WORLDviews on EVIDENCE-BASED NURSING™
Linking Evidence to Action

Original Article

Supporting Evidence-Based Practice for Nurses through Information Technologies

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ABSTRACT

Purpose: To evaluate the usability of mobile information terminals, such as personal digital assistants (PDAs) or Tablet personal computers, to improve access to information resources for nurses and to explore the relationship between PDA or Tablet-supported information resources and outcomes.

Background: The authors evaluated an initiative of the Nursing Secretariat, Ontario Ministry of Health and Long-Term Care, which provided nurses with PDAs and Tablet PCs, to enable Internet access to information resources. Nurses had access to drug and medical reference information, best practice guidelines (BPGs), and to abstracts of recent research studies.

Method: The authors took place over a 12-month period. Diffusion of Innovation theory and the Promoting Action on Research Implementation in Health Services (PARIHS) model guided the selection of variables for study. A longitudinal design involving questionnaires was used to evaluate the impact of the mobile technologies on barriers to research utilization, perceived quality of care, and on nurses' job satisfaction. The setting was 29 acute care, long-term care, home care, and correctional organizations in Ontario, Canada. The sample consisted of 488 frontline-nurses.

Results: Nurses most frequently consulted drug and medical reference information, Google, and Nursing PLUS. Overall, nurses were most satisfied with the Registered Nurses Association of Ontario (RNAO) BPGs and rated the RNAO BPGs as the easiest resource to use. Among the PDA and Tablet users, there was a significant improvement in research awareness/values, and in communication of research. There was also, for the PDA users only, a significant improvement over time in perceived quality of care and job satisfaction, but primarily in long-term care settings.

Implications: It is feasible to provide nurses with access to evidence-based practice resources via mobile information technologies to reduce the barriers to research utilization.

KEYWORDS evidence-based practice, PARIHS model, Diffusion of Innovation, research utilization, information technology, quality of care, job satisfaction

Worldviews on Evidence-Based Nursing 2010; 7(1):4–15. Copyright ©2010 Sigma Theta Tau International

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The authors gratefully acknowledge the Nursing Secretariat of Ontario's Ministry of Health and Long-Term Care for their support of this research. The opinions, results and conclusion are those of the authors. No endorsement by the Nursing Secretariat or the Ministry of Health and Long-Term Care is intended or should be inferred. They also acknowledge all of the organizations, leaders, and especially the nurses who helped make this project possible. The research team recognizes the time, energy and commitment that this required. The authors also thank the Nursing PLUS team at McMaster University for its role in providing nurses with access to evidence-based resources.

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Accepted 30 September 2009

1545-102X1/10

INTRODUCTION

In the study, the authors evaluated the potential of mobile information technologies, such as personal digital assistants (PDAs) and Tablet personal computers (PCs), to improve nurses' access to information resources to support quality patient care.

One of the greatest challenges facing health care professionals today is the effective and efficient management of an ever-increasing amount of clinical-related health information. A crucial dimension of that challenge is to ensure that pertinent information is accessible at times of decision making. Mobile information terminals, such as PDAs, have the potential to address that challenge by bringing the most relevant information directly to the point of care. For nurses, providing valuable information through convenient electronic sources may address some of the barriers that inhibit their access to and clinical use of new and pertinent research.

Recognizing the value of PDAs as an information and communication tool in nursing practice is relatively recent (Stroud et al. 2005; Honeybourne et al. 2006; Doran et al. 2007; Garrett & Klein 2008; Doran 2009; Stroud et al. 2009). Research by Hardwick et al. (2007) shows that handheld technology can be used by nurses to improve and streamline patient care by capturing clinical data, by organizing and reporting home health services, and by providing references for evidence-based practice. Doran (2009) found that PDAs can be useful for promoting timely communication, enabling evidence-based collaborative practice, and in supporting workplace learning.

Purpose of the Study

The authors evaluated the Ontario Ministry of Health and Long-Term Care Nursing Secretariat PDA initiative for this study. The primary purpose was to evaluate the feasibility and usability of mobile information terminals, such as PDAs or Tablet PCs, to improve access to information resources for nurses working in acute care hospitals, long-term care (LTC), home care, and primary care settings. The secondary purpose was to explore the possible relationships between PDA or Tablet-supported information resources and health care outcomes.

The Ontario Ministry of Health and Long-Term Care (MOHLTC) PDA Initiative

The Ontario MOHLTC used a competitive process to fund organizations in the purchase of PDAs or Tablet PCs for their nursing staff. The MOHLTC also provided funding associated with providing nurses access to the information resources for a 12-month period, including costs associated with user licenses, with cellular access in community settings, and with training nurses to use both the devices and the information resources. Health care organizations were required to submit a proposal indicating their interest in participating in the initiative. They had to commit to provide release time for nurses to attend training sessions, to provide onsite technical support, and to assume full responsibility for funding the initiative for an additional 12-month period when the MOHLTC funding ceased. The MOHLTC established an external peer-review committee to review proposals and to recommend funding awards. The health care organizations that were successful in their funding request selected the types of devices they would provide their nurses. There was a range of device types selected, examples include: PDAs: BlackBerry, HP iPAQ, Motorola Symbol, Nokia, Palm Tungsten, and Palm Treo; Tablet computers: Motion C5, Lenova Thinkpad, Fujitsu, and HP Compaq. The MOHLTC also funded our research team to evaluate the PDA initiative.

