results. Especially patients with low numeracy skills (i.e. those with limited ability to derive meaning from numbers) have been shown to have difficulties in interpreting basic laboratory test results and identifying results that fall outside the reference range [20]. The lack of supporting information and guidance on interpretation of results contributes to the problem of misinterpretation. This challenge becomes even more pronounced when a larger number of test results are presented [20]. An alternative approach to communicating test results is the use of visual displays, such as colors or graphics. These formats require less health literacy and numeracy skills for interpretation and may improve patients' understanding of the results [24-28]. Previous studies have examined a variety of presentation formats for communicating laboratory test results.

However, direct comparisons between these studies can be challenging due to the variety of presentation options and clinical contexts. In addition, not all formats may be appropriate for every clinical situation [29].

There is only limited evidence on the effect of specific presentation formats on patient outcomes. As highlighted by Witteman and Zikmund-Fisher, laboratory test results often lack meaning for the patients receiving them [17]. Test results represent data, which differs from information and actual knowledge patients commonly encounter in daily life [30, 31]. Patients have to complete several steps to go from data perception to usable knowledge. Ancker et al. described these steps as well, based on the Wickens model of human information processing [32, 33]. In a sequential order, patients need perception and behavioral intention to achieve actual health behavior. Therefore, it is important that these separate steps, or different patient outcomes, are taken into account when presentation formats are evaluated.

Our systematic review aims to synthesize the existing evidence on effective components of presentation formats for laboratory test results focusing on patients' perception, decision, action, and memory.

Methods

This review was reported in accordance with the Preferred Reporting Items for Systematic Reviews and Meta-Analyses (PRISMA) statement (Appendix 1) [34]. A protocol for this review was not previously registered.

Search strategy

The search was conducted in three databases (PubMed, Web of Science, and EMBASE) from inception up to May 31st, 2023. In each database a search was performed, which was developed by the first author (FM) together with an experienced librarian and contained both thesaurus and free text terms. For the search in EMBASE, a filter was applied to remove preprint records and to exclude MEDLINE citations, since the latter were already covered by the PubMed search. Additionally, two authors (FM and FS) performed backward snowballing by screening reference sections of all selected articles to identify relevant publications missed with the search strategy. A fully reproducible search can be found in Appendix 2.

Study selection and eligibility criteria

All identified titles and abstracts were downloaded to reference management software (Endnote) and duplicates were removed. Two authors (FM and FS) independently screened for potential eligible articles using Covidence, a Cochrane's technology platform [35]. First, titles and abstracts were screened against the eligibility criteria. Second, full texts of potentially suitable articles were rescreened using the same criteria. In case of disagreement, consensus was reached by discussion or screening by a third reviewer (JC).

We considered articles fitting for inclusion if they were original research. Studies describing or comparing different ways of presenting diagnostic laboratory test results to patients were included. Furthermore, studies needed to evaluate the effect of communicating test results on patients' comprehensibility, attitudes and/or experiences. Studies conducted in primary care and secondary/tertiary care settings were eligible, as well as studies including healthy volunteers. Studies had to be written in English or Dutch.

Studies were excluded if they:

1. Were protocols, reviews, systematic reviews, meta-analyses, book chapters, editorials, letters, practice pointers, oral presentations, or poster presentations.
2. Were about development, implementation, or adoption of electronic health records in general, or about the type of notification of laboratory test results, if they did not consider patients' interpretation of the lab results.
3. Focused on online access to notes, and not to laboratory test results.
4. Did not mention type of presentation format of lab results.
5. Focused on the development of web-based lifestyle interventions or online applications to collect patient-reported outcomes.
6. Focused on the safety or privacy issues of electronic health records.
7. Were about the effect of communicating test results in electronic health records on patients' medication management.
8. Tested the effect of test result communication on health care providers.
9. Examined communication of other types of diagnostic test results (e.g. (pharmaco)genomics, radiology, pathology, or microbiology).
10. Examined communication of test results in the context of screening programs.

Data extraction

Two authors (FM and FS) independently extracted data of the eligible studies into a prepared spreadsheet. The spreadsheet was developed by the multidisciplinary team and piloted by both authors. For each study, year of publication, country in which the study was performed, study design, number of participants, description of the study population, and the inclusion and exclusion criteria were assessed. Furthermore, information about the presentation of test results in the portal, type of laboratory test(s) studied, and whether real or mock data was used, was extracted.

Outcome measures

Previous research regarding this subject focused on a variety of patient outcomes. As stated above, Ancker et al. introduced a taxonomy to categorize different outcome measures when communicating numbers in healthcare [32]. These categories include sequentially; perception, decision/behavioral intention, action/actual health behavior, and memory. Perception is further divided into four subcategories: affective perception, perceived magnitude, cognitive perception, and perception of communication [32, 36, 37]. An explanation of the categorized patient outcome measures can be found in Textbox 1. For this review, outcome measures of each study were extracted and classified into the categories described.

Textbox 1. Explanation of the patient outcome measure categories based on Ancker et al.

- Affective perception: feelings about the laboratory result communicated.
- Perceived magnitude: perceived size of risk associated with a test result, captured with measures as “how large or small does this value seem to you?”
- Cognitive perception: understanding whether a laboratory result is elevated, normal, or below normal. Being able to identify direction of a trend over time.
- Perception of communication: preference for presentation format of test result.
- Decision: intention to seek more information or to change behavior after viewing results.
- Action: change in actual health behavior (e.g. search for more information).
- Memory: recall of a specific test result after viewing (i.e. verbatim recall).

