SMS is my BFF: Positive Impact of a Texting Intervention on Low-Income Children with Asthma

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ABSTRACT
Asthma disproportionately impacts the lives of children from low-income families. We conducted a three-month SMS intervention study with low-income children in a specialty pulmonology clinic. We found that participants that received either daily text messages or text messages on alternate days had improved lung function compared to a control group that received no messages. Moreover, children in the intervention groups reported being more emotionally connected to their pulmonologist after participating in the study. Qualitative analyses shed light on how the intervention impacted the participants. Children reported that it altered their medication management and enhanced their point of care interactions. Parent interview data indicated that the SMS messages led to increased child-driven communication about asthma. A comparative analysis of the present study with an earlier study showed greater benefits from the SMS intervention for the low- vs. middle- income cohorts. We discuss these findings in terms of how income status affects technology utilization and health outcomes. We also discuss implications for design of future studies that target pediatric patients in general and low-income patients in particular.

CCS Concepts
HCI, Empirical Studies in HCI, Health Informatics, Texting

Keywords
ICT; mhealth; Asthma; RCT; SMS; Low-income; Healthcare

1. INTRODUCTION
The World Health Organization defines asthma as a disease that causes inflammation of the airways and leads to recurrent episodes of breathlessness and wheezing. Worldwide it is the most common chronic disease among children [1]. Asthma affects about 10% of children in the United States [CDC], landing 1 in 5 patients in the emergency room. Like other chronic conditions, it disproportionately affects poor children and more severely so than their middle-income counterparts [2]. Asthma has dire consequences for children beyond their physical health. It accounts for the most absenteeism of all pediatric diseases [3,4].

American children from impoverished households are eligible to receive public health insurance, either state or national. In order to receive state health insurance, the family income needs to be less than or equal to 2.35 times the Federal Poverty Level (FPL). The FPL for a family of four is US $23.5K. Thus, in the US public insurance users are primarily from low-income households.

Short message systems (SMS) have emerged as technology to promote better asthma management in children [5, 6]. Studies have shown that patients that received daily text messages querying them about their asthma symptoms or about their asthma knowledge over a 4-month period had improved pulmonary function and improved perception of quality of life. The positive results from these studies raise a host of questions related to whether or not SMS intervention can benefit patients from low-income backgrounds. This is an important extension to previous findings because children from low-income backgrounds are disproportionately impacted by asthma and they have more negative outcomes associated with the disease. Thus, knowing if a low-cost option can be beneficial to this demographic would have wide implications. Further, it would be interesting to compare how children in two different income levels utilize information and communication technology (ICT) in general and an SMS intervention in particular. In this paper, we address the following questions:

- Do children with public insurance benefit from a text-based intervention as measured by psychological and physical health outcomes?
- Do individuals from different SES backgrounds reap different benefits?

The remainder of the paper is organized as follows. First, we present related work on chronic care management for low-income individuals. Next, we describe the study design, evaluation and results of the current study. We then present a comparison of these data to those from a previous study with a middle-income cohort of patients [6]. Finally, we discuss the implications that these results provide and suggest future direction for this domain.

2. RELATED WORK
This work builds on previous research that investigated the role of information and communication technology (ICT) for chronic care management.

2.1 ICTs for Chronic Care Management

PervasiveHealth 2016, May 16-19, Cancun, Mexico

DOI 10.4108/eai.16-5-2016.2263274

Previous research on healthcare technologies for families has focused on a wide variety of populations, including diabetics, elders, pregnant women, and children with special needs [18]. For instance, mobile applications facilitated synchronous medical communication between health care providers in supporting medical treatment to diabetic patients at home [19]. Another example used interactive web sites to support asynchronous communication between families and physicians for pediatric patients in an intensive care unit [20]. Additionally, teams of professional and family-based care providers cooperatively monitored health-related activities and shared the activity information in their daily routines with other relevant people through a variety of communication technologies [10]. However, challenges still exist for providing high quality care in teams, particularly for those as diverse as the teams supporting low-income children with asthma [21,22]. In particular, when health technologies are built to consider children, they typically target educational interventions rather than truly incorporating children into the communication and information sharing practices [18].