BACKGROUND LITERATURE AND THEORETICAL PERSPECTIVE

With the current explosion of accessible information and the continuing expansion of professional knowledge, it is a challenge for nurses to regularly access information that is current and reliable. The Internet now provides extensive and timely access to health information; however, because frontline staff nurses are task driven and cope with heavy workloads, they are limited in both their attention to and recognition of potential information needs and knowledge gaps (MacIntosh-Murray & Choo 2005). As a result, they often limit their information search to obtaining patient-specific information from patients and patients' families, the chart, and other existing clinical information systems (McKnight 2006). Information technology can help promote nurses' access and use of relevant research thereby fostering safe, high-quality care through tools that can make more extensive information accessible to frontline clinicians at the point of decision making (Bates & Gawande 2003).

Nurses in community, rural, and LTC areas may not currently be able to benefit from such innovations in information technology because they often work in organizations that lack access to reference resources, such as a health science library or electronic databases. Nurses in home care settings are also disadvantaged because they work in relative isolation, without the proximal supervisory or collegial support of co-workers or other health professionals. Improving nurses' access to information resources in these settings, beyond hospitals and clinics, should allow for more efficient access to evidence in a broader range of nursing environments. This could lead to improved quality

of care, improved quality of nurses' work life, and improved patient outcomes.

Research in the US by Stroud et al. (2009) explored the prevalence and patterns of use of PDAs among nurse practitioners (NPs). The purpose of that research was to develop recommendations for PDA use to support evidence-based practice. Using a descriptive correlation survey, the authors concluded that a large number of NPs (64%) used the device and did so mainly for access to drug referencing, medical texts, or practice guidelines. Furthermore, they reported that almost all of the NPs viewed the PDA as a useful tool in their clinical practice. It was perceived to increase productivity, to promote patient safety, and to support decision making. In an earlier article, Stroud et al. (2005) demonstrated that PDAs facilitated both student and faculty access to accurate and current knowledge, and were used to support the application of current evidence, standards, and knowledge for clinical decision making.

Research in the United Kingdom by Honeybourne et al. (2006) examined the impact of PDAs on patient care by identifying how often clinical staff accessed the materials available to inform clinical decision making. The research sample included nursing staff and participants from other health disciplines. The authors concluded that all participants used PDAs but in varying frequencies. Eleven of the 12 staff members reported a benefit of handheld systems in addressing immediate patient concerns. Eleven of the 12 staff members reported that PDAs were useful in supporting their educational needs. A key point in providing evidence at the point of care was identified as the speed at which the information can be delivered. The resources most frequently referenced in clinical settings were: drug reference information, medical calculators, guidelines information, and administrative tasks.

Research in Canada by Garrett and Klein (2008) explored the perceptions of advanced practice nurses (APNs) on the value of wireless PDA technologies in support of their practice. Using an inductive qualitative approach, the authors concluded that the APNs identified improved patient care as the major benefit of PDA use. Clinical reference applications, such as drug and diagnostic/laboratory reference applications and wireless communication, were the tools that appeared to be most useful to the participants. Moreover, the APNs found that wireless connections via the PDAs facilitated constant access to sources of expertise and technical information.

Most of the research involving PDAs in evidence-based practice has been descriptive, with small sample sizes, and limited to a single-practice setting. Our current study was designed to overcome some of these limitations by involving a larger sample of nurses from 29 different practice settings, and by utilizing a longitudinal quasi-experimental design that compared two groups of users; PDA users versus Tablet PC users.

The PDA is lightweight and easily portable. The PDA is easy to start up and offers quick data entry. It is possible to upgrade RAM in higher-end model PDAs, and there is a lower threat of virus contamination. However, software included is not always compatible with software in use by the organization, and the small viewing area can make reading long pieces of information tiresome. The larger size of the Tablet PC is more comfortable for users, and is more similar to working on a laptop or desktop PC. The Tablet PC is compatible with all Microsoft and Microsoft XP compatible applications and has the capability to be used in a docking station so it can be used with a mouse and keyboard. Tablet PCs are significantly more costly, are larger and heavier than PDAs, and may be more susceptible to virus contamination.

THEORETICAL FRAMEWORK

Two theoretical perspectives provided a framework for studying the impact of providing nurses with PDA-supported evidence-based practice resources. The first was Diffusion of Innovation theory (Rogers 2003), in which technology adoption is influenced by the following factors: relative advantage (over other ideas), compatibility (e.g., with existing values), complexity (ease of use), trialability, and observability. The second theoretical perspective was the Promoting Action on Research Implementation in Health Services (PARIHS) framework (Kitson et al. 1998; Rycroft-Malone et al. 2004), which represents successful implementation of evidence into practice as a function of the relationship between: (1) the nature of the evidence, (2) the context in which practice change will occur (prevailing culture, the leadership roles assigned, and measurement and feedback), and (3) the mechanisms by which the change is facilitated. These two theoretical perspectives have guided the selection of variables and questions for the present study.

The Four Research Questions

The first two research questions were guided by Diffusion of Innovation theory. Drawing upon that theory, we expected there would be greater utilization of PDA and Tablet-PC information resources in community and LTC settings than in acute care settings. We expected this because acute care nurses have more direct access to colleagues with whom to consult and may also have access to a health science library at the workplace. In contrast, nurses in community and LTC settings work in relative isolation and do not typically have access to a health science

library during their workday. Therefore, we expected the PDA/Tablet PC-supported information resources would have an advantage over alternative methods for accessing information resources in community and LTC settings. We did not form a priori expectations regarding the relative advantage of each type of device because the portability of the PDA gives it an advantage, whereas the size of the screen gives the Tablet PC an advantage for reading textual documents. Thus, the first two research questions were:

1. What are the relative frequencies of use of various nursing electronic resources and do these vary by device type and by health care sector?
2. What is the utility of mobile information terminals, such as PDAs and Tablet PCs, to improve access to information resources for nurses, and does utility vary by device type and health care sector?