Quality assessment

To assess quality and risk of bias of all included studies, the Mixed Methods Appraisal Tool (MMAT) was used [38]. The MMAT is designed to concomitantly appraise studies with different designs, such

as qualitative, quantitative and mixed methods studies [39]. Question sets are specific to the study design, notably qualitative studies, quantitative randomized controlled trials, quantitative non-randomized studies, quantitative descriptive studies, and mixed methods studies. For each suitable study, the appropriate category was chosen and criteria stated for this specific category were rated as 'yes', 'no', or 'can't tell'.

Two authors (FM and FS) discussed both data and quality extraction until consensus was reached.

Data synthesis

Due to the heterogeneity of study designs and primary outcomes, meta-analysis was considered inappropriate. Instead, narrative synthesis was used to integrate the findings into descriptive summaries regarding ways of presenting laboratory test results and outcomes of interest.

Results

The initial search identified 10,537 references. A total of 3,490 duplicate records were removed. After applying the exclusion criteria in the primary title and abstract screening, another 6,900 records were removed. During full-text screening of the remaining articles (n = 146), it appeared that one full-text was not available. Furthermore, 127 articles were excluded because they did not meet the eligibility criteria. Describing implementation of electronic health records, unrelated to laboratory test results, was the most common exclusion criterion (n = 55, 43.3%) (Figure 1). A total of eighteen studies were found eligible for this systematic review. Cohen's kappa for interrater reliability was 0.62 for title and abstract screening and 0.80 for full-text screening, indicating respectively a moderate and strong agreement between the two reviewers [40].

Study characteristics

Two qualitative studies, eleven quantitative studies, and five mixed methods studies were included (n = 18). The included studies were published between 2012 and 2021, and the majority were conducted in the United States of America (n = 13). The total sample size of the included studies was 12,252 participants, ranging from eight to 6,766 participants. Among the articles reporting the following characteristics, gender was almost equally distributed (52.6% female), and participants were predominantly middle aged (mean 51.1 years) and white (77.6% on average). Fourteen studies reported educational level, with 48.2% of the participants reporting a higher education (defined as

college-degree or higher). Overall characteristics of the included studies and populations are summarized in Table 1.

The most frequently used laboratory tests were lipid profile (*n* = 10) and HbA1c or glucose (*n* = 5). In total, three studies used real patients as study population, other studies used healthy volunteers, a convenience sample or a mixed sample (*n* = 12) or did not define their study population (*n* = 3). Studies used mock test results (i.e. hypothetical results) (*n* = 16), real results (*n* = 1, with real patients), or both (*n* = 1). The majority of studies used numerical values with reference ranges (*n* = 12) or horizontal line bars with colored blocks (*n* = 12) (Table 2). A more detailed overview of the different ways of presenting test results is provided in Appendix 3. An explanation of the different presentation formats can be found in Figure 2.

