Matern Child Health J (2013) 17:809–815
DOI 10.1007/s10995-012-1074-z

NOTES FROM THE FIELD

Development and Assessment of an Interactive Web-Based Breastfeeding Monitoring System (LACTOR)

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Published online: 12 July 2012

Abstract The purpose of this study is to describe an interactive web-based breastfeeding monitoring system (LACTOR), illustrate its components, explain the theoretical framework, and discuss its assessment as a model for an innovative breastfeeding support intervention. Based on the self-regulation model from Bandura Social Cognitive Theory, we have developed an interactive web-based breastfeeding monitoring system using a breastfeeding diary. The system has two main components: the *Mothers' Portal*, where mothers can enter their breastfeeding data and receive notifications, and the *Lactation Consultants' Portal*, where mothers' data can be monitored. The system is designed to send notifications to mothers in case of breastfeeding problems using triggers such as inability to latch, sleepy infant, jaundice, and maternal sore nipples. A prospective, descriptive, mixed methods study was conducted to examine the feasibility, usability, and acceptability of LACTOR among breastfeeding mothers. Eligible mothers were asked to enter their breastfeeding data into the system daily for 30 days and then submit an online system evaluation survey. Twenty-six mother/infant dyads completed the study. Feasibility of the system was established by the mothers' compliance in entering breastfeeding data. The system proved to be user-friendly. The mothers said that the monitoring was beneficial and gave them an opportunity to track their children's feeding patterns and detect any problems early. Mothers also appreciated the notifications and interventions received through the system. We concluded that the system is feasible and acceptable among breastfeeding mothers and a promising tool for maintaining communication between mothers and lactation consultants.

Keywords Breastfeeding · Web-based monitoring · Self-monitoring · Self-regulation

This Manuscript describes the process of developing an interactive breastfeeding monitoring system, illustrates the components of the system and discuss its assessment in an effort to improve breastfeeding monitoring and follow up breastfeeding mothers after hospital discharge.

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Breastfeeding provides short and long-term benefits to both infants and mothers. It protects babies from many infections and illnesses including diarrhea, ear infections, and pneumonia. Breastfed babies are less likely to develop asthma, and those who are breastfed for 6 months are less likely to become obese [1, 2]. Prolonged and exclusive breastfeeding has been shown to promote brain development. Exclusively breastfed children had significantly greater vocabularies and higher verbal IQ scores than other children [3, 4]. Exclusive breastfeeding may also be associated with lower blood cholesterol concentration in later life [6, 7]. Mothers who breastfeed are at lower risk of breast and ovarian cancers, depression, and Type 2 diabetes [1, 5].

Breastfeeding is also cost effective. In a recent study, using costs adjusted to 2007 dollars, researchers found that if 90 % of mothers in the United States breastfed exclusively for 6 months, it would save $13 billion annually from reduced direct and indirect costs and the cost of

premature death. If 80 % of U.S. families breastfed for 6 months, $10.5 billion per year would be saved [2, 8].

According to the Breastfeeding Report Card 2010, the United States has met the *Healthy People 2010* national objective for breastfeeding initiation. However, rates of breastfeeding at 6 and 12 months as well as rates of exclusive breastfeeding at 3 and 6 months are still low and only 13 % of infants are exclusively breastfed at the end of 6 months, which demonstrates the challenges mothers continue to face after hospital discharge [9].

In January 2011, the Surgeon General released a call to action to support breastfeeding [10]. The call stressed the importance of strategies that support breastfeeding after hospital discharge, including continuous lactation support to ensure that adequate breastfeeding is established, and post-discharge home monitoring and lactation counseling during the first month [10].

Post-discharge interventions that promote breastfeeding have been shown to improve breastfeeding outcomes. Lactation consultants recommend a breastfeeding diary for mothers to record breastfeeding, pumping sessions, and output in order to assess the establishment of breastfeeding [11]. Paper-based breastfeeding logs have been found useful in promoting self-regulation and full breastfeeding duration among primiparous mothers [12–14]; however, written logs are cumbersome to transport to clinicians' offices and require significant time to review. What is needed is an automated system that allows easy access to data by patients, providers, and lactation consultants.

