

Grant Final Report

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**MyMediHealth: A Paradigm for Children-centered
Medication Management**

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Structured Abstract

Purpose: Issues with medication adherence remain paramount in patients with chronic disease. Tailored text messaging may provide an opportunity to allow patients to improve medication adherence.

Scope: The goal of this study was to assess the impact of personal medication management tools featuring mobile reminders on medication adherence in adolescents with asthma.

Methods: We used a user-centered design approach. After obtaining baseline data, children and their parents were randomized either to receive access to a website called MyMediHealth where they could create medication schedules and generate medication reminders, or to receive standard therapy and education. After 3 weeks, intervention and control subjects completed repeat testing to assess adherence and to examine symptoms. In addition, a sample of intervention families received a home visit from members of our team to assess the home environment and its readiness for home personal health record-based interventions.

Results: A total of 89 children completed the study with 46 children randomized to the MyMediHealth group. There was no significant difference in baseline symptom frequency, rescue inhaler use, and self-reported medication adherence between the 2 groups. Repeat testing demonstrated significant improvement in controller adherence in the MyMediHealth group compared with the control group ($p = .011$). We observed no change in asthma control between the two groups ($p = 0.728$). However, quality of life and self-efficacy measures demonstrated mild improvement ($p = 0.016$ and $p = .037$, respectively).

Key Words: medication adherence; short messaging service (SMS); text messaging; medication scheduling

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Final Report

Purpose

Introduction

The last mile of the medication use system requires tools to help patients comply with medication administration guidelines and to monitor for side effects. Personal health records (PHRs) and emerging user-adopted communication tools promise to change the landscape of medication management; however, no research has been done to demonstrate how these tools might be constructed to support children and adolescents with special healthcare needs. The overarching goal of the MyMediHealth project was to investigate ways in which PHRs and supported applications can improve the safety and quality of medication delivery in this population.

This project employed user-centered design to identify requirements for a child-centered medication management system. We collected information through site visits, facilitated group discussions, and iterative design sessions with adult caregivers. Once design requirements were articulated and validated, we constructed an initial prototype medication scheduler, which was evaluated by 202 parents using scripted activities completed using an online interactive prototype. The results of this analysis informed the development of a working prototype.

Purpose

Personal health records (PHR) and emerging user adopted communication tools promise to change the landscape of medication management. The overarching goal of the MyMediHealth project is to investigate ways in which PHRs and supported applications can improve the safety and quality of medication delivery. MyMediHealth was envisioned to allow parents, patients, and caregivers to ensure safe and effective medication delivery.¹ This vision featured just-in-time medication reminders to children with special health care needs (CSHCN), two-way communication to log when doses have been administered or when side effects have occurred, and mechanisms to warn caregivers about side effects and drug interactions. However, much of this work was done using prototypes, storyboards, and vision videos. The goal of this project was to create a working version of MyMediHealth, and to test the hypothesis that medication adherence can be improved when children with chronic illnesses and their families are empowered with appropriate tools.

Scope

Background

Researchers and other stakeholders have described the potential benefits of personal health record technology to children with special healthcare needs,^{2,3} capitalizing on the call for patient centered care by groups such as the Institute of Medicine.^{4,5} Medication management is one area of potential benefit for PHRs, as recognized in 2005 in the Commission for Systemic Operability report⁶ and demonstrated by researchers at the National Library of Medicine.⁷ Medication administration is founded on “the five rights”– the right drug, in the right dose, by the right route (or way), at the right time, to the right patient – all of which may be improved through PHRs.^{8,9} Data suggest that as few as 34% of patients receive all doses of medication,¹⁰ mostly due to the realities of life – busy people, fragmented systems of care in the community, and a lack of appreciation for the importance of consistent adherence.

These realities are magnified in pediatrics. Medication dosing is more complex where multiple caregivers may be involved.^{6,11} This is especially true for the 12–19% of children with special health care needs who take multiple medications in a variety of forms throughout the day.¹² Data from this population are notable for the high prevalence of missed doses at school.¹³ Despite these data, there is very little research demonstrating the potential for child-centered medication management as a part of PHRs, when, in fact, PHRs may provide stakeholders with needed medication information (displaying the right drug for the right patient) and may trigger medication reminders (ensuring that doses are taken at the right time using the right route).

Therefore, the goal of our project was to design, develop, and evaluate a next-generation medication management personal health record for children with chronic disease.

Preliminary Work

After early work developing a knowledgebase of images to complement the information we used from the National Library of Medicine to enable our web site, we evaluated the feasibility of techniques to assess medication adherence. We enrolled a total of 53 English-speaking adolescents aged 13-17 and their parents who are followed in the pediatric pulmonary and general pediatrics/adolescent medicine clinics to participate in a one-month protocol utilizing three different methods to measure asthma adherence:

1. Retrospective self-report (survey at baseline and at the end of 1 month);
2. Doser CT (device attached to inhaler, with data downloaded by our research team at the end of 1 month); and
3. Interactive Voice Response (IVR-daily calls to the adolescent, using a pre-recorded voice system).

This study demonstrated that daily phone contact was feasible in this age group and more accurate than retrospective self-report, and that it provided richer data that can be used to tailor behavioral interventions. We were comfortable applying these results of feasibility from a

random phone call to a scheduled text-message reminder, and proceeded with our MMH design. In addition, because of concerns that IVR was subjectively good at reminding patients to take medications (as well as to record when they were administered) and might overly bias toward the null hypothesis, our team elected not to use this approach in concert with the text-message-based reminders that were under study.¹⁴

We will next describe the randomized trial of patients using MyMediHealth.

Context and Setting

The study took place in pediatric outpatient settings throughout an academic medical center. Participants were recruited from a variety of settings, including the adolescent medical clinic, the asthma and allergy clinic, a general pediatrics clinic and a pediatric emergency department.