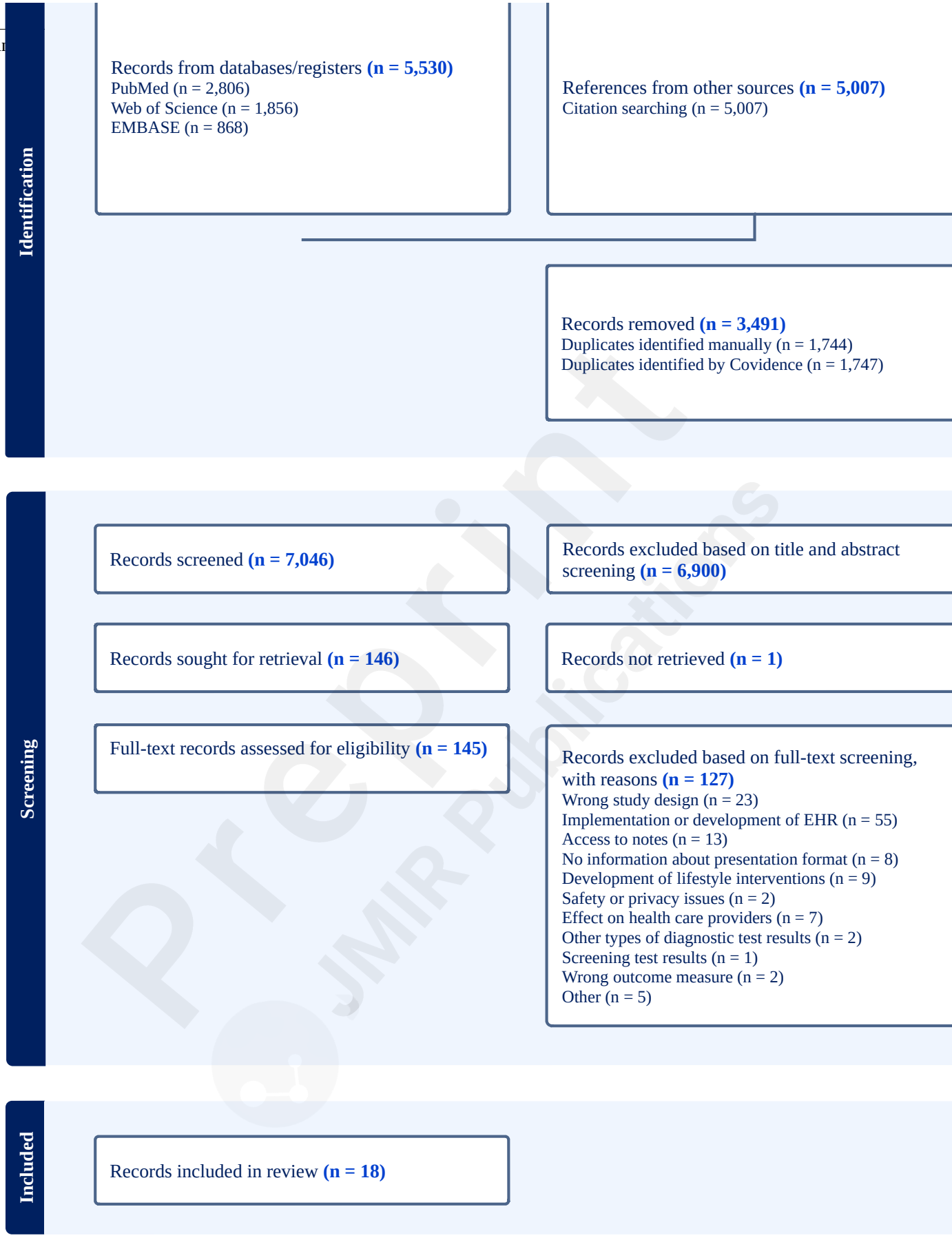

Figure 1. Flow chart of the study selection process.

Table 1. Study and population characteristics of all included studies (n = 18).

Table 1. (Continued).

Bar-Lev al. (2(									To examine
Fraccaro et al. (2018) [7]	United Kingdom	Non-randomized experimental study	20	Real patients	20	51.8 (10.3)		5 35 60 % other	To investig displays presentations personalized color in medical, patients' information interpretation laypersons' laboratory understanding results pre perceptions, through actions portals
Brewer al. (2(									To compare
Hohenstein et al. (2018) [41]	United States of America	Mixed methods study	328	Volunteers	51	46.0 (16.3, 18-90)	66.8% white, 19.6% Hispanic/ Latino/ Spanish, 12.3% black/ African American/ Negro, 4.0% Asian	0 38.2 48.2 13.6% unknown	To explore relative usabi people in medical test r tables, horizontal examined graphs, various in presenting n designs dev test to enable se electronically and consumers
Elder et al. (2012) [									To unde
Kelman et al. (2016) [48]	United States of America	Survey	211	Convenience sample	90	52.7 (10.0)	89% white, 4% African American, 6% other 0.5% preferred not to answer	0.5 57 41 1% unknown	To explore w which labo patients' experiences test results c and preferenc communicate results notif patient-friend and commun manner
Morrow et al. (2017)[b] [45]	United States of America	Mixed methods study	36		67	77 (65-89)			in primary A pilot stu settings finalize development video-enhanc messages conducting evaluation stu

Table 1. (Continued).

Morrow et al. (2019)[b] [42]	United States of America	Randomized controlled trial	144		71.5	71.9 (60-94)		18.8 13.2 68.0	To investigate to support adult comprehension and response patient po based nume information
Nystrom et al. (2018) [53]	United States of America	Mixed methods study	14	Real patients		43 (25-73)			To study pati ability to gen meaning from test result and this meaning w inform decision ma and subsec actions
Scherer et al. (2018) [43]	United States of America	Randomized controlled trial	6766	Mixed sample	50.9	49.1 (15.8)	78.2% white, 14.8% African America, 9.7% other	2.0 52.2 45.8	To test the im of inclu clinically appropriate ranges outside standard rang the visual disp of laboratory results
Struikman et al. (2020) [54]	The Netherlands	Randomized controlled trial	487	Volunteers	50.3	52.8 (15.4)		7.7 45.8 46.4	To disc whether the wa presenting b test outcomes electronic pa portal is assoc with patient h engagement whether this v across differen outcomes

Table 1. (Continued).

Talboom-Kamp et al. (2020) [44]	The Netherlands	Survey	354	Real patients					To investig attitudes, experien and self-efficacy patients using online patient po that communica laboratory test resu
Tao et al. (2018) [19]	China	Non-randomized experimental study	72	Convenience sample	58	Young adult group: 22.3 (2.6) Older adult group: 65.8 (3.6)		1.4 33.3 65.3	To examine effects of f graphical formats a age on consum comprehension, perceptions, vis attention, a preference of graphs of the use self-monitoring results
Zarcadoolas et al. (2013) [50]	United States of America	Qualitative study	28	Volunteers	64.3	40.0 (12.4, 21-63)	25.0% Hispanic, 3.6% non-Hispanic white, 67.9% non-Hispanic black, 3.6% other	46.4 53.6 0	To iden vulnerable consumers' respo to patient port their perceived uti and value, as well their reactions specific po functions
Zhang et al. (2020)[b] [15]	United States of America	Mixed methods study	203	Volunteers	48.3	63.5% 26-49	69.5% white, 4.4% Asian/ Pacific islander, 16.7% African American, 5.9% Hispanic/ Latino, 2.0% American Indian, 1.5% other	0 19.7 79.9 0.4% other	To examine challenges and ne of patients wh comprehending laboratory test resu

Table 1. (Continued).