The third research question was guided by the PARIHS framework. Drawing on this framework we expected to observe a significant reduction in barriers to research utilization as a result of providing nurses with access to the PDA or Tablet PC-supported information resources. This is because: (1) the information resources were selected based on high-quality evidence (each resource was pre-screened for quality); (2) barriers related to electronic access would be minimized and timeliness of access at point of care would be increased; and (3) over time the context for evidence-based practice would become more favourable because nurses would receive training in how to access the information resources and would be provided with ongoing technical support. Thus the third research question was:

3. Does the provision of PDA or Tablet PC-supported information resources result in a reduction in barriers to research utilization?

We were also interested in investigating the extent to which providing nurses with access to mobile technology-supported information resources would result in improvements in the quality of care and in nurses' job satisfaction. Previous research suggests that access to high-quality work environments, where nurses experience autonomy and have their information needs met, promotes high job satisfaction (McGillis Hall 2003). Therefore, the fourth research question was:

4. Does the provision of PDA or Tablet PC-supported information resources result in
   i. Improvement in the quality of care; and
   ii. Improvement in nurses' job satisfaction?

Information Resources

The MOHLTC PDA initiative provided nurses with several information resources that could be accessed through mobile information technologies. The knowledge gained through previous research (Doran et al. 2007) was used to guide the selection of those information resources. The resources made available included:

1. the Registered Nurses' Association of Ontario (RNAO) Nursing Best Practice Guidelines (BPGs);
2. best Evidence for Nursing PLUS (Health Information Research Unit 2008); and
3. a Drug Handbook, a Medical Dictionary, and Lab Values (Lexi-Comp Inc. 2009; PEPID LLC 2009).

Nursing PLUS provides nurses with e-mail alerts on new research studies relevant to their area of expertise and also enables nurses to search a database for research abstracts. At some organizations nurses were also provided with links to their organization's online internal policies and procedures. Some resources, such as the drug handbook, were downloaded onto the mobile devices and other resources were accessible through a mobile or local area wireless network; for instance, Best Evidence for Nursing PLUS and RNAO BPGs required Internet access.

STUDY METHODS

Design

A pre-post-test design was used to investigate the impact of providing nurses with access to PDA/Tablet PC-supported information resources.

Setting and Sample

The setting consisted of 29 acute care hospitals, home care nursing service providers, primary care programs (family health teams, correctional facilities), and LTC facilities participating in the MOHLTC-led PDA Initiative. Eligible study participants were Registered Nurses (RNs) and Registered Practical Nurses (RPNs) working in home care, acute care, LTC, primary care and correctional settings, who were expected to maintain a similar practice in the same setting for at least a year. Sample size calculation was based on a minimum of 15 cases per measured variable (Stevens 1996). However, it is recommended that a larger sample be collected beyond the minimum sample size recommendations in case the data are nonnormal (e.g., skewed) or incomplete. There were six variables of interest: satisfaction with PEPID/Lexi, BEN, RNAO BPG; ease of use; frequency of utilization; barriers to research utilization; quality of care; and job satisfaction. Therefore, a minimum of 90 cases were required. However to

compensate for nonnormal distribution of some data and a 60% response rate found in survey research (Polit & Hungler 1995), a minimum of 200 cases was recommended. Proportional sampling was used to achieve approximately equal numbers from each health care sector. At sites having fewer than 50 eligible staff nurses all nurses were invited to participate in the evaluation. At sites with larger numbers of eligible nurses, proportional sampling was used to identify approximately 20 participating nurses per site. The total sample consisted of 488 RNs and RPNs from the four health sectors.

Study Variables

Data were collected on nurse characteristics including age, education, role, and previous experience using computer technologies for personal and work use. The primary outcome variables were: (1) user satisfaction with the PDA-supported information resources; (2) frequency of utilization of digital sources of evidence; (3) barriers to research utilization; (4) quality of care; and (5) nurses' job satisfaction. Data were collected through survey methods. The study timeline was February 2008 to March 2009.

Data Collection Tools

Nurses' perceptions about utility of PDA and Tablet devices. An adaptation of the Questionnaire for User Interface Satisfaction (Norman et al. 1988) was used to collect data on nurses' satisfaction with features of the PDA and Tablet PC as well as the information resources available to them. Nurses were asked to rate their satisfaction with each of the resources on a 9-point scale with positive adjectives anchoring the right end (e.g., *satisfying*) and negative anchoring the left (e.g., *frustrating*). Five items examined nurses' experience with finding electronically accessible information, such as best practice guidelines or best evidence for nursing Web sites. Three items asked about characteristics of the device, including the size of screen, characters on the screen and the amount of information seen. Four items asked questions about system capabilities, including system speed, ease of correcting mistakes, network access, and network stability. The Original Questionnaire for User Interaction Satisfaction (QUIS) was created to gauge the satisfaction aspect of software usability in a standard, reliable, and valid way. The Cronbach alpha of the original 48-item was 0.95. Construct validity was measured by correlating item scores with the six concurrent general satisfaction questions validated in previous studies. The mean correlations between each main item and a general satisfaction scale ranged between 0.49 and 0.61. In this study, the overall Cronbach alpha was .92 (Table 1).