Participants

Targeted patients included English-speaking adolescents (from either Spanish or English-speaking families) between the ages of 12 and 17 with a diagnosis of asthma and who were prescribed a chronic medication for its control.

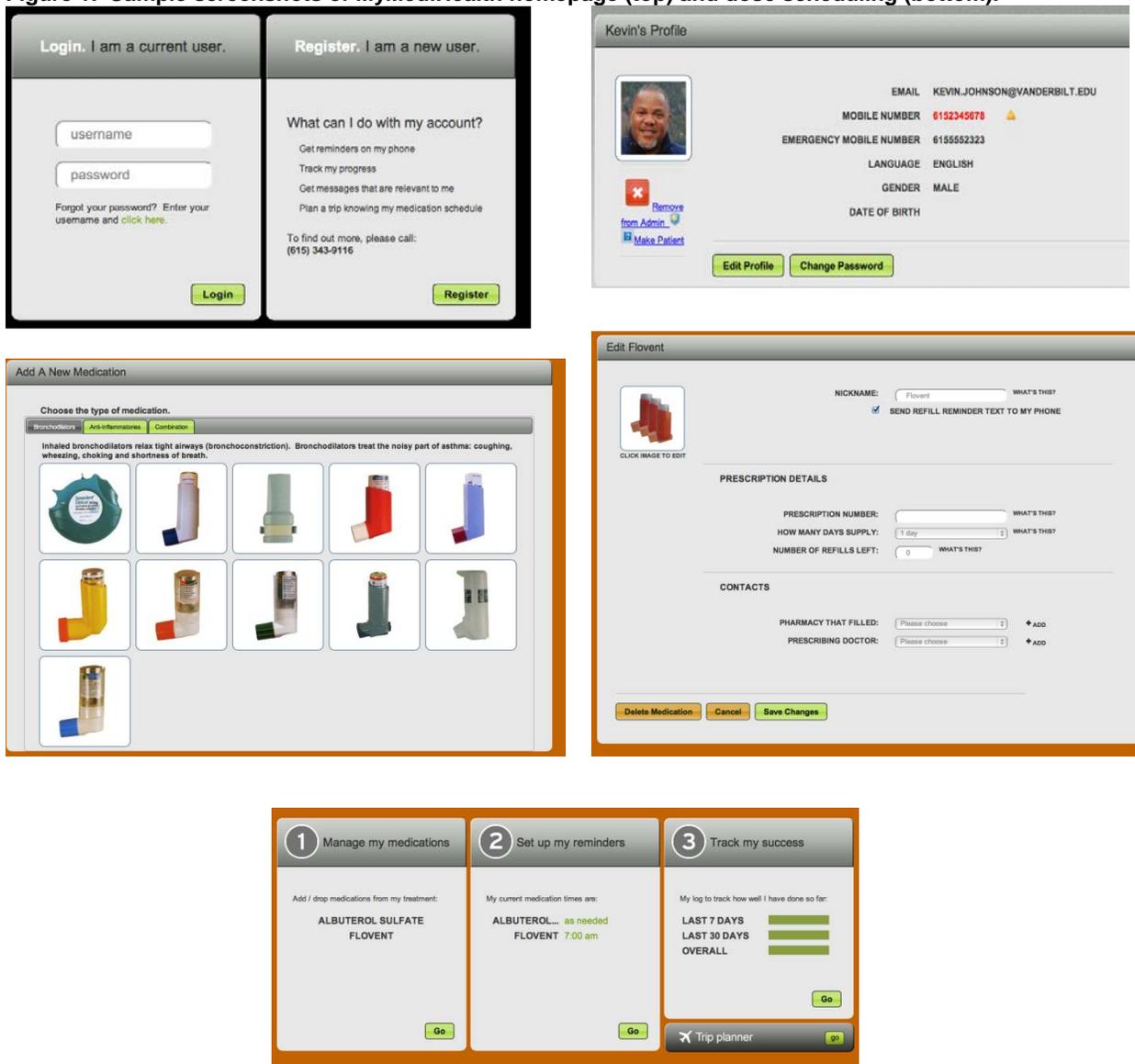
Methods

The study utilized a personal health application called MyMediHealth (MMH), a web-based tool for entering and managing medications developed by some of the authors and described more fully elsewhere.¹ The MMH system supports SMS medication reminders that patients may schedule to receive at desired times.

Figures 1-3 are snapshots of MMH (Figure 1) and reminders received by a user via their cell phone (Figs 2 and 3). To use MMH, a user first logs in and creates a profile, including a cell phone number (not shown.) The system automatically sends a text message to the number, requesting a response to verify the accuracy of the number and the carrier. Upon verification, the patient can log in and begin creating their medication list and schedule, as shown in Figure 1. For each medication, MMH includes a picture, or allows the user to create an icon based on the color and shape of the medication. All medication names are coded using the National Library of Medicine's RxNorm standard.¹⁵ Once entered into MyMediHealth, the medication schedule data works with a separate application to generate reminders, as shown in Figure 2.

MMH generates reminders based on time of administration, and will combine multiple medications into one reminder.

Figure 1. Sample screenshots of MyMediHealth homepage (top) and dose scheduling (bottom).



Users are able to reply to a reminder in two ways. First, users may type the first letter corresponding to (T)aking, (S)kipping, or (H)olding a dose (Figure 2). When a dose is taken or skipped, MMH creates an entry into an online medication administration log with the appropriate outcome. When a dose is held, MMH asks the user when they expect to take the drug (in # hours from now) and automatically generates a reminder for that time. Second, In addition to these shortcuts, MMH is constructed to support a natural language response, based on work done by Stenner and colleagues, and shown in Figure 3.¹⁶ This approach is the way in which a user is able to record that they took a medication on their list that is not scheduled (such as an “as-needed” bronchodilator.)