A web-based intervention could provide continuous monitoring after discharge, maintain communication between the mother and lactation consultant, and optimize infant feedings. Interactive web-based breastfeeding monitoring followed by immediate lactation support could fill the gap between hospital discharge and the first post-discharge primary care provider visit. Furthermore, web-based breastfeeding monitoring should continue through the first month after discharge because this is the most critical period in establishing successful breastfeeding. Internet-based interventions are growing and their use is becoming integral to daily activities of global populations [15]. *This article describes an interactive web-based breastfeeding monitoring system, illustrates its components, explains the theoretical framework, and discusses its assessment as a model for an innovative breastfeeding support intervention.*

Theoretical Framework

The self-regulation model based on Bandura's Social Cognitive Theory provided the theoretical framework for this intervention. Bandura [16] proposes that self-regulatory systems mediate external influences and provide a basis for purposeful action, allowing people to have personal control over their own thoughts, feelings, motivations, and actions. The self-regulation model has three generic sub-functions. These include self-monitoring of the behavior, adoption of goals to guide one's effort, and self-reinforcement [17]. The self-monitoring response leads to self-evaluation and self-administered consequences that alter response frequency. Effective control over one's behavior is the product of self-monitoring, self-evaluation, and self-rewards [18] (Fig. 1). Self-monitoring can be defined as "awareness of symptoms or bodily sensations that is enhanced through periodic measurement, recording, and observation to provide information for improved self-management" [19]. Goal-directed people use self-observation, self-monitoring, and self-recording to selectively attend to and perceive information that bears upon their goals. Self-monitoring is an essential part of self-regulation. Self-monitoring is the first stage in the multistage model of self-regulation [19].

The self-regulation model and self-monitoring have been used as a theoretical framework for management of chronic illnesses such as asthma, diabetes, heart disease, and obesity [20, 21] and can be adopted to explain the effect of breastfeeding monitoring on mothers' self-awareness and recognition of breastfeeding problems. Self-monitoring can be done informally (making notes on index cards) or formally (using predesigned data sheets). In any case, self-monitoring should gather necessary information but not become too lengthy or complex. The individual will lose motivation to continue monitoring if the procedure is overly time-consuming or inconvenient.

Developing a self-monitoring habit among breastfeeding mothers can help mothers develop self-awareness and regulate their breastfeeding behavior. Monitoring their progress using a breastfeeding diary will help them develop awareness of the signs of early breastfeeding problems and inadequate feeding. Comparing their data to the criteria for effective breastfeeding and receiving feedback will help them resolve breastfeeding problems. Identifying and

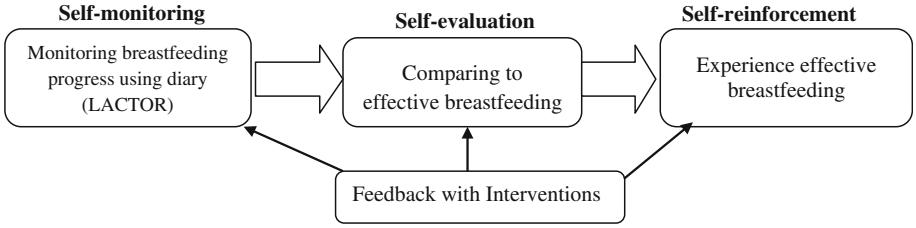

Fig. 1 Self-regulation model applied to breastfeeding

overcoming breastfeeding difficulties will motivate mothers to continue breastfeeding (self-reinforcement).

The Breastfeeding Monitoring System (LACTOR)

LACTOR, the name of the interactive breastfeeding monitoring system that the authors built, uses a breastfeeding diary developed and tested by the researcher. The diary includes times, frequency, and duration of breastfeeding sessions; number of dirty and wet diapers; latching problems; supplementation; pumping; the infant's alert state; and maternal breastfeeding problems (Table 1). The system also recognizes patterns in responses that indicate breastfeeding problems, such as difficulty with latching, infants who are too sleepy, jaundice, mothers' breast engorgement, and inadequate breastfeeding entries. When the system recognizes a breastfeeding problem, it sends suggestions to the mother for solving the problem, at the same time alerting the lactation consultant.