Zhang et al. (2021)[b] [49]	United States of America	Mixed methods study	8		50	18-64			To examine to help pat understand connections between medical co and test res and the neces support actions receiving test results
Zikmund-Fisher et al. (2017)[c] [18]	United States of America	Survey	1620	Volunteers	52.3	48.9 (15.7)	77.4% white, 13.0% African American, 7.0% other	1.9 49.9 48.2	To investigate extent to w different v displays people discriminate between results that d do not re urgent action
Zikmund-Fisher et al. (2018)[c] [47]	United States of America	Randomized controlled trial	1618	Volunteers	52.1	48.8 (19-89)	77.8% white, 13.2% black, 13.2% Hispanic, 4.0% Asian, 0.8% native American 4.3% other/ multirace	0 0 50.1 49.9% unknown	To test the e of including additional anchor refer point in v displays laboratory results

[a]Low education: primary school. Middle education: secondary/ high/ trade school, some college. High education: 4 college/ associate/ university/ undergraduate/ Bachelor's/ Master's/ advanced/ professional/ doctorate degree.

[b]The following articles are pilot and main study: Morrow et al. 2017 and 2019, Zhang et al. 2020 and 2021.

[c]The following articles originate from the same parent study: Zikmund-Fisher et al. 2017 and 2018.

Table 2. Laboratory test characteristics and presentation format used in all included studies (n = 18).

Author (year)	Laboratory test information and presentation format						
	Laboratory test	Type of data	Presentation format				
			Numerical	Horizontal line bar	Graph	Video	Tex
Bar-Lev et al. (2020)	Hemoglobin, cholesterol, progesterone	Mock	x		x		
Brewer et al. (2012)	Total cholesterol, HDL, LDL	Mock	x	x			
Elder et al. (2012)	Total cholesterol, HDL, LDL	Mock	x	x	x		
Fraccaro et al. (2018)	Creatinine, eGFR, potassium	Mock	x	x			
Hohenstein et al. (2018)	Vitamin B12, procalcitonin, cholesterol	Mock	x	x			
Kelman et al. (2016)	Rheumatoid factor	Mock	x				
Morrow et al. (2017)	Total cholesterol, HDL, LDL, TG, HbA1c	Mock				x	
Morrow et al. (2019)	Total cholesterol, HDL, LDL, TG, HbA1c	Mock	x	x		x	
Nystrom et al. (2018)	Total cholesterol, HDL, LDL, TG	Mock		x			
Scherer et al. (2018)	HbA1c	Mock	x	x			
Struikman et al. (2020)	Hemoglobin, TSH, vitamin D	Mock	x	x			
Talboom-Kamp et al. (2020)	Type of test differed per patient	Real		x			
Tao et al. (2018)	Glucose (fasting and postprandial)	Mock		x			
Zarcadoolas et al. (2013)	Total cholesterol, HDL, LDL, TG, HbA1c	Mock	x				
Zhang et al. (2020)	Total cholesterol, HDL, LDL, TG	Real and mock	x				
Zhang et al. (2021)	Total cholesterol, HDL, LDL	Mock		x			
Zikmund-Fisher et al. (2017)	Platelet count, ALT, creatinine	Mock	x	x			
Zikmund-Fisher et al. (2018)	Platelet count, ALT, creatinine	Mock		x			

Abbreviations: ALT, alanine aminotransferase; eGFR, estimated glomerular filtration rate; HbA1c, hemoglobin A1c; high-density lipoprotein; LDL, low-density lipoprotein; TG, triglycerides; TSH, thyroid stimulating hormone.

