

Clinical Decision Support Tools: Performance of Personal Digital Assistant versus Online Drug Information Databases

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Study Objectives. To evaluate personal digital assistant (PDA) drug information databases used to support clinical decision-making, and to compare the performance of PDA databases with their online versions.

Design. Prospective evaluation with descriptive analysis.

Methods. Five drug information databases available for PDAs and online were evaluated according to their scope (inclusion of correct answers), completeness (on a 3-point scale), and ease of use; 158 question-answer pairs across 15 weighted categories of drug information essential to health care professionals were used to evaluate these databases. An overall composite score integrating these three measures was then calculated. Scores for the PDA databases and for each PDA-online pair were compared.

Results. Among the PDA databases, composite rankings, from highest to lowest, were as follows: Lexi-Drugs, Clinical Pharmacology OnHand, Epocrates Rx Pro, *mobile*Micromedex (now called Thomson Clinical Xpert), and Epocrates Rx free version. When we compared database pairs, online databases that had greater scope than their PDA counterparts were Clinical Pharmacology (137 vs 100 answers, $p < 0.001$), Micromedex (132 vs 96 answers, $p < 0.001$), Lexi-Comp Online (131 vs 119 answers, $p < 0.001$), and Epocrates Online Premium (103 vs 98 answers, $p = 0.001$). Only Micromedex online was more complete than its PDA version ($p = 0.008$). Regarding ease of use, the Lexi-Drugs PDA database was superior to Lexi-Comp Online ($p < 0.001$); however, Epocrates Online Premium, Epocrates Online Free, and Micromedex online were easier to use than their PDA counterparts ($p < 0.001$). In terms of composite scores, only the online versions of Clinical Pharmacology and Micromedex demonstrated superiority over their PDA versions ($p < 0.01$).

Conclusion. Online and PDA drug information databases assist practitioners in improving their clinical decision-making. Lexi-Drugs performed significantly better than all of the other PDA databases evaluated. No PDA database demonstrated superiority to its online counterpart; however, the online versions of Clinical Pharmacology and Micromedex were superior to their PDA versions in answering questions.

Key Words: personal digital assistant, PDA, handheld computers, drug information, clinical decision-making, clinical decision support, informatics, pharmacy informatics, online drug information databases.

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One of the greatest challenges health care professionals face is managing an ever-increasing amount of medical and drug information. Clinicians devote numerous hours to develop

expertise in their fields. Those wishing to stay current with the full range of literature would have to read more than 16,000 articles a day.¹ One way to help address this challenge is the use

of clinical decision support tools. An oft-cited definition of such a tool, also referred to as a medical decision support system, appeared in an article published 20 years ago, which defined it as “any computer program designed to help health professionals make clinical decisions.”² Although the technology and terminology have changed since then, in many ways the definition is as applicable now as it was then.

The emphasis on clinical decision support initially centered on diagnostic tools and was perceived as primarily a medical domain.³ Likewise, most of the original literature, which was often published outside the United States, focused on medical informatics.⁴ However, times have changed, as many health care professionals have embraced the utility and applicability of informatics. This progress was evident in the expansion of the PubMed Medical Subject Headings by the National Library of Medicine. The term medical informatics, introduced in 1987, was expanded to include public health informatics in 2003, nursing informatics in 2005, and even dental informatics in 2005. A term for pharmacy informatics is regrettably still absent. However, an encouraging sign is that the Accreditation Council for Pharmacy Education has emphasized informatics in its new standards, guidelines, and competencies for Doctor of Pharmacy programs.⁵

Clinical decision support tools have already demonstrated their ability to positively influence safety in health care.^{6,7} If patient data and properly conveyed evidence are available at the point of clinical decision-making, 30–60% of decisions may be different.⁸ Furthermore, a study of systems failure showed that the most common reason for observed adverse drug events was poor dissemination of drug knowledge.⁹