Components and Features of LACTOR

The system has two main components: the *Mothers' Portal*, where mothers can enter breastfeeding data and receive notifications (www.lactor.org), and the *Lactation Consultants' Portal*, where lactation consultants can monitor mothers' data, send the system evaluation survey, and download the data into comma-separated values that can be easily read using a program like Microsoft Excel to facilitate statistical analysis (www.lactor.org/admin).

Mothers' Portal Functionality

Login, Adding, and Modifying Entries

Mothers are invited to the system by the lactation consultant. Upon invitation, the mother receives an e-mail with a temporary password. The first time a mother logs in, she is asked to change the password and input demographic information. She is then directed to the main "add entry" page (Fig. 2). The "add entry" screen has four tabs for adding data related to breastfeeding, supplementations, output, and health issues. Through the "add entry" tab, the mother can add, modify, and view her entries and notifications. The mother can enter her data at any time and can add more than one entry each time she accesses the system. If all data are entered correctly, without any missing items, the mother receives a confirmation message. The mother also can modify her data within 48 h to correct any incorrect entries. Through the "breastfeeding tab," the mother enters the duration of breastfeeding for each breast, indicates whether the baby is latching or not, and notes the infant's alert state, mother's breast problems, and pumping

Table 1 Breastfeeding diary

Day/Time	Breastfeeding duration		Latching	Infant State	Supplementation Amount/type/method	Output		Pumping Methods/amount	Maternal Breastfeeding Problems
	Left	Right				Urine	Stool		

Variables Alternatives

Breastfeeding duration
a. 1-2 minutes
b. 3-4 minutes
c. 5-10 minutes
d. 10-15 minutes

Latching
a. Not at all latch correctly
b. Slipping off the breast
c. Latch with nipple shield
d. Latch correctly

Infant state
a. Difficult to awake
b. Drowsy (semi- dozing)
c. Quite alert
d. Active alert
e. Crying

Supplementation
Type
a. Expressed milk;
b. Pasteurized human milk
c. Formula
Method
a. Bottle
b. Cup
c. Supplemental set

Output
Urine (color)
a. Amber yellow
b. Dark yellow
Diaper Saturation
a. Slightly wet
b. Moderately wet
c. Heavily wet

Output
stool color
a. Black/tarry
b. Black/tarry
c. Yellow
Consistency
a. Seedy/lose
b. Formed
c. Watery

Pumping: a. Hand pump b. Manual hand pump c. Double electric pump

Breastfeeding Problems: a. Breast tissue is soft/no milk coming in b. Sore nipples c. Flat/inverted nipple d. Engorgement e. Mastitis