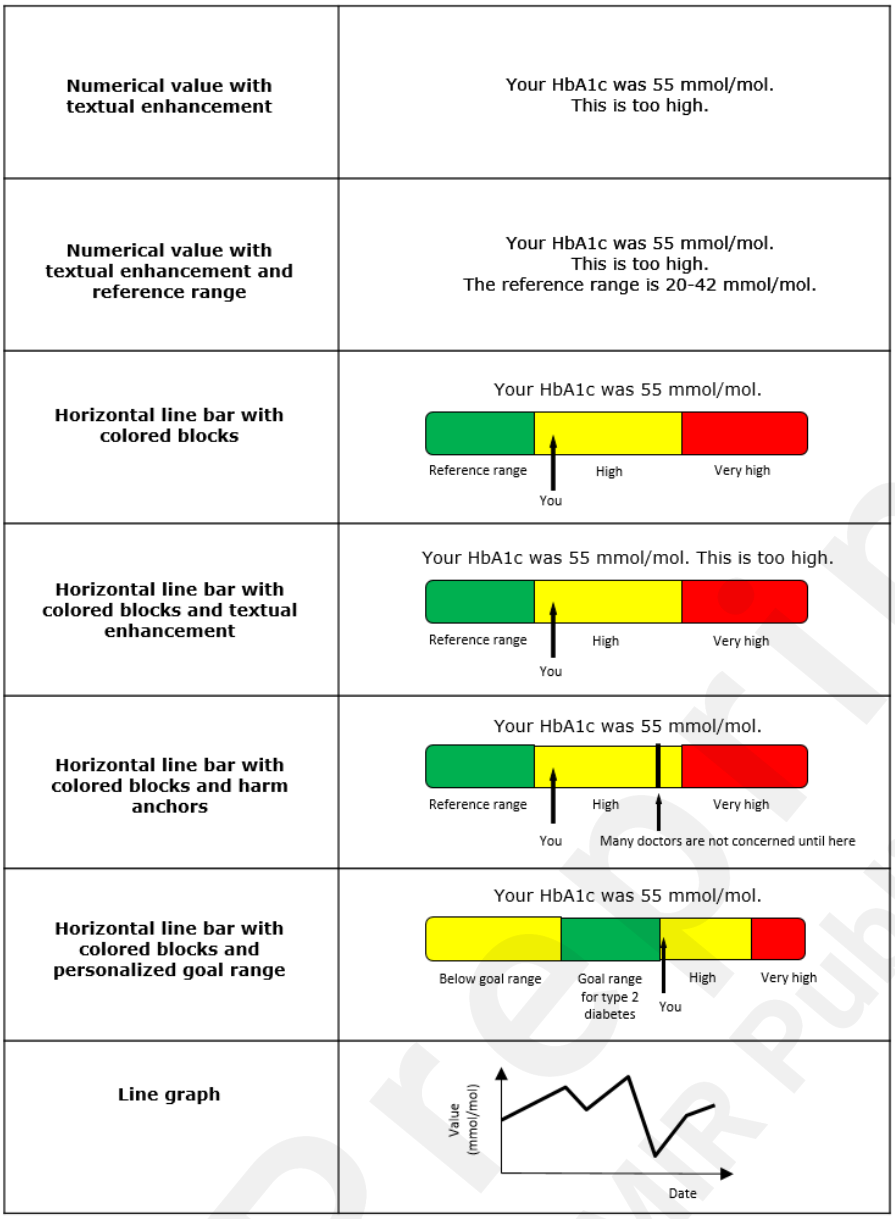

Figure 2. Examples of presentation formats used for displaying laboratory test results. The examples are based on a hypothetical HbA1c (hemoglobin A1c) test result. A combination of different presentation formats is possible.

Quality assessment

The quality assessment tool (MMAT) includes five assessment criteria per study design, each of which is given a score of 20% each if present (Appendix 4). Both qualitative articles (n = 2) scored 100%, indicating excellent quality. Quantitative articles (n = 11) scored between 0% and 100%, indicating a broad range of quality. These articles lost points mainly for sampling issues (biased sampling strategies and unrepresentative samples), randomization issues (unclear randomization process and incomparable groups at baseline), unclear blinding process, and lack of clarity about

completeness of outcome data and nonresponse bias. Mixed methods articles (n = 5) scored between 60% and 100% (low-to-high quality), for the same reasons as described above. In addition, weaknesses in these articles included having an unclear rationale for using a mixed methods design, unclear presentation format, and failure to adequately interpret the results of the integration of qualitative and quantitative findings.

Outcome measures

In all eighteen studies, perception was an outcome measure, further categorized into affective perception (n = 7), perceived magnitude (n = 6), cognitive perception (n = 10), and perception of communication (n = 14) (Table 3, Textbox 1). Additionally, ten studies assessed behavioral intention, while memory was considered as outcome measure in three of the included studies.

Affective perception

Several studies explored participants' confidence and concerns while viewing and interpreting laboratory results [15, 41-44]. Talboom et al. demonstrated that presenting laboratory test results in horizontal line bar format with colored blocks and textual explanation enhanced participants confidence in managing their own health, although this effect was not significant [44]. No comparison between different presentation formats and the influence on confidence was described. These comparisons were also lacking in the other studies.

When results were presented in a horizontal line bar format with colored blocks and a personalized goal range, negative affect was significantly higher than when results were presented without colored blocks [43].

Scherer et al. studied the use of personalized reference values or goal ranges [43]. A type 2 diabetes mellitus scenario was studied, in which standard reference ranges are often not applicable. Replacing standard ranges with goal ranges significantly reduced perceived discouragement compared to situations without goal display, highlighting a positive effect of goal ranges on affective perception [43]. Furthermore, two other studies recommended the use of personalized reference ranges in their discussion [41, 44].

In three studies, whether laboratory test results were within reference ranges seemed to be more important than the presentation format. As results moved further from the reference range, positive emotions decreased and negative emotions increased [15, 42, 45]. This change in affective perception was not influenced by message format.

Perceived magnitude

Perceived magnitude of risk of extremely out-of-range results remained unaffected by the presentation formats in all studies. However, for near-normal or slightly out-of-range results participants encountered difficulties in estimating test result severity. Accurate risk perception was lacking, since the severity of these results was inconsistently overestimated or underestimated [7, 18, 42, 46, 47]. Zikmund et al. demonstrated that the incorporation of harm anchors (i.e. a threshold line outside the reference range labeled “many doctors are not concerned until here”) significantly enhanced adequate estimations of test result severity for slightly out-of-range results [47].

Three studies investigated the effect of presentation format on perceived size of risk [18, 19, 42]. Morrow et al. compared horizontal line bars with both numerical and video-enhanced formats. For both low and borderline risk scenarios, perceived magnitude of risk was significantly higher when horizontal line bars were used, indicating that participants tend to overestimate risk for normal results [42]. Tao et al. did not specify whether result normality affected risk perception using different types of horizontal line bars. However, when personalized information was added to the line bar, risk was perceived as significantly higher. Interestingly, despite this, participants expressed a preference for personalized line bars [19]. Zikmund et al. compared different types of horizontal line bars with a numerical format. Participants expressed the highest risk perception when near-normal results were presented in a numerical format with a reference range, whereas perceived risk was lowest when horizontal line bars with gradient colors were used [18].

Cognitive perception

In all ten studies assessing this outcome, participants consistently demonstrated the ability to understand or identify out-of-range results. There was consensus among these studies that presenting numbers with a reference range only was insufficient and that tailored information is needed [48-50]. A qualitative study revealed that participants preferred the inclusion of textual explanations [51]. In two studies using horizontal line bars as presentation format, understanding was significantly increased when color, text, or personalized information (e.g. goal range) was added [19, 43].