Clinical decision support tools are provided in

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a number of media and formats. One example is a drug information database. A drug information database that is broad, complete, and easily accessible can be paramount in choosing a tool to enhance the delivery of superior pharmaceutical care and improve outcomes. These tools are most commonly available as online databases or software for personal digital assistants (PDAs). However, few objective evaluations of these tools have been conducted. To our knowledge, only three systematic evaluations of online databases have been reported. One was a progressive paper from 1997,¹⁰ one involved a 10-question sample from librarians and pharmacists,¹¹ and the most recent one focused exclusively on online databases.¹²

Regarding PDA tools, objective evaluations of various scopes have been conducted.^{13–16} Numerous subjective reviews, including two wide-ranging overviews,^{17,18} have been published. Specialized reports have also been written.^{19,20} To our knowledge, no researchers have systematically compared online databases with their PDA counterparts. The objectives of this study were to evaluate PDA databases, and to compare the performance of PDA databases with their online versions. Details about our process for evaluating the online databases have been published previously.¹²

Methods

Database Selection Criteria

The databases we selected had to be able to answer a wide variety of drug information questions useful to pharmacists and practitioners in a broad range of fields. In particular, they must have been able to answer questions from all of the top four question categories we developed and from 12 of the 15 question categories overall. The databases also needed to be available as comparable online and PDA versions. Online databases that were full-text electronic versions of a book (e.g., *American Hospital Formulary Service Drug Information*) were not eligible for inclusion. We also excluded online databases for which the basic package was substantially different from its PDA counterpart. For example, Facts & Comparisons 4.0 Online contained content from multiple resources, whereas the PDA versions were available only as a limited selection of individual components. Direct comparisons of these databases therefore would have been difficult and possibly biased.

Extended features of the databases that required separate purchases were excluded (e.g.,

the online version of Micromedex offers as a separate purchase the full online text of *Martindale: The Complete Drug Reference*). Another example was Lexi-Comp Online, which similarly offers several specialty PDA databases for purchase, such as Lexi-Interact, Lexi-Infectious Diseases, and Pediatric Lexi-Drugs, which did not fulfill the inclusion criteria; only the comprehensive drug information database (e.g., Lexi-Drugs) was included for evaluation.

All databases were evaluated on the Pocket PC 2003 operating system.

Question Development

An analysis of current published literature and queries recorded at the Drug Information Centers at Nova Southeastern University led to the creation of 158 question-answer pairs in 15 categories of drug information essential to health care professionals. Categories deemed essential to patient care and clinical decision-making received more questions, whereas categories of peripheral or occasional importance to clinicians received fewer. By weighting the categories, we attempted to mimic the realistic usage and importance of the online and PDA databases.

A external panel of pharmacists representing practices in community pharmacy, hospital pharmacy, academia, and industry reviewed the questions for relevance and appropriateness. Correct answers to the questions were established by means of primary literature searches and verification against at least one authoritative source, such as the product package insert, the *United States Pharmacopeia*,²¹ or the *Handbook of Injectable Drugs*.²²

Evaluation Criteria

The qualifying databases were evaluated for scope, completeness, and ease of use for both the PDA and online versions. Scope was based on answers to our questions. If an answer was found, the database was assigned a value of one. If the answer was missing or incorrect, it was assigned a value of zero. No penalty, such as assigning a negative value, was imposed on a database for having a wrong answer.

Completeness was the extent to which an answer was given. A scale of 1–3 was used to indicate the completeness of an answer, with 3 representing the most complete and 1 representing the least complete.

Ease of use was determined by counting the number of steps required to reach an answer in

the most direct route.

A final composite score was calculated for each of these assessments by weighting the scope score 70% and the completeness score 30% and then subtracting the ease-of-use score.

At least two authors independently evaluated the databases. The evaluations were performed concurrently during November 2005 to ensure consistency in value assignment. Inconsistencies were reviewed, and a consensus was reached. The raw data were compiled and compared between the online versions and their PDA counterparts.