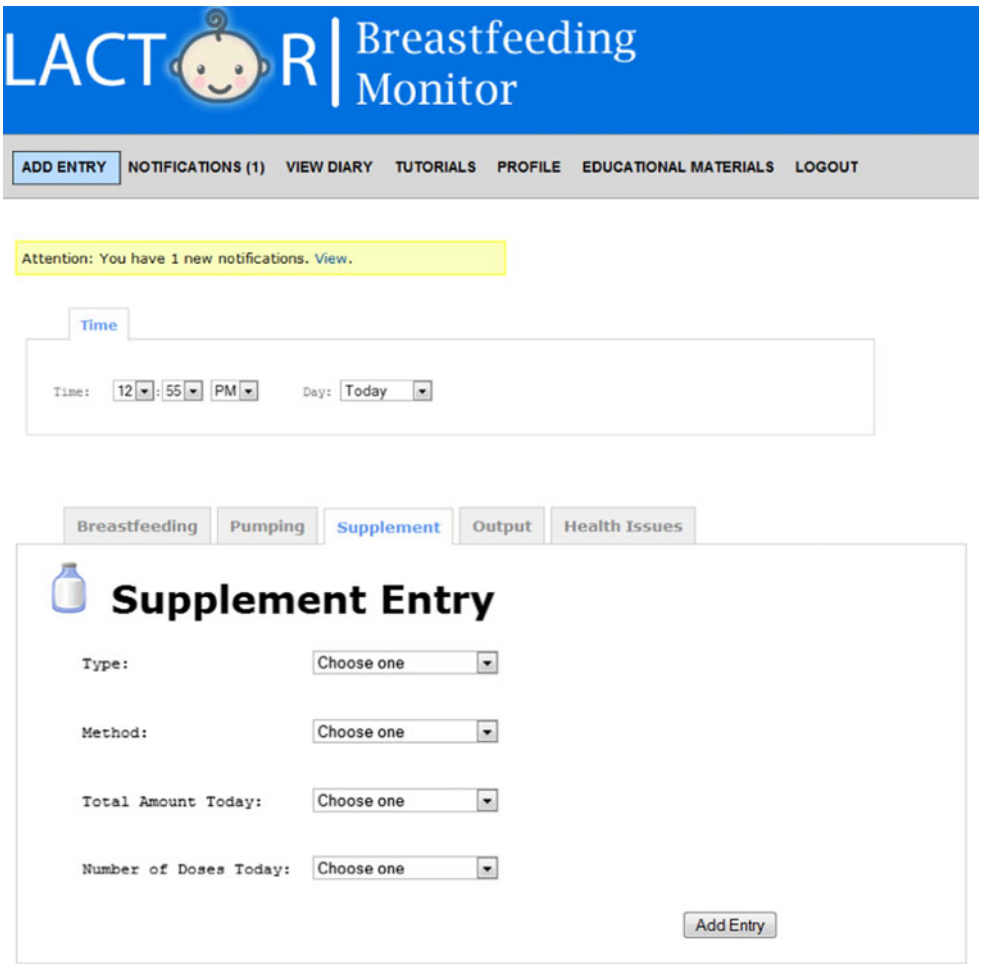

Fig. 2 Screen shot form LACTOR data entry/ supplement/mother portal

information. The mother can choose data from a dropdown box with alternatives for each item.

The "supplementation tab" displays data related to the types and methods of supplementation, while the "output tab" displays data about the number of wet and dirty diapers with the color of the urine and consistency of the stool. Through the "health issues" tab the mother can indicate whether her baby has developed any health problems after hospital discharge such as jaundice, dehydration, weight loss, decreased blood glucose, decrease in body temperature, or infection.

Viewing Entries and Notifications

The mother can display all her previous entries at any time and check her entries and adequacy of breastfeeding. She also can choose to view past entries from any date by changing the date range parameters. This allows mothers to compare their daily data and monitor their progress. It also helps mothers detect any problems and see any need for improvement.

The system is designed to send notifications to mothers using triggers such as the infant's inability to latch, inability to wake up for feeding, or jaundice, as well as mother's breast engorgement, sore nipples, or insufficient breastfeeding entries (fewer than six times/day). The system gives notification through an "alert banner" that is displayed on the screen. Both the mother and the lactation consultant receive a notification through the system as well as through e-mail. The mother is expected to acknowledge that she received the notification and once a notification is acknowledged, it is grouped with previously issued and acknowledged notifications. Notifications that have not been marked as read persist in the notifications tab to make sure the mother reads her notifications. The notification message sends intervention steps to help mothers maintain milk secretion, such as "pump every 2–3 h" or "contact your lactation consultant." if the baby is not latching. The system is also designed to make sure that the lactation consultant reads the notification to be aware of the mother's problem.

Tutorials and Profile

To help mothers understand how to use the system, we developed three video clips that explain how the system

works. The tutorials encompass all functionalities of the system including adding entries, reading notifications, and managing the mothers' accounts. The tutorials are at a sixth grade reading level and last from 3 to 5 min. They come in the form of embedded *YouTube* videos inside the system (http://www.youtube.com/watch?v=b-l7TwIW4fM). Through the "profile tab," mothers can view and administer their information. They can also change their password and see the demographic information they entered during registration and the information entered by the lactation consultant about their infants.