Figure 2. Sample text message dialog.

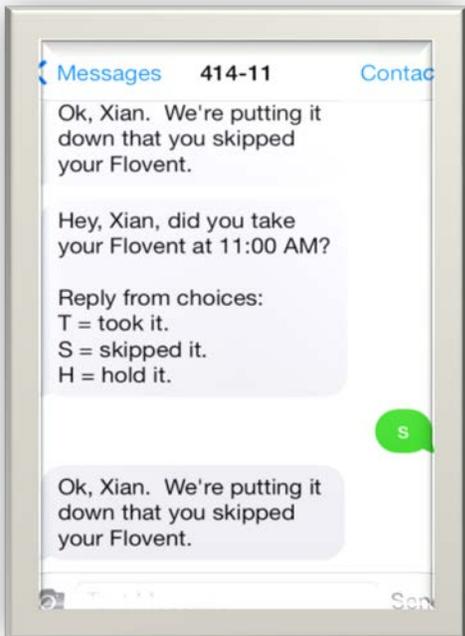
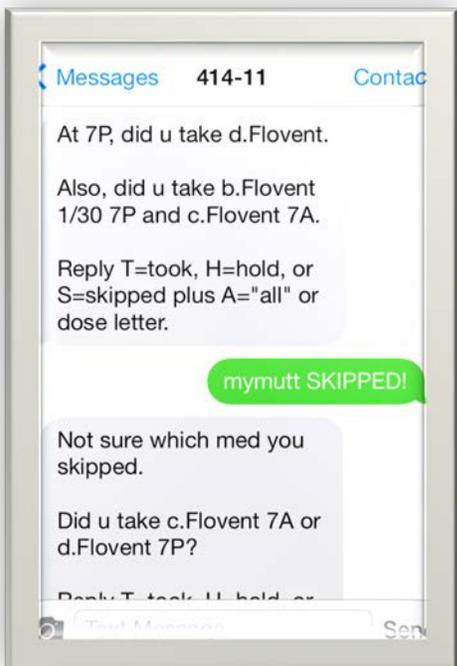


Figure 3. "Combination" text message. MMH creates a single text message for unanswered doses or simultaneously scheduled doses.



Study Design

The study used a randomized, controlled design in which Participants were block randomized into either the Intervention or Control group after enrollment and completion of a baseline survey to ensure equivalent randomization to groups during the entire recruitment period.

Participants were recruited through a variety of methods. We placed flyers and interest card boxes in three locations with high volumes of patients who were diagnosed with asthma (adolescent medical clinic, asthma and allergy clinic, pediatric emergency department, and general pediatrics clinic) and a study advertisement was placed on the medical center's research notifications listserv. Additionally, adolescent patients diagnosed with asthma were identified by a clinician on the study team and sent study recruitment letters via postal mail. Participants from a previous related study¹⁴ who had indicated they were interested in participating in future studies also were re-contacted. A research assistant on the team assessed all interested parent-adolescent dyads for eligibility over the phone. Eligible participants were English-speaking, between the ages of 12 and 17 years old, prescribed an asthma medication, able to access the Internet, and in possession of a cell phone with SMS capabilities. Verbal consent and assent were obtained from parents (or guardians) of eligible adolescents and the adolescents themselves, respectively. The parent and adolescent then each received a link to separate online baseline surveys. An option of completing the baseline survey over the phone also was available. Investigators confirmed consent at the beginning of the baseline survey. A follow-up survey containing some of the same measures collected at baseline was then completed at the end of the 3-week trial.

Data Sources/Collection and Measures

Survey responses were collected from all adolescents and their parents at two time points (baseline and follow-up at the end of the 3-week trial.) Additional information about the MMH system was collected from usage log data and home visits conducted with Intervention participants.

The following types of information were collected from parents in the baseline survey:

- Family demographics
- Adolescent's asthma medication regimen
- Asthma Control Test (ACT)¹⁷
- Control medication adherence item: "On how many of the last 7 days did your child use his/her asthma control medication (e.g., Flovent)?" (Score ranging from 1 to 7 days)
- Perceptions of asthma medication (P-PAM, 14 items, 5-point scale ranging from 1 to 5, least to most negative perception - DePaola¹⁸)
- Adolescent's asthma management self-efficacy (5-point scale ranging from 1="Not at all sure" to 5="Completely sure")¹⁹

The following types of information were collected from adolescents in the baseline survey:

- Asthma Control Test (ACT, same as parent)
Control medication adherence item (same as parent)
- Asthma management self-efficacy
- Perceptions of asthma medication (C-PAM, 11 items, 5-point scale ranging from 1 to 5, least to most negative perception - DePaola¹⁸)
- Mobile phone and Internet use
- Barriers to asthma management (IMS – 5 items, 5-point scale scored from 1 to 5, ranging from least to most impairment - Logan²⁰)
- Quality of life (mini PAQLQ, 13 items, 7-point scale scored from least to highest quality²¹)

The follow-up survey at the end of the 3-week trial consisted of a subset of items identical to those assessed at baseline; both parents and adolescents responded to items regarding the adolescent's asthma control (ACT) and control medication adherence. Adolescents also provided information about asthma self-efficacy, asthma control (ACT), and quality of life (PAQLQ). Intervention adolescents received an abridged version of a usability survey known as the post-test usability assessment tool and answered open-ended questions related to their usage of various aspects of the MMH web site, SMS messaging system and their opinion of MMH's value to them.

Usage log data consisting of Intervention participants' activity on the MMH website (e.g., types of medications entered into the system, number of reminders set up) and SMS activity (e.g., responses to SMS medication reminders) were collected during the 3-week trial period. We excluded the first week of data to ensure that all participants received adequate time to log in and set up an account with at least one medication reminder in the MMH system.