Following the increase in mobile device use, the study of mobile applications for chronic care is also increasing [7]. One of the current health management areas where a mobile application has been employed is in supporting communication between patients and physicians [8]. Communication tools to support patients and health care providers include: 1) telemonitoring, to monitor patients from a distance; 2) teleconsulting, to enable consultation between geographically separated individuals; and 3) patient education [9]. The dominant technologies to support communication include web applications, e-mail communication, and mobile phone (SMS and voice mail). Some studies for general health management or chronic care were assessed in ecologically valid settings, but they provided patients with additional digital equipment, and did not directly assess health outcomes [10]. Another challenge is that the communication mechanism needs to fit into the daily routines of clinical practitioners [9]. Evaluation of novel technologies in clinical settings is also challenging because labor is expensive as well as highly distributed across space and time in clinical settings, such as doctor's offices and hospitals [11]. Emerging technologies change the patient–physician relationship. This change might lead to improved pediatric asthma management.

2.2 Supporting High-Risk Individuals with Asthma

Pediatric asthma management requires substantial financial resources, education, and health care providers; asthma disproportionately affects low-income populations [12]. Poor children usually have a 40% higher rate of hospitalization and 40% lower rate of preventive ambulatory services. Additionally, low-income households have low health literacy, regardless of actual literacy [13]. Simply providing public health insurance is not enough to ensure access to care [14].

Consequently, many investigators have explored pediatric asthma management strategies that focus on these high-risk populations. Effective outpatient care is one of the solutions to prevent adverse health outcomes for high-risk populations. However, these populations typically rely on acute care instead of routine preventive care [15].

To address the needs of children with asthma in these populations, previous researchers developed and evaluated interventions including asthma education and outreach programs in various settings [16]. However, few controlled studies have been conducted with low-income individuals [15, 17]. There has been a call in the literature for future studies to consider the arrangement of the delivery system, particularly the availability of continuous care for these individuals [14].

Our intervention bridges the gap in the research space that encompasses low-SES pediatric asthma and ICT in three important ways. First we make the child the primary target of the intervention. Second, we use technology that the child is using already rather introducing a new ICT. A related advantage is that text-messaging is available in both feature and smart phones. This broadens the participation base. Third, the intervention is delivered in an ecologically valid setting, their pulmonologist's office, which is a continuous care setting.

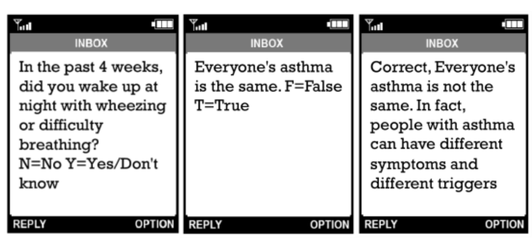
3. METHOD

In this study, the same protocol and ICT system was used as in two previous studies [5, 6]. Participants were recruited and enrolled in the study at the same time and in the same location as those in [5]. This is important because it provides a valid comparison between the two groups. Specifically, extraneous variables (i.e., time of year) are not causing differences in pre- and post- measures.

3.1 Intervention Rationale

We chose texting for the delivery of our intervention because data from a national poll indicated that American children that had cell phones preferred texting to other forms of communication [23]. We decided on the random control study procedure because we wanted to ascertain that there was a causal link between our intervention and health outcomes.

The Health Belief Model (HBM) [8,24] was central to our conceptualization of the design of the intervention. The HBM is a cognitive theory of behavior modification. The main idea is that cognitive variables (beliefs, perceptions, reflection/awareness) are important and drive behavior. The role that increased knowledge and awareness of asthma symptoms plays in improving health outcomes has been previously investigated [5,6]. The goal of raising the child's awareness about the effect of asthma on their life led us to present children with queries rather than simple affirmations (see Figure 1). In this study, children were asked to think about the severity of their asthma and how it has impacted their health and the medication they were taking (Figure 1, A) In the HBM, knowledge is also a variable. Thus, we decided to also query participants about asthma myths (Figure 1, B1). Once participants answered a query, they received a second text containing a factoid about asthma (Figure 1, B2). Fifteen symptoms and knowledge texts were used in this study (see [5] for the complete list).