Statistical Analysis

Scores for the PDA databases were evaluated for statistical significance of scope, completeness, and ease of use and in their composite scores. Descriptive statistics were used to summarize the components we evaluated. The χ^2 test was used to compare the PDA databases. We applied the McNemar test (for scope) and Wilcoxon signed rank test (for completeness, ease of use, and composite scores) to compare the PDA and online versions of the same database. Sensitivity analyses of the composite scores were performed to determine the influence of the percentages assigned to the scope and completeness data. A *p* value of 0.05 or less was considered to indicate a statistically significant difference.

Results

We identified five pairs of drug information databases as clinical decision support tools that could provide comprehensive information about drug therapy (Table 1).

Scope

The top performers for the PDA databases in scope were Lexi-Drugs, Clinical Pharmacology OnHand, and Epocrates Rx Pro. Individual scores by question category are presented in Table 2. Figure 1 shows the total number of questions the PDA and online databases answered successfully.

Only one answer for scope was incorrect among the PDA databases. To a question about the dosage of paroxetine for general anxiety disorder, Clinical Pharmacology answered, "Initially, 10 mg p.o. once daily, usually in the morning. Doses should be increased by 10 mg/day at weekly intervals if needed and tolerated. The target dose is 40 mg p.o. once daily and maximum dose is 60

Table 1. Pairs of PDA and Online Databases Evaluated

Online Version	PDA Version	Developer (location)	Web Site
Micromedex	<i>mobile</i> Micromedex ^a	Thomson Micromedex (Greenwood Village, CO)	www.micromedex.com
Clinical Pharmacology	Clinical Pharmacology OnHand	Gold Standard (Tampa, FL)	www.clinicalpharmacology.com
Lexi-Comp Online	Lexi-Drugs	Lexi-Comp, Inc. (Hudson, OH)	www.lexi.com
Epocrates Online Premium	Epocrates Rx Pro	Epocrates, Inc. (San Mateo, CA)	www.epocrates.com
Epocrates Online Free	Epocrates Rx Free	Epocrates, Inc. (San Mateo, CA)	www.epocrates.com

PDA = personal digital assistant.

^aNow called Thomson Clinical Xpert.**Table 2. Scope of the PDA and Online Databases**

Question Category (no. of questions)	CP		EF		EP		LC		MM	
	PDA	Online	PDA	Online	PDA	Online	PDA	Online	PDA	Online
No. of Questions Answered Correctly										
Dosage, schedule (17)	15	16	12	12	12	13	13	13	14	15
Drug interactions (17)	14	14	12	12	13	13	13	13	13	15
Methods of administration (13)	12	12	10	10	10	12	12	12	11	13
Adverse drug reactions (13)	10	13	9	9	9	9	12	12	9	13
Over-the-counter products (13)	5	11	4	4	4	4	9	9	0	6
Indications, unlabeled uses (11)	11	11	6	6	6	6	10	10	7	10
Identification, content (10)	5	10	5	5	5	7	6	9	5	8
Pharmacokinetics (10)	2	8	3	3	5	5	7	8	5	9
Compatibility, stability (9)	4	8	1	1	4	4	9	9	4	8
Contraindications (9)	6	9	5	5	6	6	7	7	9	9
Dietary supplements (8)	7	8	0	0	7	7	1	6	7	8
Pharmacology, MOA (8)	4	8	7	7	7	7	8	8	5	7
Pregnancy and lactation (8)	5	7	6	6	6	6	8	8	7	8
Foreign drug identification (7)	0	1	0	0	0	0	0	3	0	3
Cost and economics (5)	0	1	4	4	4	4	4	4	0	0
Percentage of Total Questions										
Total questions (158)	63.3	86.7	53.2	53.2	62.0	65.2	75.3	82.9	60.8	83.5

CP = Clinical Pharmacology OnHand and online; EF = Epocrates Rx Free and Online Free; EP = Epocrates Rx Pro and Online Premium; LC = Lexi-Drugs and Lexi-Comp Online; MM = *mobile*Micromedex and Micromedex; PDA = personal digital assistant; MOA = mechanism of action.

mg/day.” However, the package insert stated that the recommended starting dosage and the established effective dosage were both 20 mg/day and that evidence was insufficient to suggest additional benefit with dosages higher than 20 mg/day. Therefore, the answer in the database conflicted with the answer identified in our evaluation, but it was not in opposition to the dosage range used in clinical practice.