In addition, a convenience sample of intervention participants was asked to participate in a home visit lasting up to 2 hours. The purpose of the home visit was to assess the home environment, conduct an interview regarding family asthma management routines in the home context, and assess MMH usability. The interviews were guided by the Asthma Impact Interview²², which is designed to explore caregivers' experiences with diagnosis and management of pediatric asthma. Teens and other family members present were encouraged to participate in the interview. The interview was enhanced by a walk-through of the home with the family, identifying important places (e.g. bathroom, kitchen cabinet) and artifacts (e.g. special medication bag, or box) that figured into the family's strategy for managing asthma at home. The interviewer used video to capture the walk-through, allowing the participant's verbal description of the role of the place or artifact to be captured in context with an image.

Intervention

Participants assigned to the intervention group were instructed to sign up for a MMH account and to set up 1 or more medication SMS reminders. To ensure that participants were able to use MMH, a research coordinator monitored participant activity for the first week and attempted to contact participants to troubleshoot any issues regarding MMH use that may have surfaced. For participants who failed to activate a MMH Account and add at least one medication into the system within that 1 week period, the research coordinator determined if this was due to technical issues, and, if not, conducted a brief interview to understand why the participant did not sign up for the MMH account. If the participant chose not to participate any longer, s/he was dropped from the study. If the participant was not accessible at the 1-week mark, the RA continued to make approximately 3 attempts to contact the participant. Intervention participants were responsible for SMS costs incurred for this study.

The Vanderbilt University Institutional Review Board approved all study methods.

Data Analysis

Intervention and control characteristics collected at baseline were summarized with descriptive statistics (mean \pm SD or frequency). To determine if there were any differences in characteristics between groups, we used a Wilcoxon test and Pearson's Chi-square test for categorical variables and likelihood ratio test of the proportional odds model for ordinal variables. Responses collected from adolescents and their parents about asthma control and medication adherence in the follow-up survey were compared to those collected at baseline using a Wilcoxon test. Adolescents' responses to asthma self-efficacy and quality of life scales were also compared between the two time points using a Wilcoxon test. MMH usage patterns were examined and categorized qualitatively by two co-authors (KBJ and YXH). Differences in usage and responses to the usability survey were examined and compared between subgroups in the Intervention group using Wilcoxon and Pearson tests and comments were reviewed and described qualitatively.

Results

Figure 4 summarizes the results of our enrollment process. There were 159 dyads contacted by our research team for eligibility assessment. Of these, 98 were determined to be eligible for the study. One of the most common reasons for exclusion was that the parent (and/or child) declined to participate (19 parent-child dyads). All remaining dyads were randomized after completion of their baseline surveys.

Figure 4. CONSORT Trial Diagram

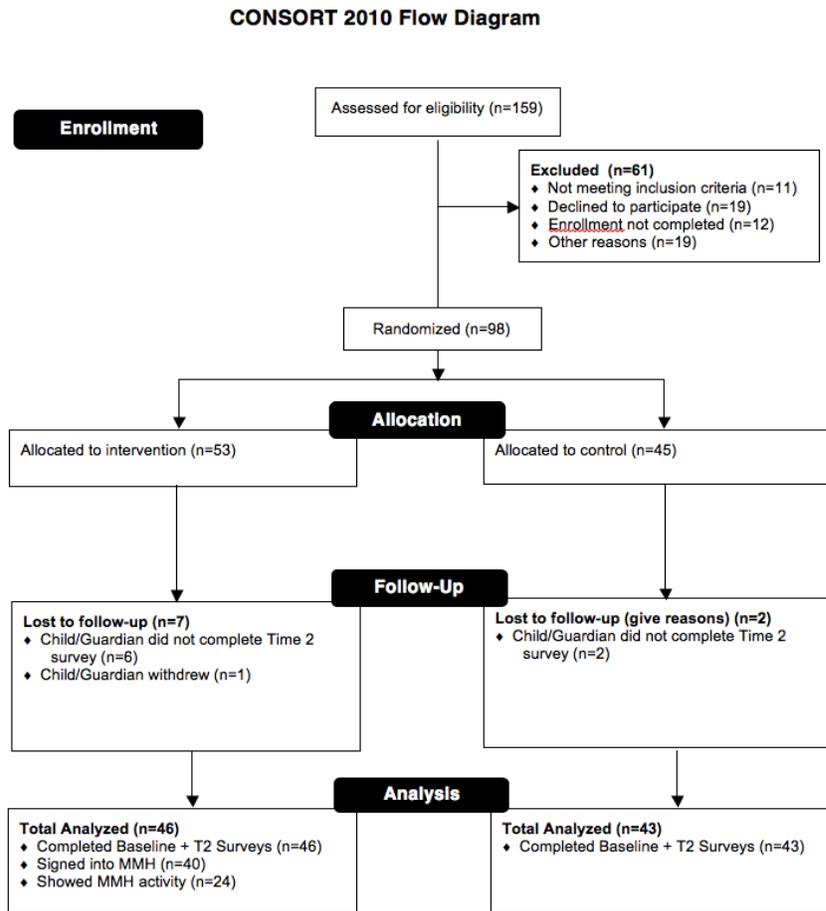


Table 1 summarizes demographic information and other measures collected at baseline for control and intervention groups. There were no statistically significant differences between the 2 groups; however, there was a trend towards significance in whether the child needed to earn his/her mobile phone. Notably, both groups had similar scores of self-reported asthma control and medication adherence, as measured by the ACT and SDSA, respectively.

Table 1. Summary of Control and Intervention Group Baseline Characteristics.