TABLE 1
Reliability of major study variables

	CRONBACH ALPHA	
	BASELINE	FOLLOW-UP
Barriers to Research Utilization Subscales		
Characteristics of Nurse	0.81	0.84
Characteristics of Organization	0.81	0.87
Characteristics of Innovation	0.82	0.86
Characteristics of Communication	0.77	0.79
Questionnaire for User Interface Satisfaction	–	0.92
Quality of Care	0.91	0.91
Job Satisfaction	0.83	0.83

Use of information resources. An author-developed questionnaire was used to collect data on the frequency with which nurses utilized the resources provided. Frequency was measured on a scale of 1 (never) to 5 (several times a day).

Barriers to research utilization. The Funk et al. (1991) BARRIERS scale was used to measure barriers to research utilization. The scale consists of 28 items, which are summed and averaged to create four subscales: characteristics of the adopter (nurses' research values), characteristics of the organization (work environment barriers and limitations), characteristics of the innovation (qualities of research), and characteristics of the communication (presentation and accessibility of the research). The respondents rated the items on a 4-point scale (1 = to no extent, 2 = to a little extent, 3 = to a moderate extent, and 4 = to a great extent). Face and content validity of the scale were established by a panel of judges (Funk et al. 1991) and the scale was originally tested in a random sample of 5,000 USA nurses (Funk et al. 1991). Principal components and principal axis factor analyses supported the four independent factors. In the original study, Cronbach's alphas ranged from 0.65 to 0.80 with the communication subscale having the only alpha below 0.70. In this study, the Cronbach alpha's for each of the subscales were all above 0.70 (Table 1).

Quality of care. Five items, modelled on items from the nursing subscale of the Patient Judgement of Hospital Quality questionnaire (Rubin et al. 1990) and developed by the researchers were used to measure quality of patient care. The respondents rated the items on a 5-point scale (1 = poor, 2 = fair, 3 = good, 4 = very good, and 5 = excellent). Nurses were asked to rate the quality of nursing care on their unit, communication with other nurses on their unit, communication with doctors, communication

with patients/clients and the effectiveness of their setting in achieving good health outcomes. Two items were developed by the researchers to measure change, relative to the 6-month period prior to the study, in the extent to which the unit achieved high health outcomes and quality of care. The respondents rated the items on a 5-point scale (1 = much worse, 2 = slightly worse, 3 = same, 4 = slightly improved, and 5 = much improved). A Cronbach alpha of 0.94 has been reported in previous research (Doran et al. 2002). In this study, the Cronbach alpha was 0.91.

Job satisfaction. This was measured using a global measure of work satisfaction (Laschinger & Havens 1996), which measures employees' overall satisfaction with their jobs. Adapted from the Job Diagnostic Survey (JDS) (Hackman & Oldham 1980), the scale consists of four items measured on a Likert scale that ranges from 1 "strongly disagree" to 5 "strongly agree." A confirmatory factor analysis revealed a good fit of the hypothesized factor with standardized factor loadings of 0.68 to 0.81 (Laschinger et al. 2001). The modified scale has been used in several nursing populations and has been found to have good internal consistency with Cronbach alpha's ranging from 0.82 to 0.84 (Laschinger & Havens 1996; Laschinger et al. 2001; Laschinger et al. 2003). In this study, the Cronbach alpha was 0.83.

Nurse demographic characteristics. These were measured using a structured questionnaire developed by the authors. Nurses completed the BARRIERS scale, Quality of Care, and Job Satisfaction scales at baseline, prior to using the PDAs/Tablet PCs and approximately 6 months later.

Human Subjects and Recruitment Process

The study received human-subject approval from the University of Toronto Research Ethics office and from the research ethics boards of participating sites that had one. Each participating organization provided a list of the nurses who were expected to participate in the MOHLTC PDA Initiative. An information package prepared by the research team was distributed to eligible nurses by the site liaison. The package included a Baseline Questionnaire and two copies of the information letter and consent. It also included two self-addressed stamped envelopes, one for the return of the questionnaire and a second for the return of the consent form. Approximately 3 weeks after the packages were distributed, a Thank You and Reminder was distributed, and duplicate packages were sent to nonrespondents approximately 3 weeks after that.

STUDY RESULTS

A description of the nurse respondents is provided, followed by the findings related to each study question.

Nurse Participants

At baseline, the 488 nurses who participated in the study included 174 acute care nurses, 175 home care nurses, 121 LTC nurses, and 18 primary care nurses (including nurses who work in corrections settings). At follow-up, the 223 nurses who participated included 76 acute care nurses, 78 home care nurses, 58 LTC nurses, and 11 primary care nurses. Some of the reasons for participants withdrawing included: no longer with the organization, transferred from the unit where PDAs were being utilized, maternity leave, and unknown. The "average" nurse participant was a 45-year-old female with 18 years of experience in nursing, 8 years on current unit and 10 years in current organization. The majority of nurses worked full-time (73%) with an average of 36 hours each week, and had received a RN diploma (65%) as their highest level of nursing education. Prior to this study, the majority of nurses reported that, during a typical week, they often used a desktop or laptop computer several times a day (56%). Their main uses included information seeking and patient/client electronic health records. The largest majority of nurses did not use a PDA for personal use (88%) or work use (88%) and did not use a Tablet PC for personal use (93%) or work use (90%).