Table 3. The outcomes assessed in all included studies (*n* = 18).

Author (year)	Perception				Decision	Act
	Affective perception	Perceived magnitude	Cognitive perception	Perception of communication	Behavioral intention	Hea
Bar-Lev et al. (2020)		x			x	
Brewer et al. (2012)				x		
Elder et al. (2012)			x	x		
Fraccaro et al. (2018)		x			x	
Hohenstein et al. (2018)	x		x	x		
Kelman et al. (2016)			x	x	x	
Morrow et al. (2017)	x		x	x		
Morrow et al. (2019)	x	x		x	x	
Nystrom et al. (2018)				x	x	
Scherer et al. (2018)	x		x		x	
Struikman et al. (2020)	x		x		x	
Talboom-Kamp et al. (2020)	x			x	x	
Tao et al. (2018)		x	x	x		
Zarcadoolas et al. (2013)			x	x		
Zhang et al. (2020)	x		x	x		
Zhang et al. (2021)			x	x		
Zikmund-Fisher et al. (2017)		x		x	x	
Zikmund-Fisher et al. (2018)		x		x	x	

Perception of communication

The majority of included studies observed a significant association between presentation format, participant satisfaction and ease of use. In general, satisfaction and ease of use were rated higher when test results were presented using horizontal line bars with colored blocks, as compared to other presentation formats [18, 19, 42, 44, 49, 51, 52]. In one qualitative study, numerical presentation with reference ranges was deemed insufficient, while graphs were considered too complex for easy comprehension [51]. Both quantitative and qualitative studies demonstrated that adding textual information, such as explanations about the meaning and normality of test results, and background information about testing, enhanced understanding and effective utilization of results. Particularly, the use of lay terms played an important role [15, 19, 41, 44, 48-50, 53]. Furthermore, two studies found a significant positive effect on participant satisfaction when personalized information or goal ranges were incorporated [19, 44]. This addition was also recommended by two qualitative studies [49, 51]. Zikmund-Fisher et al. specifically studied different types of horizontal line bars and showed no significant differences in participants' preferences among the studied formats.

Decision

Behavioral intention was assessed in ten studies, with varying focuses among them. Some authors examined whether participants would contact their physician [7, 18, 43, 47, 53], while others inquired about participants seeking additional information online [46, 48, 53], or making lifestyle changes after reviewing lab results [42, 44, 53].

Two studies demonstrated that presentation format did not significantly influence participants' need to contact their health care provider [7, 43]. Conversely, Zikmund-Fisher et al. demonstrated in two studies that participants who viewed near-normal results in a numerical format were significantly more likely to contact their doctor compared to those viewing the same results in one of the horizontal line formats. The use of harm-anchors in horizontal line bars substantially reduced the number of participants who would want to contact their physician [18, 47].

Participants' tendency to seek information online was significantly influenced by the presentation format, with a significant higher inclination observed for the numerical format compared to the textual format [46]. Kelman et al. and Nystrom et al. similarly found that approximately half of the participants would look for additional information after receiving test results in numerical format with reference ranges and textual enhancement, or horizontal line bars with colored blocks, respectively. However, no comparison was made between presentation formats in these studies [48, 53].

Intention to make lifestyle changes after viewing laboratory results was mentioned as an outcome in three studies [42, 44, 53]. Only one of these studies compared several presentation formats, but found no significant differences between using a numerical format, horizontal line bars with colored blocks, or video-enhanced format in terms of health-beneficial intentions [42].

Action

There was limited data concerning the actions patients take to comprehend their test results. One mixed methods study used a numerical format with reference ranges as presentation format [15]. Participants with abnormal test results were significantly more likely to take action compared to those with normal test results. As no comparison between presentation formats was investigated, the effect of format on action remains unstudied.

Memory

Variation in presentation format of test results, using either a numerical format with reference ranges and textual enhancement, horizontal line bars with colored blocks, video presentation, or grouped presentation, did not significantly impact participant recall [7, 42, 52]. However, one study found a small but statistically significant effect of test result normality on memory [42].

Struikman et al. looked at patient health engagement (PHE), a composite measure comprising affective perception, cognitive perception and behavioral intention. When test results were presented with explanatory text and visualization, PHE was significantly higher compared to when no explanatory information was provided [54].

Discussion

Principle results

Based on reviewing eighteen articles assessing various presentation formats of laboratory test results, we can conclude there is not only one optimal presentation format in terms of patients' perception, decision, action, and memory. Nevertheless, the results suggest that presentation format is important for patient outcomes.

Presentation formats differed between articles, but numerical values with reference ranges or horizontal line bars with colored blocks were most commonly used. All included studies investigated perception as an outcome measure, most frequently perception of communication (n = 14/18).

Patients' cognitive perception and perception of communication improved when results were presented using horizontal line bars accompanied with colored blocks and textual information. Incorporation of reference ranges or personalized goal ranges further enhanced patients' perception levels. Using horizontal line bars with harm anchors significantly reduced the number of participants who would want to contact their physician compared to using a numerical format. Furthermore, using the numerical format significantly increased participants' tendency to search for information online, compared to a textual format. Therefore, although no specific format is dissuaded in the included studies, the results suggest that presenting only numbers with reference ranges is suboptimal. Furthermore, adding too many colors and other information to test results could lead to an overload of visual information for some patients, and therefore ultimately decrease the amount of usable knowledge [43]. Action and memory were less frequently studied, respectively in one and three studies. Action was studied in a descriptive study not comparing different presentation formats, while memory was not significantly impacted by presentation format.