Lactation Consultant Portal Functionality

The Lactation Consultant portal has four tabs that organize its functionalities: dashboard, notifications, data displays, and managing mothers' accounts (Fig. 3).

Dashboard, Notifications, and Display Data

Lactation consultants can monitor mothers' entries daily to provide the best possible feedback. To achieve this, the first screen displayed upon login is the dashboard, which displays information on the latest entry for each mother for the current date. Through the "notification tab," the lactation consultant can view, query, and download notifications for mothers. Through this tab, the lactation consultant can also acknowledge that she read a notification. Mothers' data can be retrieved through the "display data" tab. There is great flexibility in terms of query parameters; they can be search by date and by mother/s. Queries can be downloaded in CSV format to be manipulated in Microsoft Excel.

Mother Accounts

In this section, an administrator can issue new lactation consultant or mother accounts. Upon issuing an account, an e-mail is sent to the user with a randomly generated password, and a login credential is created in the database. Different login states will activate as soon as the mother logs in.

Mobile Version of LACTOR

The mobile version of LACTOR has most of the functionalities of the system and mothers can enter and display their data through their Smart phones (mLACTOR).

Confidentiality and Technical Support

Our web application is hosted on a secure server maintained by Purdue University's Department of Computer Science. Access to the server is limited to team members and protected through user name and password. Lactation consultants can only access their own mothers' data, so the privacy of mothers is guaranteed. Moreover, the system is designed to ensure the protection of all data. We have secured the site with an SSL certification and the information to and from the site is encrypted. In addition, the

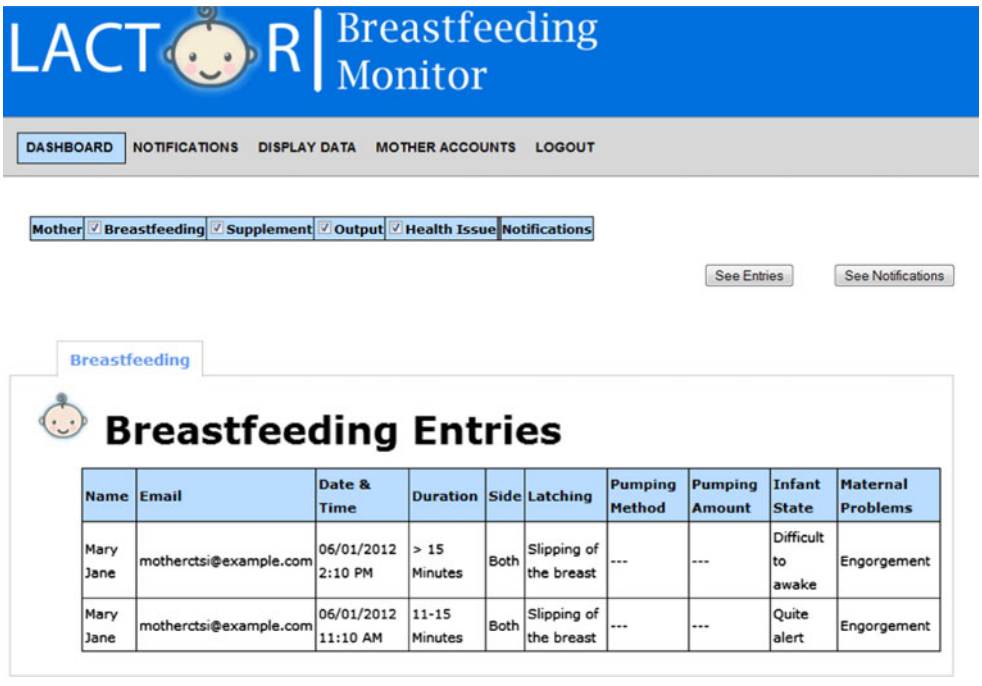

Fig. 3 Screen shot from LACTOR/lactation consultant portal

system server is positioned in a professional data center and is physically secured against fire, forcible entry, or vandalism. Professional web-builder and database experts are available for support in case of problem or emergencies. Mothers can send a report of any technical problem to the support system.