Research Questions Responses

The first research question asked "What are the relative frequencies of use of various nursing electronic resources and do these vary by device type and by health care sector?" Twenty-five nurses used both devices during the study and were excluded from these analyses. Furthermore, not all participants chose to answer the questions about frequency of use, thus the effective sample size for question 1 was 182 respondents.

Frequency of Device Use

The frequency with which a PDA or Tablet PC was used in this initiative is shown in Table 2. Overall, over 44.5% of the nurses used a PDA or Tablet PC at least once every few days, with nurses in primary care (75%) and LTC (54%) using the devices most frequently. The PDA device was used more frequently than the Tablet device; however, this varied by sector. Acute care, LTC, and primary care used the PDA more frequently while the Tablet device was used more frequently in home care.

One hundred nurses reported that they "never" or "almost never" used a PDA or Tablet during the study, offering 110 responses as explanation. The reasons cited include: technical issues, 28%; no or poor network, battery always dead, too slow, inconvenient or no need, 28%; prefer desktop, need keyboard, device too heavy, time restrictions, 16%; no time at work, workload overwhelming,

TABLE 2
Use of PDA/tablet devices during study

	ACUTE CARE				HOME CARE				LTC				PRIMARY CARE			
	PDA		TABLET		PDA		TABLET		PDA		TABLET		PDA		TABLET	
DURING STUDY	***n***	**%**	***n***	**%**	***n***	**%**	***n***	**%**	***n***	**%**	***n***	**%**	***n***	**%**	***n***	**%**
PDA/Tablet Use																
Several times a day	4	8.5	–	–	2	11.1	4	8.2	9	34.6	–	–	1	33.3	–	–
About once a day	6	12.8	2	8.3	1	5.6	4	8.2	2	7.7	–	–	–		–	–
Once every few days	8	17	5	20.8	4	22.2	16	32.7	7	26.9	4	26.7	2	66.7	–	–
Almost never	15	31.9	8	33.3	10	55.6	14	28.6	3	11.5	5	33.3	–	–	1	10
Never	13	27.7	9	37.5	1	5.6	11	22.4	5	19.2	6	40.0	–	–	–	0
Total responses	46		24		18		49		26		15		3		1	–

training/learning needs, 16%; no/inadequate training, computer shy, device unavailable, 12%; and device taken away only returned this week, unavailable for 3 months.

Next, differences in the frequency with which nurses reported using the information resources provided were examined. The results are presented in Table 3. When the results were examined by device used, the results showed that nurses, who used a Tablet PC accessed Google and in-house resources significantly more often than nurses who used a PDA ($t = -2.4, -2.3$ respectively, $p < .01$). In contrast, nurses who used a PDA accessed PEPID or Lexi significantly more often than nurses who used a Tablet PC ($t = 3.1$, $p < .001$). No significant differences between devices were observed in the self-reported frequency with which nurses accessed Nursing PLUS or RNAO BPGs. When the results were examined by sector, acute care nurses accessed in-house resources significantly more frequently than home care nurses ($F = 3.2$, Bonferroni post hoc test of differences $= p < 0.04$). No other significant difference between sectors was observed.

The second research question asked, "What is the feasibility and usability of mobile information terminals to improve access to information resources?" This question was addressed by assessing nurses' perceptions of the utility of the PDA/Tablet PCs and the usefulness of the information resources for practice.

Nurses' Perceptions About the Utility of PDA and Tablet Devices

Satisfaction. Nurses were asked to rate their satisfaction with each of the resources on a 9-point scale ranging from frustrating to satisfying. The results are presented in Table 4. Overall, nurses were most satisfied with their experience using the RNAO BPGs. However, when examined by device, nurses who used the PDA were most satisfied with the PEPID or Lexi resource, and the nurses who used the Tablet PC were more satisfied with the RNAO BPG resource. Independent *t*-tests, however, showed that these differences were not statistically significant. No differences were observed among sectors where the nurses worked.

Ease of use. Nurses were asked to rate the ease of each resource on a 9-point scale ranging from difficult to easy. Overall, nurses rated the RNAO BPG as the easiest to use. Similar to the results for satisfaction levels, nurses who used a PDA found the PEPID or Lexi resource the easiest while nurses who used a Tablet PC found the RNAO BPG the easiest. Independent *t*-tests showed that there were no significant differences in the means. No differences were observed among sectors where the nurses worked.

Device characteristics. Nurses were asked to rate seven characteristics of the device they used on a 9-point scale. Nurses who used a Tablet PC rated the amount of information on the screen to be significantly more adequate than did nurses who used the PDA ($t = -2.19$, $p < 0.05$). In contrast, nurses who used a PDA rated the speed of the PDA significantly faster than did nurses who used the Tablet PC ($t = 2.03$, $p < 0.05$). There were no significant differences between the other characteristics, however, nurses who used a Tablet PC reported a more adequate size of screen, characters that were easier to read, greater ease in correcting mistakes, and better network stability. The PDA was reported to have better network access. No differences were observed among sectors where the nurses worked.

The third and fourth research questions asked whether the provision of PDA and Tablet PC-supported information resources result in a reduction in barriers to research utilization, and an improvement in the quality of care and nurses' job satisfaction.