Several studies highlighted that patients' affective perception, action, and memory were not only influenced by presentation format, but also by whether test results were within or outside the reference range. Presentation format appeared to be secondary to test result normality if results were extremely out-of-range. Nevertheless, when results were near-normal, presentation format was more important than result normality regarding effects on patient outcomes.

Overall, the results of this review indicate that presentation format affects patient outcomes, especially in case of normal or near-normal test results.

Strengths and limitations

A multidisciplinary team of general practitioners, behavioral scientists and clinical chemists were involved in this review, which is one of its strengths. Both presentation formats and outcomes used in the included studies were standardized by the authors using a published taxonomy to enable comparison of different studies. As the results of our review are narrative, there is a potential risk of bias when describing them, introduced by the authors. Furthermore, selection bias arising from heterogeneity of studies represents a notable limitation of this review.

A limitation of the included studies is the use of volunteers or participants recruited via convenience sampling. Only three out of eighteen studies used real patients, of which one study used real test results. Sixteen studies used mock test results. Displaying mock data is common practice in system evaluation. This method involves less burden and privacy risks for participants, as no personal medical data is collected. Nonetheless, participants lack personal relevance of test results when

hypothetical scenarios are used. Therefore, it is possible that most of the included studies did not reflect how participants would respond in real life to their own personal health information. This may limit the generalizability of the findings. However, using personal test results could have negatively affected the comparability between studies, as each participant would have encountered different data.

Another limitation is the study heterogeneity. Included articles varied widely in methods, presentation formats, and outcome measures used. Comparison of presentation formats is challenging, especially since laboratory test result communication can have a wide range of possible purposes, from interpreting one single value, to identifying important trends on time [24]. Therefore, useful presentation formats may vary per clinical scenario, which presents new challenges for designing a preferred format.

As stated above, patients have to complete several steps to go from data perception to usable knowledge [17, 32]. The majority of the included studies studied the first two steps of this taxonomy, perception and decision. Only one study examined action as outcome measure, and three studies obtained information about memory. Therefore, little is known about the impact of presentation formats on actual health behavior and usable knowledge.

Comparison with prior work

In 2019, Witteman and Zikmund-Fisher formulated ten recommendations to communicate laboratory test results via online portals in ways that support understanding and actionable knowledge for patients [17]. Our findings align with several of their recommendations, such as the importance of providing a clear takeaway message for each result, establishing thresholds for concern and action whenever feasible, and personalizing the frame of reference by permitting custom reference ranges.

Several initiatives aim to inform and educate patients about laboratory test results while incorporating the insights described above. One example is Lab Tests Online, a website that provided patients with general information about laboratory tests and their meaning [55]. Recently, the usability of ChatGPT (i.e. an upcoming tool based on natural language processing) to interpret laboratory test results was examined [56]. ChatGPT appeared to provide somewhat superficial interpretations, which were not always correct, and is therefore not yet usable as a primary information source for patients. However, this may change in the future with the further development of these type of tools. While our review focused on different presentation formats of laboratory test results, interpretative comments provided by laboratory specialists were not studied. Laboratory

specialists often add comments to test results to assist general practitioners [57, 58]. A pilot study by Verboeket et al. demonstrated a positive impact on patient empowerment when patients had access to these patient specific comments [59]. Therefore, further research should explore the impact of adding interpretative comments to laboratory test results on patient outcomes.

Patients now have online access to not only their laboratory test results, but also to medical imaging and microbiology results. Given the variations in these types of diagnostic test results, further research is warranted to explore effective components for communicating these other types of test results to patients in their electronic health record.

Conclusions

As patients increasingly receive their diagnostic laboratory test results via electronic health records, it is becoming more and more important to make test results meaningful to them. Unnecessary confusion or anxiety should be avoided, especially when test results are outside of the reference range. The data from our systematic review suggest that horizontal line bars with colored blocks and reference ranges or personalized goal ranges increase patients' cognitive perception and perception of communication. Furthermore, this format might reduce patients' concerns and their tendency to contact their physician. Nevertheless, there is a need for further research that involves more comprehensive data collection and reporting, as well as more systematic evaluation methods. By using these findings, further research could inform the development of an interpretation support tool for laboratory test results.

Acknowledgements

Authors' contributions: all authors contributed to the conception of the review. FM and FS conducted the screening and data extraction. FM and FS drafted the manuscript. JJ, JB, SM and JC gave guidance throughout the whole research process. All authors critically revised and approved the manuscript.

Funding: this study received funding by a partnership between Care Research Netherlands and the Medical Sciences domain of the Dutch Research Council (Dutch abbreviation ZonMW) (project number 08391052120002). ZonMW had no direct involvement in any facet of the design of the study, analysis or interpretation of the data or writing of the manuscript.

Conflicts of interest

None declared.