	N	Control (N=43)	Intervention (N=46)	P-value
Age	88	13.93±1.54	14.17±1.83	0.644 ¹
Gender	89			
Male		53% (23)	48% (22)	
Female		47% (20)	52% (24)	
Race	89			0.273 ²
White		47% (20)	46% (21)	
African American		47% (20)	50% (23)	
Hispanic		0% (0)	4%(2)	

Other ³		7% (3)	0% (0)	
Family Income	89			0.389 ²
Less than \$20,000		26% (11)	33% (15)	
\$20,001-\$40,000		16% (7)	28% (13)	
\$40,001-\$70,000		19% (8)	15% (7)	
More than \$70,000		16% (7)	13% (6)	
Declined to answer		23% (10)	11% (5)	
Parent/Guardian Education	89			0.422 ²
Some high school		33% (14)	48% (22)	
High school degree		9% (4)	11% (5)	
Some college, no degree		28% (12)	24% (11)	
College degree		21% (9)	15% (7)	
Graduate degree		9% (4)	2% (1)	
Adolescent needs to earn phone	89			0.083 ²
Yes		19% (8)	7% (3)	
No		81% (35)	93% (43)	
Type of asthma inhaler	89			0.250 ²
Rescue		33% (14)	22% (10)	
Rescue + Control		67% (29)	78% (36)	
Asthma control				
Adolescent	89	19.37±3.75	19.13±3.96	0.951 ¹
Parent/Guardian	89	19.37±4.34	19.02± 4.11	0.570 ¹

Medication adherence (Rescue+ Controller subjects only)

Adolescent	65	5.17±2.22	4.25±2.06	0.058 ¹
Parent/Guardian	65	5.34±2.24	5.06±2.35	0.762 ¹
Self-Efficacy				
Adolescent	89	4.31±0.45	4.04±0.66	0.089 ¹
Parent/Guardian	89	4.46±0.56	4.30±0.57	0.107 ¹

Perceptions of Asthma Medication

Adolescent	89	1.87±0.63	2.11±0.67	0.063 ¹
Parent/Guardian	89	1.72±0.76	1.82±0.73	0.437 ¹
Quality of Life - Adolescent	89	5.90±0.90	5.36±1.36	0.107 ¹
IMS - Adolescent	89	2.37±1.01	2.66±0.91	0.200 ¹
Num. of times child absent from school in the last month because of asthma	89	0.58±1.72	0.48±1.60	0.433 ¹
Num. of times child had to go to doctor's office because of asthma	89	0.44±0.91	0.59±1.02	0.466 ¹
Num. of times child had to go to ER because of asthma	89	0.16±0.53	0.15±0.42	0.659 ¹
Num. of times child admitted to hospital because of asthma	89	0.05±0.31	0.07±0.33	0.618 ¹

$x \pm s$ represents *Mean ± 1 SD*

N is the number of non-missing values

¹ Wilcoxon test; ² Pearson test

Use of MyMediHealth

Out of the 53 dyads enrolled in the MMH intervention group, 46 dyads with completed baseline and follow-up survey instruments were included in analyses. We analyzed the audit logs from our website to assess overall usage patterns. Out of the 46 enrollees, 6 (13%) did not sign into MMH to use the system. A total of 15 subjects (38%) did not enter any medications despite reporting the use of a controller and rescue inhaler; 6 (15%) patients who did enter medications did not create any reminders. Among these users, the primary barrier to MMH use could not be identified because participants could not be reached by phone or email.

During the study, intervention subjects logged into MMH an average of 2.5 times, with a range of 1 to 6 times over a 2-week period. There were 20 subjects who added asthma control medications (e.g., Flovent, Singulair), 18 subjects who added asthma rescue inhalers (e.g., Albuterol), and 8 subjects who added non-asthma-related medication (e.g., Clarinex, Flonase) to their medication lists. Participants entered a maximum of 2 control medications, 2 rescue medications, or 3 non-asthma medications. On average, participants who added medications added 1.4 (SD = 1.5) medications to their medication list, with a range of 0 to 5 medications. Figure 2 summarizes the potential flow of use from the home screen to the medication list creation screen to the medication alerts and reminders screen. As summarized in this figure, patients utilized all aspects of the MMH interface. In particular, vacation feature was examined by all patients, though the results of the vacation feature were printed by almost no patients. Based on usage patterns, we identified a subset of 24 (out of 46) participants in the intervention group who participated in at least one text message exchange recorded in the system usage log (“users”). There were no statistical differences in baseline characteristics between this subset and intervention patients who did not use MMH with regard to age, gender, family income, education, child’s need to earn cell phone or inhaler type between non-users and users. However, 77% (17) of intervention non-users were African American compared to 25% (6) of intervention users ($p = 0.001$).

As shown in Table 2, of the 21 (46%) intervention participants who set up medication reminders, 20 participants received reminders as requested. A total of 17 participants responded to their reminders, Participants received an average of 12 initial reminders (with subsequent SMS dialog as shown in Figures 2 and 3) over the course of the 2-week trial period. Based on responses to medication reminders accepted by the system, patients took their daily medication an average of 10 times over 2 weeks.

MMH was set up by 18 (39%) intervention patients to support rescue medication use; however, only 5 patients attempted to log their use of a rescue inhaler during the study period.

Outcomes

Table 2. Impact of MMH on Medication Adherence, perceptions of self-efficacy, and quality of life.