TABLE 3
Frequency of use of information resources by device and sector during a typical week

	ACUTE CARE		HOME CARE		LONG-TERM CARE		PRIMARY CARE	
INFORMATION RESOURCES	**PDA *N* = 32**	**TABLET *N* = 14**	**PDA *N* = 18**	**TABLET *N* = 37**	**PDA *N* = 23**	**TABLET *N* = 8**	**PDA *N* = 3**	**TABLET *N* = 1**
Google	1.0	1.4	0.61	1.8	0.87	0.38	2.8	0
RNAO BPG	0.91	0.84	0.24	1.1	1.2	0.63	2.0	1.0
Ben + e-mail alerts	1.0	1.1	0.78	1.7	1.5	0.50	2.0	1.0
Ben + Database	0.87	0.93	0.78	1.1	1.2	0.50	2.0	0
Lexi/PEPID	1.7	0.93	1.4	1.5	2.1	1.4	2.0	1.0
In-House resources	0.47	0.71	0.39	1.2	0.83	0.25	2.0	1.5

Note: Mean represents a score ranging from 0 "never" to 4 "several times per day."

TABLE 4
Utility of resources by device and sector (9 point scale)

	ACUTE CARE						HOME CARE						LONG-TERM CARE					
	PDA			TABLET			PDA			TABLET			PDA			TABLET		
	n	**M**	***SD***	***n***	**M**	***SD***	***n***	**M**	***SD***	***n***	**M**	***SD***	***n***	**M**	***SD***	***n***	**M**	***SD***
Satisfaction																		
PEPID or Lexi	25	4.6	2.7	10	4.3	1.9	16	4.6	2.1	34	4.9	2.4	20	6.2	2.3	5	4.0	2.8
BEN+	20	4.9	2.4	10	6.0	2.1	10	4.9	1.7	32	5.2	2.3	19	4.5	1.8	0	–	–
RNAO BPG	21	5.0	1.7	12	6.3	1.2	10	3.6	1.1	30	5.3	2.1	19	5.3	2.4	3	6.3	4.6
Ease of Use																		
PEPID or Lexi	24	5.4	2.4	10	4.4	1.9	15	4.5	2.3	32	5.2	2.4	20	6.3	2.4	5	5.2	2.4
BEN+	20	5.1	2.3	9	6.6	1.7	10	4.6	1.6	30	5.1	2.3	19	4.5	2.1	0	–	–
RNAO BPG	20	5.6	2.0	10	6.1	1.4	10	3.5	1.4	29	5.2	2.2	19	5.9	2.6	3	6.3	4.6
Device Characteristics																		
Size of Screen	29	5.3	2.7	13	6.4	2.7	17	5.6	2.7	35	5.9	2.6	21	6.4	2.1	5	6.0	1.6
Characters on Screen	29	5.9	2.6	13	6.5	2.4	17	4.7	2.6	35	5.9	2.6	21	6.6	1.7	5	5.6	1.5
Amount of Information on Screen	29	5.7	2.5	13	6.9	1.5	17	5.0	2.4	34	6.3	2.4	21	6.1	1.9	5	7.0	1.0
System Speed	38	6.4	1.7	13	5.6	2.9	14	5.1	2.7	35	5.0	2.7	21	6.1	2.2	5	5.4	1.7
Correcting mistakes	26	5.5	2.2	9	6.0	1.7	15	4.7	2.5	33	5.3	2.5	20	5.4	2.0	4	6.0	1.2
Network Access	28	5.4	2.5	13	5.0	2.4	16	3.8	2.0	34	5.6	2.8	21	6.2	2.3	5	4.0	2.0
Network Stability	26	5.5	2.7	12	4.8	2.5	13	4.0	2.9	34	5.8	2.8	22	5.7	2.5	5	5.0	1.4

Changes in Outcomes Over Time

Paired *t*-tests were used to evaluate change in the outcomes (i.e., barriers to research utilization, job satisfaction, and quality of care) from baseline to follow-up. The analyses were done first for the overall sample. As shown in Table 5, there was a decrease in the extent to which nurses thought each subscale of the BARRIERS scale was a barrier to their use of research, and this decrease was significant for the characteristics of the nurse and the characteristics of the communication. As nurses used the PDA or Tablet PC devices, they felt a significant improvement in their own research values, skills, and awareness, as well in the presentation and accessibility to research evidence. Table 5 also shows minimal overall change in the quality of care and job satisfaction of the nurses.

To assess whether nurses using different devices and working in different sectors differ with regard to reduced barriers to research utilization and improved rating of quality of care and job satisfaction, and whether there is an interaction between sector and device used, a multivariate analysis of variance (MANOVA) was conducted, with the change scores as the dependent variable. These analyses were conducted separately for the four barriers scales and the two outcome variables, quality of care and job satisfaction. The results of the MANOVA are presented in Table 6. The assumption of homogeneity was met with Box Test and Levine's tests, both not significant.

Job satisfaction and quality of care. Multivariate test showed that the main effect of device and interaction were significant, but not the main effect of sector, with Wilks'

TABLE 5
Paired *t*-tests—changes in major study variables over time for overall sample

VARIABLE	*n*	TIME 1 Mean (*SD*)	TIME 2 Mean (*SD*)	*T* Value
Barriers				
Characteristics of Nurse	196	2.35 (0.70)	2.24 (0.71)	1.89*
Characteristics of Organization	200	2.83 (0.62)	2.77 (0.70)	1.23
Characteristics of Innovation	181	2.36 (0.65)	2.30 (0.70)	1.11
Characteristics of Communication	185	2.69 (0.66)	2.59 (0.67)	1.75*
Quality of Care	194	3.80 (0.70)	3.81 (0.70)	−0.33
Job Satisfaction	183	3.52 (0.86)	3.52 (0.86)	−0.05

*$p < 0.05$.