(A) **(B1)** **(B2)**

Figure 1. Example texts: *Symptom* (A) and *Knowledge* (B1, B2)

3.2 Protocol and Measures

Study recruitment was conducted at a private pediatric pulmonology clinic in a Southeastern American city. The study protocol was authorized by the university's internal review board. Parents were approached with information about the study and were also presented with the inclusion criteria. The inclusion criteria were met if a child was at least ten years old, had previously attended a routine examination at the clinic, had unlimited text-messaging plan on their own cell phone and was able to read at a 5th grade level. Parents provided written consent and children provided written assent. In this paper, when we refer to participants we mean the children in the study. While a number of measures were collected from the parents, here we only report interview data.

While waiting for their appointment, participants filled out demographic information and surveys about asthma knowledge and technology utilization. We used two standard measures of health outcomes. The Pediatric Asthma Quality of Life Questionnaire [PAQLQ, 25] is a 7-point Likert-scale that assesses perception of asthma's impact on daily life. The FEF25-75%, an index of pulmonary function, is considered a sensitive index of airway obstruction in children [26, 27].

After participants saw their doctor they also filled out a Patient Reaction Assessment (PRA) questionnaire. This is a brief 15-item survey with three subscales [28]. The Information Index represents the patient's perception that the doctor is giving them relevant information. The Patient Communication Scale measures the patient's ability to initiate communication about their illness. The Patient Affective Index serves as a measure of the emotional response the patient has toward the physician. This measure was included because we wanted to know if the intervention was changing the participant's perception of their relationship with their pulmonologist.

As mentioned earlier, the HBM postulates that the individual's awareness of the severity of their condition is a very important variable in the process of behavior modification. We hypothesize that the simple act of having the participants answer the "symptom" queries would raise their awareness of their current lung health status. To test this hypothesis, participants were asked to assign the severity of their asthma symptoms into one of four categories: 1) Intermittent – have symptoms 2 or less days per week; 2) mild – have symptoms more than 2 days per week; 3) moderate – have symptoms daily; and 4) severe – have symptoms throughout the day. We could then correlate their subjective response to the pulmonary function value, the objective measure of their current lung health.

Once all of the survey data was collected, participants were reminded about the 3 arms of the study and that their physician would be able to view their SMS responses. They were asked what time they would like to receive text messages from the clinic. They were also provided with a flyer about text messaging etiquette. This reminded them not to text at school or when they were walking or driving, among other things. It was only after all of this information was conveyed that participants were presented with an envelope that revealed the condition to which they were randomly assigned.

Participants in the ***Symptoms and Knowledge (S&K)*** conditions received daily texts that alternated between the two types of content (Figure 1, A and B). Participants in the ***Knowledge (K)*** condition received messages every other day that queried what they know about asthma (Figure 1, B1 and B2). Participants received $25 for enrolling in the study and $25 for participating in the follow-up visit. The follow-up visit was scheduled to coincide with their next doctor's appointment, typically 3-4 months later.

The literature indicates that low-SES children have more severe asthma symptoms than middle-SES children. We hypothesized that participants in the intervention conditions (***K*** or ***S&K***) would have improved outcomes compared to the participants in the control condition (***C***, no messages) because the intervention is likely to be more effective in children with more severe asthma. In other words, the intervention will have more power [29]

Table 1. Research Measures

Enrollment (Pre)	**Between Visits**	**Follow-up (Post)**
Technology survey	SMS log	Technology survey
Asthma knowledge		Asthma knowledge
PAQLQ		PAQLQ
Pulmonary function, FEF25-75%		Pulmonary function, FEF25-75%
PRA		PRA
Severity Awareness		Severity Awareness
		Exit interview with Child and Parent

4. RESULTS

Thirty participants were randomly assigned to the control, *Symptoms & Knowledge* or *Knowledge* group. There were an equal number of males and females in each condition.

4.1 Baseline Measures at Enrollment

The three groups did not differ on the PAQLQ, PRA or FEF25-75%. They only differed in age. The mean age in the control group was younger (m=11.5 sd=.8) than for the ***Knowledge*** (***K***) group (m=13.0 sd=.7) or the ***Symptoms & Knowledge*** (***S&K*** group (m=14.7, sd=.7). Age was also found to be significantly correlated with their asthma knowledge scores ($r = 0.450$, $p = .00408$). There was no correlation between their symptom awareness and their actual lung function (clinical measure).