Completeness

The PDA databases that provided the most complete correct answers were Lexi-Drugs, Clinical Pharmacology OnHand, and *mobile*Micromedex. Table 3 lists the mean completeness scores for

each question category and completion percentages for each database.

Ease of Use

The most user-friendly PDA databases, as determined by ease of use, were Lexi-Drugs, Epocrates Rx Free, and Epocrates Rx Pro. Table 4 provides the full results for ease of use.

Composite Scores

A sensitivity analysis was performed to determine the influence of weighting the scope score 70% and the completeness score 30%. Varying the weighting factors to 60% and 40% or 50% and

Table 3. Completeness of the PDA and Online Databases

Question Category (no. of questions)	CP		EF		EP		LC		MM	
	PDA	Online	PDA	Online	PDA	Online	PDA	Online	PDA	Online
Score ^a										
Dosage, schedule (17)	2.87	2.88	2.92	2.92	2.92	2.92	2.92	2.92	3.00	3.00
Drug interactions (17)	2.93	2.93	2.67	2.67	2.69	2.69	2.77	2.77	3.00	3.00
Methods of administration (13)	2.92	2.92	2.60	2.60	2.60	2.67	3.00	3.00	2.82	2.92
Adverse drug reactions (13)	2.60	2.69	2.89	2.89	2.89	2.89	2.92	2.92	2.89	3.00
Over-the-counter products (13)	2.60	2.73	2.75	2.75	2.75	2.75	2.89	2.89	NA	2.17
Indications, unlabeled uses (11)	3.00	3.00	2.67	2.67	2.67	2.67	3.00	3.00	2.71	3.00
Identification, content (10)	2.80	2.90	2.80	2.80	2.80	2.86	2.83	2.89	2.40	2.88
Pharmacokinetics (10)	2.50	2.88	3.00	3.00	2.60	2.60	2.86	2.63	2.60	2.67
Compatibility, stability (9)	3.00	2.88	3.00	3.00	2.75	2.75	2.89	2.89	3.00	3.00
Contraindications (9)	3.00	3.00	3.00	3.00	3.00	3.00	2.86	2.86	3.00	2.89
Dietary supplements (8)	3.00	3.00	NA	NA	2.86	2.86	2.00	2.33	3.00	3.00
Pharmacology, MOA (8)	2.75	2.88	2.71	2.71	2.71	2.71	2.63	2.63	2.80	3.00
Pregnancy and lactation (8)	2.80	3.00	2.83	2.83	2.67	2.83	3.00	3.00	2.14	2.88
Foreign drug identification (7)	NA	3.00	NA	NA	NA	NA	NA	3.00	NA	3.00
Cost and economics (5)	NA	3.00	3.00	3.00	3.00	3.00	3.00	3.00	NA	NA
Percentage of Total Questions										
Total questions (158)	95.3	96.4	93.3	93.3	92.5	93.2	96.1	95.2	94.1	97.0

CP = Clinical Pharmacology OnHand and online; EF = Epocrates Rx Free and Online Free; EP = Epocrates Rx Pro and Online Premium; LC = Lexi-Drugs and Lexi-Comp Online; MM = *mobile*Micromedex and Micromedex; PDA = personal digital assistant; NA = not applicable (database did not answer the question); MOA = mechanism of action.

^aRange = 1–3, with 3 being the most complete answer and 1 being the least complete answer.