Table 2a. Asthma control

	N	Control (N=43)	Intervention (N=46)	P-value
Baseline, child	89	17.00 20.00 22.00 (19.37±3.75)	18.00 19.00 22.00 (19.13±3.96)	0.951
Study end, child	89	19.00 22.00 23.50 (21.12±3.28)	19.25 22.00 23.75 (20.78±3.72)	0.731
CHANGE, child	89	0.00 2.00 4.00 (1.74±3.35)	-0.75 1.00 3.75 (1.65±3.91)	0.728

Baseline, parent	89	16.50 20.00 22.50 (19.37±4.34)	17.00 19.00 22.00 (19.02±4.11)	0.570
Study end, parent	89	19.50 22.00 24.50 (21.40±3.22)	19.00 21.00 23.00 (20.63±3.19)	0.211
CHANGE, parent	89	-0.50 2.00 4.50 (2.02±3.81)	-1.00 1.00 4.00 (1.61±3.95)	0.564

Table 2b. 7-day controller adherence (controller subjects only)

Baseline, child	65	4.00 6.00 7.00 (5.17±2.22)	2.75 4.00 6.0 (4.25±2.06)	0.058
Study end, child	65	1.00 4.00 7.00 (3.83±2.47)	3.00 6.00 7.00 (4.86±2.44)	0.117
CHANGE, child	65	-3.00 0.00 0.00 (-1.35±2.61)	-2.00 1.00 3.00 (0.61±3.16)	0.011
Baseline, parent	65	5.00 6.00 7.00 (5.34±2.24)	3.00 6.00 7.00 (5.06±2.35)	0.762
Study end, parent	65	2.00 7.00 7.00 (4.93±2.63)	2.75 6.50 7.00 (4.83±2.55)	0.826
CHANGE, parent	65	-2.00 0.00 1.00 (-0.41±2.68)	-1.50 0.00 1.00 (-0.22±3.24)	0.707

Table 2c. Self-Efficacy

Baseline, child	89	4.00 4.25 4.69 (4.31±0.45)	3.41 4.13 4.59 (4.04±0.68)	0.089
Study end, child	89	4.00 4.38 4.63 (4.28±0.54)	4.00 4.38 4.75 (4.32±0.54)	0.662
CHANGE, child	89	-0.31 0.00 0.31 (-0.03±0.55)	0.00 0.25 0.72 (0.28±0.67)	0.016
Baseline, parent	89	4.20 4.60 4.80 (4.46±0.56)	4.00 4.40 4.75 (4.30±0.57)	0.107

Table 2d. Quality of life

Baseline, child	89	5.31 6.08 6.69 (5.90±0.90)	4.60 5.65 6.54 (5.36±1.36)	0.107
Study end, child	87	5.69 6.23 6.69 (6.05±0.99)	5.25 6.31 6.77 (5.89±1.18)	0.816
CHANGE, child	87	-0.08 0.08 0.69 (0.10±0.94)	0.02 0.35 0.96 (0.53±1.02)	0.037

In Table 2, *a b c* represent the lower quartile *a*, the median *b*, and the upper quartile *c* for continuous variables. $\bar{x}\pm s$ represents Mean±1SD. N is the number of non-missing values. A Wilcoxon test was used to compare control and intervention groups.

Table 2 summarizes the impact of MMH access on a number of outcomes. Compared with control patients, intervention patients had a significant improvement in self-reported 7-day adherence, with a gain of one day of adherence, and median change from 4 days to 6 days, compared with no median change in the control group (P= 0.011; median data not shown). These numbers were consistent with observed behaviors documented by MMH for the Intervention group.

Adolescent perceptions of self-efficacy also rose from a median of 4.1 to 4.4 (between “quite sure” and “completely sure” of self-efficacy in asthma management; p = 0.016). Quality of life increased from a median of 5.7 to 6.3 (on a 7 point scale) in the intervention group, compared with a small positive change in the control group (P = 0.037).

Patients who never received reminders from MMH had either worsening or unchanged measures of impact, including no change in 7-day self-reported adherence or perception of self-efficacy.

Attitudes About and Barriers to the Use of MyMediHealth. In our post-use assessment, participant attitudes towards the system ranged from neutral to positive depending on the aspect of the system queried. Average scores per item for users ranged from 56 to 86 (out of a possible 100) and for non-users, 68 to 83. There were no significant differences between user and non-user scores, except for one item in which non-users rated the ability to tell if an error or mistake was made using the MMH website an average score of 73 versus 57 for users ($p = 0.048$). Other relatively low-scoring items included “If I noticed an error or was alerted by the website that there was an error or problem, I was able to make the changes needed to fix the problem” (users: 56, non-users: 69) and “The website effectively alerts me to any potential errors or problems” (users: 68, non-users: 68). Highest scoring items (80 or greater) included the following: “I felt comfortable interacting with the MyMediHealth website”, “MyMediHealth is easy to learn”, and “The website has a pleasing and appropriate appearance.” A total of 78% (18) of users and 86% (18) of non-users expressed interest in continuing to use MMH. When asked why they would continue using MMH, most participants responded that MMH was helpful—“It reminds me to take my medicine” and “it might help me later on.” One non-user remarked, “I will continue to use MyMediHealth because it kind of help (sic) me with the medicine even though I really don’t know how to use it.” Another non-user said that MMH “didn’t work on my phone.”

Qualitative Data Summary. We conducted home visits with nine participants and their caregivers to explore how asthma is managed in everyday life and to conduct a usability interview regarding the MMH tool. The Asthma Impact and Family Routines Interview²² was used to structure the home visit, which also included a walk-through of the various physical spaces (e.g. bathroom, kitchen counter) and artifacts (e.g. backpack, plastic bag of medications) that were relevant to everyday asthma management.

Themes emerged that illuminated the context in which the participants managed asthma symptoms and medications. In the interviews, parents discussed not only their caregiving and advocacy activities, but also actions they took to help the young person transition to independent management of asthma. The themes below describe areas of independent illness management competency that emerged in the interviews.