4.2 Quantitative Outcomes

Complete data was available for 21 children with asthma (see Table 2). The age range of the participants was 10-17 years of age. Nine participants did not return for their scheduled follow-up visit. No attempt was made to get them to reschedule because we wanted to have an ecologically valid sample. The time between the two visits for the 21 participants with public insurance ranged from 58 to 152 days (median 102, mean 99 days). This gap between routine visits is within the expected range for children with their level of asthma severity.

Table 2. Outcome measures, shading denotes statistically significant difference between intervention and control groups, p >.05

	Control N=6 Females =2; Males=4		*Knowledge (K) N=7* Females =3; Males=4		*Symptom & Knowledge (S&K) N=8* Females =4; Males=4	
Measures	**Pre**	**Post**	**Pre**	**Post**	**Pre**	**Post**
Knowledge	12.3±3.2	13.2±2.3	12.7±1.6	14.9±1.1	13.1±2.3	14.6±2.0
PAQLQ	4.3±1.2	4.4±1.2	4.8±1.5	4.9±1.8	5.7±1.5	5.9±1.3
FEF25-75%	91.1±26.6	73.5±27.5	51.3±21.0	65.5±25.7*	78.2±32.0	84.2±31.7
PRA (AI)	4.5±0.7	4.2±0.8	4.3±0.4	4.6±.9	4.1±0.5	4.2±0.7

Since there was an age difference between the study groups, at the start of the intervention, we conducted an analyses of covariance (ANCOVA) to determine if age had an effect on health outcomes (the pre-post differences of PAQLQ and FEF25%-75%). No such effect was found. Thus, the fact that the children in the control group were younger did not impact their pre/post measures.

Paired t-tests showed that the ***K*** group and the ***S&K*** group had statistically significant improvement in their asthma knowledge assessment (t (6) = 5.3 p = 0.0009, effect-size r = 0.908; t (7) = 3 p = 0.01, effect-size r = 0.75, respectively). There was no intervention effect on the quality of life measure (PAQLQ). However there was an intervention effect on physiological outcomes for both intervention groups. Participants in the ***S&K*** group and the ***K*** group demonstrated improved pulmonary function results, as compared to the controls (t(12) = 1.77 p = 0.05, effect-size r = 0.46); (t(11) = 2.22 p = 0.024, effect-size r = 0.56), respectively.

We found significant changes in patients' perception of their relationship with their pulmonologist. Compared to the control group, participants in both intervention groups reported greater PRA improvements in the Affective Index (***K*** group, t(11) = 1.93 p = 0.039, effect-size r = 0.503; ***S&K*** group, t(11) = 1.71 p =0.05, effect-size r = 0.458). This subscale shows that patients felt more valued and respected after participating in the study.

To evaluate the hypothesis that symptom awareness improves the patient's perceived severity of their asthma, we compared the severity assignments and their pulmonary function (their actual severity status). Spearman's rank correlation (ρ) indicated that the ***S&K*** group had statistically significant improvement in their perceived versus actual asthma severity, FEF25-75%, ρ = 0.8456 p = 0.0082.

4.3 Interview Outcomes

During the follow-up visit, we conducted interviews with children and parents in the intervention groups. The interviews were recorded and transcribed. Two researchers analyzed the interviews using thematic analysis [30]. Here we present analyses to interpret the quantitative outcomes and to help understand how the system was perceived by parents and children.

4.3.1 Making sense of the quantitative outcomes

We found that the SMS intervention led to statistically significant pulmonary function improvement. Our clinical partners deemed that these changes were also clinically significant. We now turn to analyses from the interview data to shed light on how it is that the text messages might have driven asthma management change. We present three themes and supporting evidence for each theme. We also present quotes from children and parents to underscore the themes.[1]

4.3.1.1 Theme 1: Altered medication management

Interview data indicate that the intervention encouraged change in asthma management. Specifically, some children mentioned that receiving text messages worked as a reminder to take their medication. This was common in both the Knowledge (***K***) group and the Symptom & Knowledge **(S&K)** group. The text messages did not explicitly remind participants to take their medication. However, participants appropriated the system to do so. For example, some participants set the text receiving time when they wanted to take a medication: *G15K-C "I took my inhaler. When I got the text messages, I took the medicine." B1SK-C "Normally when I woke up, I took my inhaler two puffs every day, and after getting text messages, I did messages and then I took the medicine"*