50% for scope and completeness scores did not change the ordering of the databases in terms of composite scores. The PDA databases ranked highest to lowest were Lexi-Drugs, Clinical Pharmacology OnHand, Epocrates Rx Pro,

*mobile*Micromedex, and Epocrates Rx Free. Only Lexi-Drugs was significantly superior to the other databases ($p < 0.05$).

Online versus PDA Databases

Online databases that had a significantly greater scope than their PDA version were Clinical Pharmacology online (137 vs 100 answers, $p < 0.001$), Micromedex (132 vs 96 answers, $p < 0.001$), Lexi-Comp Online (131 vs 119 answers, $p < 0.001$), and Epocrates Online Premium (103 vs 98, $p = 0.001$). Epocrates Online Free and Epocrates Rx Free for PDA were not significantly different in scope and resulted in the same scores (84 vs 84, $p = 0.474$; Figure 1).

Regarding completeness, only Micromedex was significantly more complete than its PDA counterpart ($p = 0.008$). No significant difference in completeness was observed between Clinical Pharmacology OnHand and online ($p = 0.18$), Epocrates Rx Pro and Online Premium ($p = 0.564$), Epocrates Rx Free and Online Free ($p = 1.0$), or Lexi-Drugs and Lexi-Comp Online ($p = 1.0$). When online-PDA pairs provided answers, the answers did not conflict.

The ease-of-use category revealed that Lexi-Drugs for PDAs was significantly superior to its online version ($p < 0.001$). However, the online databases were significantly easier to use in the case of the Micromedex pair and the two pairs

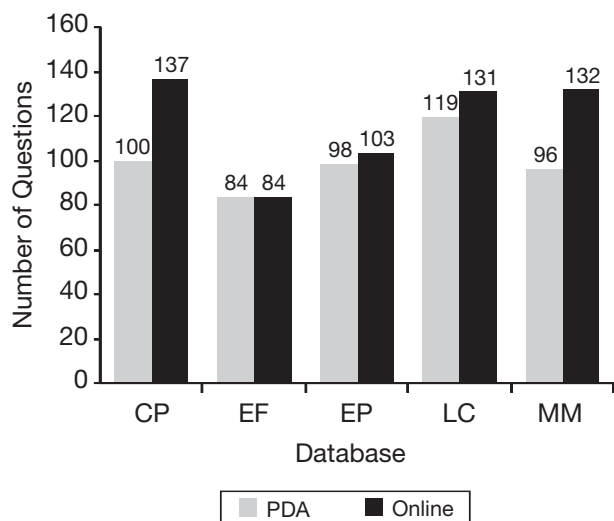


Figure 1. Scope (number of questions answered correctly out of 158 questions) of the personal digital assistant (PDA) and online databases evaluated. CP = Clinical Pharmacology OnHand and online; EF = Epocrates Rx Free and Online Free; EP = Epocrates Rx Pro and Online Premium; LC = Lexi-Drugs and Lexi-Comp Online; MM = *mobile*Micromedex and Micromedex.