1. **Establishing medication-taking routines.** Parents helped children establish medication routines that are connected to other routines, particularly in the morning and in the evening [“That’s when I become the nag. Have you brushed your hair, brushed your teeth and taken your meds.”] [“I’ve been showing him how to do it himself but it’s like nebulizer medicine, he still ain’t got to the point where he can mix, put it in there himself....[so] if he happen to be on the nebulizer, I do, I still do the medicine.”]
2. **Connecting the experience of symptoms to a well-defined action plan.** One measure of independence used by the parents was the child’s ability to express his or her physical status to others. [... “let me see how you are doing at football... so I let him go by himself and see if he’ll tell me how he feeling]. These parents complained that their children stopped talking and did not share with adults or others when they were having trouble breathing, resulting in teachers and coaches being surprised when asthma attacks

flared. When a crisis occurred, a well-defined plan was the key to success [“You have to make sure you have an action plan with the doctor and it really works and you got to make sure everybody that is associated with the child know the plan. If nobody knows the plan, the worst case scenario the parent is not like right there at that moment, and the child... we got to make sure he memorized the plan cause they could go and not remember the plan”].

3. **Advocacy.** Parents reported substantial activities in bureaucracy (filling out forms, getting forms signed by doctors) and advocating for the child with respect to the schools and health care institutions. Over time, this activity changes as the child transitions to less restrictive environments with respect to mediations, e.g. from school to workplace or college, but may take a different form, such as demonstrating a need for time off from work or school.
4. **Identifying triggers.** Parents discussed learning triggers as a long process of trial and error. Several had been instructed to keep their homes clean, only to eventually discover that fumes from cleaning products were much more of an asthma trigger than dust. Children knew their triggers, which were often remembered with cautionary tales, e.g. the time a child’s asthma got out of control on the 4th of July, sparklers used at a party produced smoke.
5. **Understanding the consequences of letting asthma get out of control.** The children were learning that a trip to the emergency room in the night meant feeling horrible the next day. Strategies for calming were important; in one case the child developed an approach using meditation, and another was soothed by his mother massaging his chest with aloe. Another parent worked with her child to develop several ways to manage stress, which was one of the child’s triggers, including prayer, listening to music, and writing.

Scheduling Medications & Reminders. All nine homes visited were for children participants who had an MMH account and user profile set-up. Five parents used the website and established or helped their child establish the account. Seven of the children (78%) who had created an MMH account also created a medication schedule with at least one medication and enabled the medication reminders feature. One child and their parent thought they were told that a member of the research team had set-up their medication schedule for them. Therefore, they never received any medication reminders and didn’t know that they could use such a feature. Once they were told about the medication reminders feature, both the child and parent expressed interest in starting to use their medication schedules and receiving reminders. Another child did not set up a medication schedule since, after setting up an account and logging into the MMH website a couple of times, they found the website to be confusing and didn’t really know where to begin or what to do. Therefore, the child stopped using the website shortly after setting up an account.

One subject was unable to schedule one of their medications. When trying to search for the medication to add it to her schedule, the medication appeared in the list as able to be selected. However, when clicking on the medication and after multiple attempts, the application would not respond and that particular medication was never added to the schedule. Therefore, this subject was only able to schedule 2 of her 3 medications. The only other medication scheduling issue

was that some subjects were unable to see the image of their medication when searching for it. This minor issue was experienced by 3 subjects and for only one of their medications. One of these subjects was able to resolve the issue and was able to view the medication image after logging back into the website and re-attempting to schedule that medication.

SMS Medication Reminders. All children who had requested to receive medication reminders by enabling this feature were able to successfully receive a medication reminder on time and respond to the reminder (i.e., confirming receipt of the reminder and indicating whether they: took the medication, “snooze” their reminder and be reminded later, or skip a scheduled medication dosage) for at least one medication.

All subjects who used the medication reminders feature, received their scheduled notification SMS successfully and on time. Two users had initial problems sending SMS responses, which are intended to allow the MMH system to register each text message received from a user as one of three responses (i.e., took it, will skip it, or remind me later) for each scheduled administration of a particular medication, but eventually figured out how to respond successfully, as confirmed in a follow-up response by the MMH text messaging system (e.g., “Way to go, <child’s first name>! We’re putting it down that you took your <medication name>.”), and continued to use the reminders for the duration of the study.

Another user had particular problems with reminders for medications that were scheduled to be taken at the same time. In these cases, MMH was designed, based on pilot testing feedback from teenagers (and as shown in Figure 3) to send one text message that simultaneously notified him/her that it was time to take all of those medications and instructed them about how to respond for each of the listed medications. The subject and their parent found the message, which contains multiple questions and instructions requiring multiple responses/messages, to be too confusing and complex. Therefore, after several tries and types of attempts (e.g., one text message reply with the response for each of the simultaneously scheduled medications, separate text messages for each medication listed), the subject gave up on simultaneously scheduling the medications. However, the subject was still able to receive and successfully respond to reminder messages for medications that were scheduled on an individual basis.

A minor issue was discovered that was due to features of mobile computing software and not the MMH application. It was found that users, especially those who had a certain type of smartphone, had to be careful about the auto-fill and auto-correct features and review their text right before sending their messages. Therefore, medication names in users’ text messages were auto-corrected and replaced with a different word after a user finished typing the word and hit send without noticing. This was particularly an issue with messages related to medicine since most of the names and terms are not recognized by the text messaging software. Table 3 summarizes the issues uncovered during these patient interviews.

Table 3. MyMediHealth Usage Issues

Issue	Solution
Getting an image corresponding to a medication in the knowledgebase to appear on screen	Unclear what the root cause of this was. Neither developer testing nor pilot testing disclosed this behavior. It is possible that the save button was not pressed.
Message that combined multiple simultaneously scheduled doses into one message was confusing.	Usability problem that will require additional testing and feedback.