Assessment of LACTOR

We have conducted a prospective, descriptive, mixed methods study to examine the feasibility, usability, and acceptability of LACTOR among breastfeeding mothers. Feasibility was defined as the mothers' compliance in entering their breastfeeding data, completing the breastfeeding diary daily, and reading their notifications. Usability was defined as mothers' responses about the ease and user friendliness of the system, while acceptability was defined as mothers' responses about their experience in using the system and data entry. Mothers were asked to enter their breastfeeding frequency data, infant outputs (wet and dirty diapers), pumping, supplementation, and any health problems into the system daily for 30 days and then submit online surveys including a usability scale and their perceptions of the system. We invited 50 mother/infant dyads to use the system and 26 mothers completed the study. Ten mothers stopped breastfeeding after discharge, and another 10 did not complete the study for various reasons, such as maternal postpartum complications, infant re-hospitalization or computer problems. Four mothers could not be reached.

Feasibility of the system was established by the mothers' compliance in entering their breastfeeding data daily. The majority of the mothers entered their infants' output daily and read their notifications. The system proved to be user-friendly. In a content analysis of mothers' perceptions of the system, three themes were identified including recognizing infants' feeding patterns and problems; usefulness of the notifications in preventing or minimizing breastfeeding problems; and convenience and ease of the mobile version [22]. The mothers said that the monitoring was beneficial and gave them an opportunity to track their children's feeding patterns and detect any problems early. Mothers also appreciated the notifications received through the system. We concluded that the system is feasible and acceptable among breastfeeding mothers and a promising tool for maintaining communication between mothers and lactation consultants [22]. Results from this study and mothers comments will be used to upgrade LCATOR and add more educational material such as preparing to go back to work/school, working and breastfeeding, how to deal with fussy infant, and understanding infant's breastfeeding behavior. In addition, we will use graphs to display mothers' data and add positive notifications to enhance mothers' breastfeeding confidence.

Implications to Clinical Practice

This system represents a major and critical step toward improving breastfeeding success and maintaining communication between mothers and lactation consultants after hospital discharge. The system allows the lactation consultant to monitor mothers' breastfeeding data after discharge and intervene immediately in case of any breastfeeding problems. It also allows the mother to display her current data as well as previous data, allowing her to follow her progress in breastfeeding and identify problems. The system may also improve the quality of mothers' breastfeeding experiences by making available information to deal with any breastfeeding problems.

The daily diary approach is an important step in self-monitoring that helps mothers develop self-awareness of the early signs of breastfeeding problems, which reinforces their ability to identify and overcome breastfeeding difficulties. The web-based monitoring system facilitates continuous monitoring of infants' daily feedings and output, and mothers receive immediate feedback about when they should seek help from a lactation consultant. In addition, there is daily monitoring by a lactation consultant who can call the mother directly in case of a breastfeeding problem.

This is the first web-based software that allows 24/7 breastfeeding monitoring. Currently, no other software is tailored for continuous breastfeeding monitoring by lactation consultants. There are software applications for a breastfeeding diary available in the market; however, they do not give a lactation consultant access to mothers' breastfeeding data. With LACTOR, the lactation consultant portal allows the lactation consultant to monitor all mothers' data and provide immediate intervention. The interactive feature alerts the mother about her baby's breastfeeding problem and provides simple interventions to solve the problem.

Continuity of care in breastfeeding is a main step to successful breastfeeding. Action 8 in the Surgeon General's Call for Actions to Support Breastfeeding stresses the importance of developing systems to guarantee continuity of skilled support for lactation between hospitals and healthcare settings in the community [10]. LACTOR has the potential to be implemented in different clinical settings such as hospitals' postpartum units, pediatricians' offices or primary care settings, lactation consultants' private offices, and Special Supplemental Nutrition Program for Women, Infants and Children (WIC) offices. LACTOR can be used as a community-based intervention to enhance

the communication between hospitals and primacy care settings and ensures the continuity of care for breastfeeding mothers as recommended by the U.S. Department of Health and Human Services [9].

Acknowledgments This study was funded by a grant from the International Lactation Consultants Association (ILCA).

Conflict of interest The authors declare no conflict of interest for this article.

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