Table 4. Ease of Use of the PDA and Online Databases

Question Category (no. of questions)	CP		EF		EP		LC		MM	
	PDA	Online	PDA	Online	PDA	Online	PDA	Online	PDA	Online
No. of Steps Needed to Obtain an Answer										
Dosage, schedule (17)	4.00	3.94	1.33	1.58	1.33	1.54	1.00	2.00	3.14	2.80
Drug interactions (17)	3.86	4.07	4.33	2.92	4.38	2.77	1.38	2.31	3.23	2.40
Methods of administration (13)	3.00	3.00	1.10	1.30	1.10	1.33	1.00	2.00	3.00	2.54
Adverse drug reactions (13)	3.20	3.62	3.33	1.78	3.33	1.78	1.00	2.00	3.00	2.69
Over-the-counter products (13)	3.80	4.25	3.50	1.75	3.50	1.75	1.00	2.00	NA	3.00
Indications, unlabeled uses (11)	3.82	3.55	1.33	1.50	1.33	1.50	1.00	2.00	3.00	2.90
Identification, content (10)	2.60	3.10	1.40	1.40	1.40	1.43	1.00	2.44	3.00	2.38
Pharmacokinetics (10)	5.00	2.63	3.33	1.33	2.80	1.60	1.00	2.00	3.00	2.89
Compatibility, stability (9)	3.00	3.50	1.00	1.00	2.50	2.25	1.00	2.00	3.00	2.75
Contraindications (9)	3.00	3.33	3.00	1.20	3.00	1.33	1.00	2.33	3.00	2.78
Dietary supplements (8)	3.00	3.25	NA	NA	2.57	2.29	1.00	2.67	3.14	2.25
Pharmacology, MOA (8)	1.50	2.00	3.00	1.00	3.00	1.00	1.00	2.00	3.00	3.00
Pregnancy and lactation (8)	3.00	3.00	2.83	1.33	2.83	1.17	1.25	2.00	3.00	2.75
Foreign drug identification (7)	NA	4.00	NA	NA	NA	NA	NA	2.00	NA	3.33
Cost and economics (5)	NA	14.00	4.25	2.00	4.25	2.00	3.50	3.75	NA	NA
Mean										
Total questions (158)	3.38	3.50	2.61	1.66	2.63	1.72	1.14	2.16	3.06	2.70

CP = Clinical Pharmacology OnHand and online; EF = Epocrates Rx Free and Online Free; EP = Epocrates Rx Pro and Online Premium; LC = Lexi-Drugs and Lexi-Comp Online; MM = *mobile*Micromedex and Micromedex; PDA = personal digital assistant; NA = not applicable (database did not answer the question); MOA = mechanism of action.

from Epocrates ($p < 0.001$). No significant difference was seen between the versions of Clinical Pharmacology ($p = 0.246$).

Finally, for composite scores, only the online versions of Clinical Pharmacology and Micromedex were significantly superior to their PDA counterparts ($p < 0.01$). No significant difference was observed between the other three pairs. Figure 2 depicts the composite scores for the PDA and online databases.

Discussion

The prevalence of PDA use among health care professionals is steadily increasing.²³ However, usage typically predates an analysis of and research into the applications being used. Because of this gap, health care professionals lack guidance in choosing a PDA or online drug information database to assist them in clinical decision-making. We generated scores for scope, completeness, and ease of use, with overall composite scores, to help illustrate the strengths and weaknesses of five drug information databases available for PDAs and online. Health care professionals can use the composite scores to determine if these databases might fulfill their needs in general, or they can use the category scores or groupings to address their specific needs.

Our findings for the PDA databases reinforced results from previous studies showing that Lexi-

Drugs was the best performer overall.¹³⁻¹⁶ However, we went a step further in finding that Lexi-Drugs was significantly superior to other databases ($p < 0.05$). Since those previous studies were conducted, the PDA databases that have made the greatest strides, particularly in terms of scope, are Clinical Pharmacology OnHand and

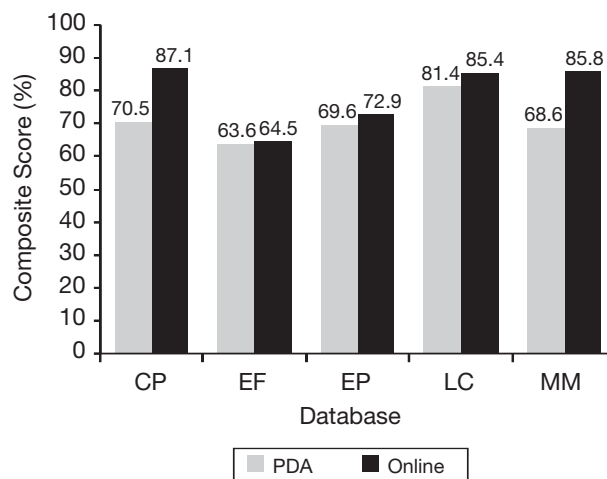


Figure 2. Composite scores for the personal digital assistant (PDA) and online databases evaluated. CP = Clinical Pharmacology OnHand and online; EF = Epocrates Rx Free and Online Free; EP = Epocrates Rx Pro and Online Premium; LC = Lexi-Drugs and Lexi-Comp Online; MM = *mobile*Micromedex and Micromedex.