Abbreviations

ALT: alanine aminotransferase

ChatGPT: Chat Generative Pre-trained Transformer

eGFR: estimated glomerular filtration rate

EHR: electronic health record

HbA1c: hemoglobin A1c

HDL: high-density lipoprotein

LDL: low-density lipoprotein

MMAT: Mixed Methods Appraisal Tool

PRISMA: Preferred Reporting Items for Systematic Reviews and Meta-Analyses

TG: triglycerides

TSH: thyroid stimulating hormone

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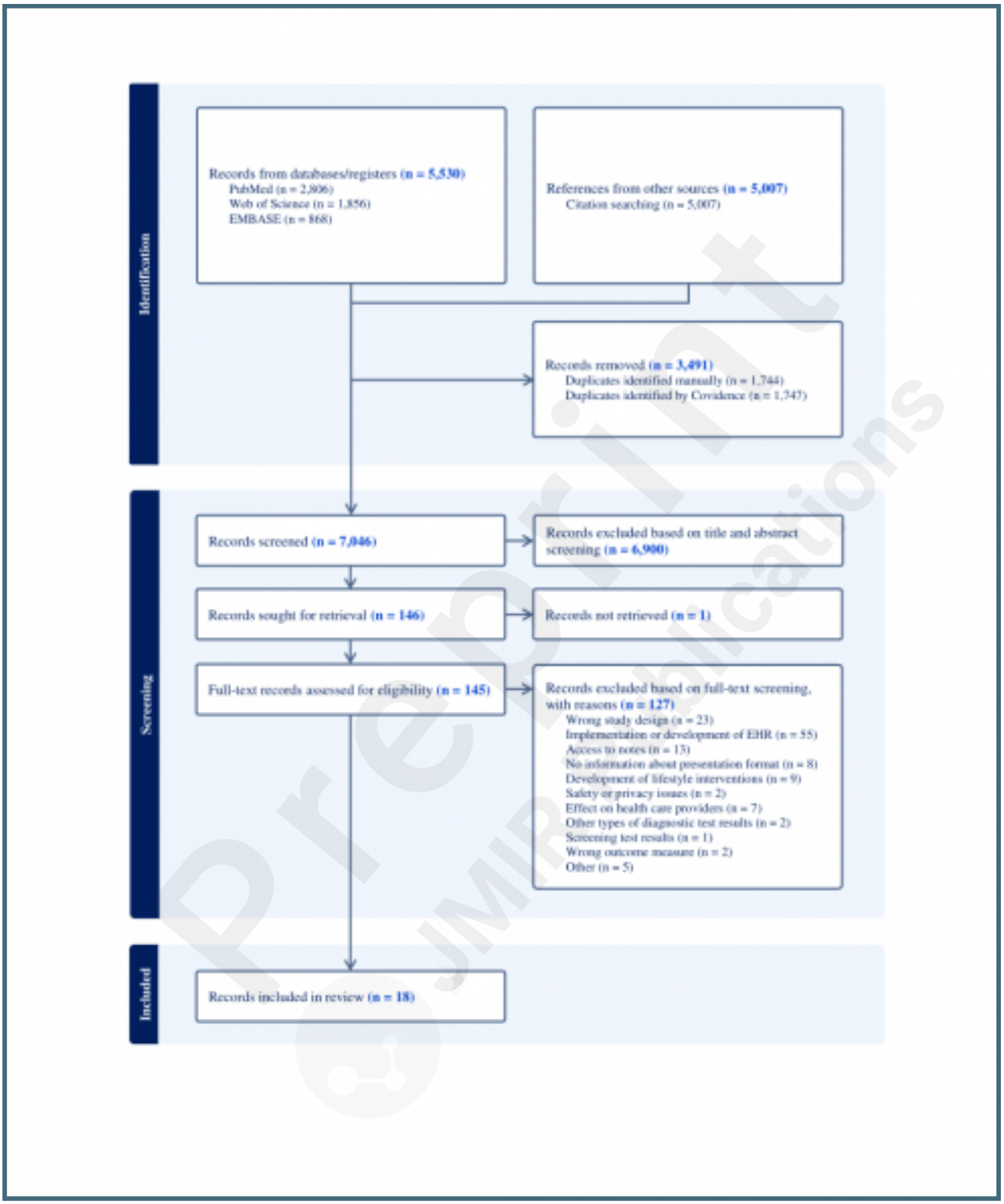
Supplementary Files

Figures

Flow chart of the study selection process.



Examples of presentation formats used for displaying laboratory test results. The examples are based on a hypothetical HbA1c (hemoglobin A1c) test result. A combination of different presentation formats is possible.

Numerical value with textual enhancement	Your HbA1c was 55 mmol/mol. This is too high.
Numerical value with textual enhancement and reference range	Your HbA1c was 55 mmol/mol. This is too high. The reference range is 20-42 mmol/mol.
Horizontal line bar with colored blocks	Your HbA1c was 55 mmol/mol. 
Horizontal line bar with colored blocks and textual enhancement	Your HbA1c was 55 mmol/mol. This is too high. 
Horizontal line bar with colored blocks and harm anchors	Your HbA1c was 55 mmol/mol. 
Horizontal line bar with colored blocks and personalized goal range	Your HbA1c was 55 mmol/mol. 
Line graph	

Multimedia Appendixes

PRISMA 2020 checklist.
URL: http://asset.jmir.pub/assets/e33587b23dc5cf9468dc5c3e3a4ca145.docx

Search strategy for PubMed, Web of Science, and EMBASE up to May 31st, 2023.
URL: http://asset.jmir.pub/assets/c1bef606b5e3c9a1a24d656dee202211.docx

Detailed overview of laboratory test results presentation formats in all included studies (n = 18).
URL: http://asset.jmir.pub/assets/1309329a877da53523f035fcbce7de42.docx

Detailed overview of quality assessment of all included studies (n = 18).
URL: http://asset.jmir.pub/assets/e28fc1ed3eca7e4632479951d11f61a1.docx

CONSORT (or other) checklists

PRISMA 2020 checklist.
URL: http://asset.jmir.pub/assets/47e35c085eb353a35f1530b0239745f7.pdf