Auto-correct feature sabotaging patient's attempt to send a text message about a med.	Device "feature" that will need to be discussed during training.
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Overall Impressions. On a scale from 1 (i.e., “disagree”) to 5 (i.e., “agree”), with an average rating of 4.8 ± 0.6 (mean \pm SD) and 85% of the home visit participants providing a rating of 5, the vast majority of the subjects indicated that they felt comfortable using the MMH software. With an average rating of 3.9 ± 1.5 and 69.2% of the subjects providing a rating of 4, the majority of participants felt that the MMH software was easy to learn. All but one of the subjects who participated in the home visits expressed an interest in using the MMH system in the future. The subject who said s/he wouldn't use it in the future liked the MMH website and reminder system but felt that s/he did not need it during the school year since the schedule creates a routine that helps to remember when to take medications. Many of the children and their parents seemed to really like the medication reminders feature the most since they often forget to take their medications. One child also mentioned that they prefer being reminded by their phone rather than having humans (e.g., parents or family) reminding them, which can seem like “nagging” or be “annoying.” One family, who found MMH to be very helpful, suggested that the study institution add the MMH system and functionality to their patient portal so that all patients and their families could manage their medication schedules, receive reminders, and use the other features (e.g., prescription refill reminders, medication compliance feedback reports, etc.) that they didn't even realize they could use until the demonstration during the home visit.

Discussion

A number of research projects have appeared in the past 3 years demonstrating the potential benefits of SMS-based reminders for patients with chronic illness.^{23 24} Though this is a small study, it is one of the first to demonstrate in a randomized, controlled fashion, even a short-term impact on medication adherence and perceptions of self-efficacy.

The use of SMS-based reminders for medication management holds much promise, given the pervasive nature of smartphone technology and computer literate young adults and children. This technology represents an obvious starting point for patient engagement and for teenager based self-care. Based on this study, a relatively straightforward web-based application was highly usable by children, viewed favorably by their parents, and was associated with short-term improvement in medication adherence. Home visits validated the extent to which children were able to use the site without adult supervision, as well as their overall level of enthusiasm for self-care using this tool.

The study's findings need to be considered in light of a number of limitations. First, despite user-centered design and pilot testing, there were a small number of persistent usability problems identified during home visits. It is likely, from an inspection of the audit log data, that other users had initial challenges using MMH that might be easily remedied with more testing and feedback. Second, although we used an intention-to-treat approach for this analysis, there was a subset of participants enrolled in the intervention arm who never logged into MMH. This subset was disproportionately African American, with no other distinguishing characteristic (other than a slight increase in the need for their child to earn the right to use his or her cell phone.) While this trend may turn out to be significant in a larger study, we are unable to identify the cause of this access disparity in this small study. Finally, our text-messaging service was unable to join

outgoing and incoming messages. We attempted to add an ID to the message itself, but this additional information was confusing to users during our pilot phase. This limitation had an impact on the ability for MMH to link messages to responses, and partially explains the challenges we experienced creating a clear message about multiple medications scheduled for the same time. In addition to these methodological or design limitations, it is important to recall that participants were required to have a cell phone with both texting and data service, as well as access to the Internet to set up the web site. While access to this sort of technology is commonplace, it is not universally available. In some cases, although patients have access to the technology, they are not facile with its use. Although we provided video tutorials for patients and families, we are not able to determine if they were necessary or sufficient training, though our home visits suggest that more training (or more assistance) might be required. Of note, our earliest prototypes for MMH included a number of features not studied in the project. For example, we did not include tools for medication reconciliation, links to information from MEDLINEPLus, or intelligent scheduling interfaces (ensuring that the timing of medications would not affect bioavailability or impact the likelihood of adverse events.) Given the results to date, we believe that a more comprehensive, mobile, medication management system will be viewed favorably by at least some patients. However, our results also suggest that a more complex mobile interface will require support from the healthcare system to be truly effective.

Behavior change is an extraordinarily complex subject in health care. We designed this initial version of MMH to address a specific population of patients whose problem with medication adherence is forgetting to take a routine medication. However, adherence behavior has been associated with a number of other barriers, as specific by the Information-motivation and behavioral (IMB) skills model,²⁵ among others. Using the IMB model as a guide, we hypothesize that MMH users might benefit from information about their medications and the reason to comply with dosing regimens, information about how to schedule medications, information about side effects; tools or system design that that increase motivation, self-efficacy, and social support; and skill training or tools to improve performance. We clearly have only begun to explore many of these determinants of consistent health behavior performance with this version of MMH.

Conclusion

Using an intention to treat analysis, we found a significant improvement in controller medication adherence, quality of life, and self-efficacy with the MMH intervention. Furthermore, while only about half of the MMH participants actually used the system, this cohort showed a significant improvement in adherence compared to those who did not use the system. Interestingly, we also found a significant difference in race between those who used the system and those who did not. Our results suggest that a text message medication reminder system such as MMH can potentially promote better asthma management in the adolescent population, though further research is needed to identify and address barriers to adoption that can preclude individuals from benefitting from such a system.

Significance

Adolescence is a uniquely sensitive and potentially stressful transition from child to adulthood. An adolescent with a chronic illness such as asthma is faced with additional responsibilities including managing medications and juggling illness management with school and extracurricular activities. Our study is one of the first to develop and investigate the integration of a relatively simple SMS reminder system into adolescents' daily routines to aid medication management. The continued development of systems such as MMH can potentially serve a dual role in improving the livelihood of adolescents with chronic illness as well as understanding their medication taking behaviors. Findings supporting improvement in self-efficacy and even short term quality of life should catalyze larger and longer-term testing of this medication management approach.

Implications

While findings from this study are somewhat limited in scope, we suggest that SMS-based systems such as MMH have the potential to support a variety of individuals varying in age and chronic illness, and extending far beyond medication adherence into tools that enhance self-efficacy for these patients caring for these illnesses as a part of their daily lives.

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List of Publications and Products

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