*mobile*Micromedex. Clinical Pharmacology OnHand has risen from a good performer to second overall, and Micromedex, which was ranked lowest in one evaluation, has improved considerably.¹⁴ Although the overall scope of the Epocrates PDA products have increased, they have lost ground to their competitors in these evaluations.

For many categories of questions, the online and PDA versions produced similar scores for scope. However, significant differences in scope were found for the Clinical Pharmacology and Micromedex pairs. As noted in Table 2, Clinical Pharmacology online successfully answered 11 of 13 questions in the over-the-counter category, whereas Clinical Pharmacology OnHand for PDAs answered only five. Micromedex online answered six of 13 questions in this category, whereas *mobile*Micromedex answered none. Other categories in which the online and PDA versions yielded disparate scores were identification and content, pharmacokinetics, and compatibility and stability (Table 2).

Although the number of questions was too few for us to state definitively the ability of a database to answer any question a practitioner may pose in any given category, the change in scope may highlight fundamental differences between a PDA version and its online counterpart. In the interest of speed or memory capacity, the designers of the PDA versions may have chosen to eliminate or scale down the amount of information in specific categories, such as over-the-counter products, so they could more completely present other topics, such as dosage. Of interest, the Clinical Pharmacology and Micromedex databases, which originated as online and/or CD-ROM resources and then were later adapted for PDAs, were the only ones to demonstrate significant differences between their online and PDA versions. Their developers likely needed to remove content to feasibly fit the memory restrictions of the PDAs available at that time.

Since the 2002 publication of the first study¹³ of PDA drug databases, memory for these devices has increased. As a result, database developers may have been able to use more of their original content as PDAs evolved. This reason may partially explain why the performances of evaluated databases have improved over the years. Databases that were originally created for the PDA never had to deal with this issue. This difference may also account for why their online counterparts perform more poorly than databases that began online.

Limitations

Because we omitted databases that did not satisfy the inclusion criteria, some commonly used PDA software packages, such as American Hospital Formulary Service Drug Information and Facts & Comparisons A to Z Facts were not evaluated. This omission exacerbates an existing problem in the literature in that these databases have largely been excluded from previous evaluations, a situation that prohibits comparisons.

The databases evaluated in this study are dynamic entities that must change and adapt to an ever-increasing volume of drug information. Both the online and the PDA versions of these databases are updated at various frequencies. The data we collected reflected information in the databases when our assessment occurred.

Furthermore, the online database and PDA counterpart may or may not have been updated with the same frequency. Repeated evaluation of the same question-answers pairs could have produced slightly different scores. However, because the five database pairs regularly update their information, similar evaluations would likely produce similar overall results that reflected the abilities of the resources at that time.

In addition, publishers periodically change the format, distribution, or content of their databases. For example, the publishers of *mobile*Micromedex have retitled the database as Thomson Clinical Xpert. Lexi-Comp, Inc., has joined their content with that of the American Hospital Formulary Service Drug Information in their online version and may be launching a similar product for its PDA counterpart. Epocrates has bundled their online and PDA content as Epocrates Essentials Deluxe. Finally, Clinical Pharmacology has implemented a new user-interface and launched several new features.

Conclusion

Online and PDA databases that focus on drug information assist practitioners in improving their clinical decision-making. Lexi-Drugs performed significantly better than the other PDA databases we evaluated. No PDA database demonstrated superiority to its online counterpart; however, the online versions of Clinical Pharmacology and Micromedex were significantly better at answering questions than their PDA versions.

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