TABLE 6
Multivariate analysis of variance for change in outcomes over time by device used and sector

EFFECT	WILKS' LAMBDA	*F*	HYPOTHESIS *DF*	ERROR *DF*	SIGNIFICANCE	PARTIAL ETA SQUARE
Quality of Care and Job Satisfaction – Multivariate Effects						
Intercept	0.999	0.061	2	141	0.941	0.00
Sector	0.964	1.30	4	0.282	0.270	0.02
Device	0.889	8.82	2	141	0.002	0.11
Device by Sector	0.922	2.94	4	282	0.021	0.04
Funk BARRIERS Scales – Multivariate Effects						
Intercept	0.685	16.92	4	147	0.001	0.32
Sector	0.929	1.38	8	294	0.206	0.04
Device	0.951	1.89	4	147	0.114	0.05
Device by Sector	0.912	1.7	8	294	0.091	0.06

Lambda = 0.889 ($p < 0.001$) for Device and Wilks' Lambda = 0.922 ($p < 0.05$) for the interaction. This indicates that PDA and Tablet computer users differed in their linear composite of change scores of quality of care and job satisfaction (between two time points), and such effect varied by the sector where they were employed. A follow-up ANOVA test indicates the effect of sector, after controlling for device use, was not significant for both outcome measures although post hoc tests after Bonferroni correction showed nurses in LTC and home care differed in their improved ratings of quality of care. In addition, the between subject tests show the effect of device use was significant for both measures (Quality [$F = 8.12$, $p < 0.01$] Job Satisfaction [$F = 15.4$, $p < 0.001$]) but such effect varies with the sector where they were employed. The graph (Figures 1 and 2) showed that PDA users had a higher rating change/improvement than Tablet computer users, but such device effect on both measures was larger in the LTC sector than the home care and acute care sectors.

Barriers to research utilization. Multivariate test showed that the main effect of device and interaction were not significant.

DISCUSSION

Study Limitations

The study was a natural experiment in which organizations were at liberty to select the device type they chose to provide their nurses. Therefore it was not possible to balance the number of device types by sector, and as a result, there were some sectors, such as primary care and LTC, where a device type was underrepresented. Further, there are considerable differences in performance within device types, especially for PDAs (e.g., service provider, network speed, keyboard) that could not be controlled. This meant it was not possible to fully explore the extent to which the impact on outcomes of providing nurses with mobile technologies was device specific, sector specific, or a combination of the two. Second, as with any natural experiment, it is not possible to control for other extraneous confounding factors that could have influenced the results. For example, the recruitment of nurses and participation rates varied considerably from site to site, and may have been confounded by device choices. Third, the study relied on self-report of PDA or Tablet PC use and self-report for the outcome measures. Validation of the self-reported

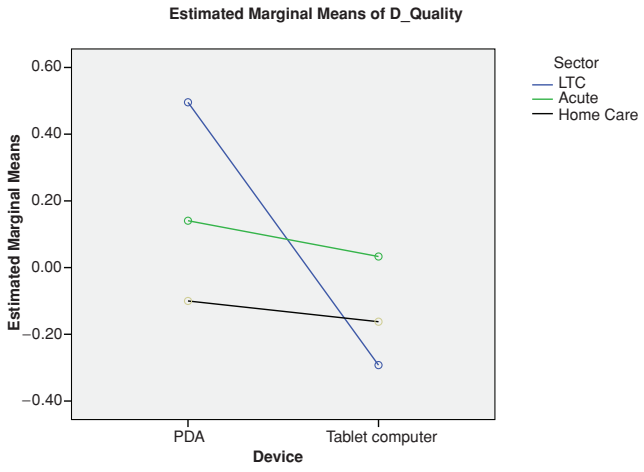

Figure 1. Plot of quality of care difference scores for device and sector.

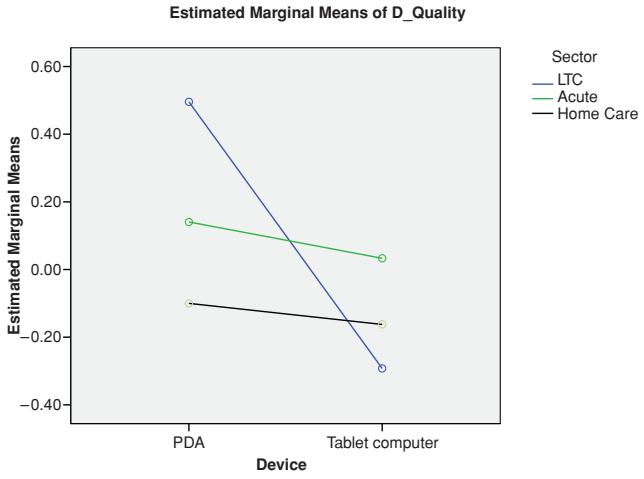

Figure 2. Plot of job satisfaction difference score for device and sector.

outcomes through observation and or electronically tracking nurses' use would strengthen the methodology. Finally, the study was limited to a 12-month time period. It would be interesting to assess whether use patterns are sustained, strengthened, or lessened over time.

Research Findings

The study explored the potential of mobile information terminals, such as PDAs and Tablet computers, to improve nurses' access to research evidence and other information resources with the overall goal of improving the quality of nurses' work-life and the quality of patient care. The research findings suggest that mobile technologies have the potential to realize these goals; however, their impact depends to some extent on the type of device used and on the sector in which the nurses work.

Prior to the study a large majority of nurses had not used a PDA or Tablet PC. At the conclusion of the study 41.5% of the nurse respondents indicated they were using a PDA or Tablet PC once every few days or more often, and 29% indicated that they never used it. There have been a number of studies that have explored the various resources that nurses utilize and the kinds of knowledge they require in their day-to-day work (Royle et al. 1995, 2000; Thompson et al. 2008). Royle et al. (2000) found that, to access professional information, two-thirds of the nurses in their study consulted with colleagues daily, most used reference sources and textbooks weekly, and two-thirds of them read journal articles monthly. Thompson et al. (2008) found that nurses preferred human sources of information and that colleagues, other members of the primary care team, or senior members of the clinical team were viewed as the most useful and accessible information sources (Thompson et al. 2008). In another study, observation of nurses' information-seeking behaviour through work-sampling methodology confirmed that nurses most often sought information from other colleagues (Doran et al. 2007). Nurses expressed stronger preferences for reference information and procedural information than for research information. In that study hospital nurses' top priorities for information resources at the point-of-care were information on intravenous (IV) drug compatibility, a drug dictionary, and IV medication protocols. Access to the types of information identified by these nurses is now readily available on PDAs and other mobile technologies, such as Tablet PCs (Scollin et al. 2006).

Building on that previous research, the current study provided nurses with access to three information resources via their PDAs/Tablet PCs: (1) RNAO Best Practice Guidelines; (2) Nursing PLUS (Health Information Research Unit 2008); and (3) PEPID/Lexi (Lexi-Comp Inc. 2009, PEPID LLC 2009).

Nurses also had access, at their own discretion, to other Internet resources and search engines such as Google. The findings from this study indicated that the most frequent resources nurses reported using were drug dictionaries and medical reference information, both of which were included in the PEPID and Lexi suite. It is interesting to note that Google was accessed every few days or more frequently by 38% of the respondents. Nurses identified using Nursing PLUS e-mail alerts more frequently (36%) than searching the Nursing PLUS database (30%). When asked about the ease of use and satisfaction with the

information resources, nurses reported the RNAO BPGs were most satisfying and easiest to use.

The Funk et al. (1991) BARRIERS scale was used to assess nurses' perception of four types of barriers to research utilization: characteristics of the adopter (nurses' research values), characteristics of the organization (work environment barriers and limitations), characteristics of the innovation (qualities of research), and characteristics of the communication (presentation and accessibility of the research). The results of the paired *t*-tests indicated a significant reduction in two of the barrier subscales among both PDA users and Tablet PC users. Nurses' values and attitudes toward research became more positive, and characteristics of the communication of research became more positive over time. The results of the multivariate analysis of variance indicated no significant main effects for device type and interaction between device type and sector. Therefore, the change in barriers to research utilization did not seem to depend on the type of device used or sector in which nurses worked.

In contrast to these findings, the multivariate analysis of variance indicated a significant main effect on change in quality of care and job satisfaction for device and the interaction with sector. PDA users had higher rating change/improvement than Tablet users, but such device effect on both quality of care and job satisfaction was larger in the LTC sector than in the home care and acute care sectors. Qualitative data from the nurses provide insight into why positive change occurred among PDA users and not among Tablet PC user—despite the fact that both groups had access to the device, which they were able to carry with them and personalize with telephone numbers and other Web pages. In contrast, the Tablet PC users tended to share the device with multiple users. Nurses also commented that the Tablet PCs were bulky/heavy to carry, slower to power-up and load, and in some models writing functions were inefficient because handwriting text was not always recognized and often required rewriting.

Collectively, these patterns of findings offer evidence that small, portable, wireless, handheld computers such as PDAs have the potential to improve research utilization in nursing practice—leading to improvements in the quality of patient care and nurses' job satisfaction. These improvements are more likely to be realized in settings where nurses work in relative isolation, do not have the benefit of close collegial support, and lack infrastructure such as libraries, desktop computers, and on-site expertise.

Every care activity involves decision-making. Research indicates that there is significant variation in the decisions that nurses make about appropriate interventions for managing patients' health concerns such as functional impairment, pain, nausea, dyspnea, fatigue, and pressure ulcers (Doran et al. 2006). Evidence-based nursing resources could address such variation in nursing practice by providing reliable information about nursing interventions that have been effective for particular patient concerns. There is evidence to suggest that timely access to research evidence, especially if imbedded into the clinical processes of care, minimizes variation in clinical practice (Kawamoto et al. 2005). The results of the current study demonstrate the usefulness of PDAs and Tablet computers in delivering this type of decision support to nurses at the point of care.

CONCLUSIONS

Use of PDAs and Tablet computers for accessing information resources resulted in improvement in nurses' research values and awareness, and in the presentation and accessibility of research evidence. PDA users demonstrated higher improvements in the quality of care and job satisfaction than Tablet users, and these improvements were highest in the LTC sector. Nurses felt that having access to the mobile devices changed their use of RNAO BPGs, that the information resources assisted in clinical practice, that the resources positively impacted care, and that they supported their learning needs. One possible explanation for the differential impact of PDAs on quality of care and job satisfaction is that nurses were able to have their own personal PDA, which they could customize with additional resources and phone numbers, whereas nurses typically had to share a Tablet PC. Nurses in the study also reported that Tablet PCs were heavy to carry and slow to load. Although the PDAs were considered less desirable with regard to screen size than the Tablet PCs, nurses liked the speed with which the PDAs were able to access the Internet.

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