4.3.1.2 Theme 2: Facilitated Communication

The interview data with parents and children showed that receiving and answering text messages seeded conversation with various stakeholders. After children received text messages, they tried to initiate conversations. For example, they asked their parents detailed questions about their asthma: B1K-C *"It was very good. When I didn't mention anything about his asthma, he actually came to me with questions. He asked detailed questions.*

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[1] Interview quote starts with Participant (#) then with his sex ("b"=boy and "g"=girl); study arm (***K*** and ***S&K***) and C for child or P=parent)

It wasn't just like mommy I'm sick...why am I sick? It was more related to his asthma why he has things and how to fix it."

The text messages increased conversation about asthma between children and caregivers. It generally changed the frequency of conversation: *B5K-P "We had more conversations about his asthma because the questions that he didn't understand, and he asked me the questions that he said you guys said it was wrong he would ask me."*

The SMS service also broadened the scope of communication. The conversation usually had been between children and primary caregivers (usually, mothers). Children attempted to share the information with those who usually had not done. Specifically, the knowledge questions made children reach other caregivers, who they usually did not discuss asthma with: *G5S&K-P "I was saying once a week. I heard text messages she was finding out the information she want to share with family."*

Even though a participant initiated communication, sometimes the primary caregiver wanted him/her to be independent; primary caregivers were satisfied with the intervention since it reduced their direct involvement: *G8K-P "She told me hey look at this. She didn't share all of them with me. But, when she was unsure of her answer. She wanted me to look at it, I just told her 'no! you need to answer it if it's wrong it will tell you'. So I was happy to something she can do independently without intervention from me."*

The SMS service facilitated communication not only with caregivers, but also with healthcare providers. When children had the follow-up visits, the SMS service deepened understanding of what a doctor was saying or when children had more questions about their asthma. It increased patient's knowledge and understanding of their asthma: *G8K-C "Uh, well, I can understand what he is talking about now. like before I didn't understand some of the questions." G5S&K-C "It (conversation) changed because now I understand about the asthma"*

4.3.1.3 Theme 3: Change in Asthma Knowledge

Children expressed diverse experiences about gaining knowledge through the SMS intervention. We received positive and negative feedback on the knowledge part of the SMS intervention. Children and parents agreed that there was increased knowledge, which made them feel better. *B2S&K-C "It will tell me something I probably didn't know before. I will probably say 'unsure' or 'I'm not sure what it is', but it did help me." G8K-P "She did well manage her asthma. I think she understands better now...what things might cause triggers. I just don't think she even knew what asthma meant before."*

The knowledge questions were relatively easy for older children. However, "easy" did not necessarily mean that participants were unsatisfied with the questions. These "easy" questions helped them confirm their knowledge. *B2S&K-C "It's pretty easy because I already knew I mean some of it. Chihuahua (question) I know that because I'm not allergic to it. It won't trigger any of my respiratory problems. Some of them, I wanted to answer. Like I already knew answers but I was like, yes! this is great. I wanted to know this is right." G8 K-C "(I'm) very confident with my answers. It was very easy after they started repeating the questions."*

On the other hand, younger children and their parents thought the questions were too difficult to answer: *B11K-C "It was a little bit difficult (to answer it), but I am fine with that since they gave me the correct answers." B11K-P "I think that some of the questions that were asked him. He didn't understand it, but then he understood it. You know alternative asthma medicine is better or not better. So yes, he was little confused, so I think he guessed it and then the answer came through."*

4.3.2 How the SMS system was perceived by the children

We received feedback about the SMS system. First, SMS was the correct deployment method for the intervention because it is ubiquitous and simple to use. This was evident in the high response rate, 85.6% (Median 91.3%, ranging from 36% to 100%). Participants also appreciated the volume of messages and the way they could answer the questions: *G8K-C "(It's) very easy to text. I didn't need to type whole letters (TRUE or FALSE)."*

Second, since we sent out the same questions every month, children felt bored, especially those who had the follow-up visits later. They would have preferred a variety of questions. Despite this problem, children maintained a high response rate. *G15K-C "Some questions stayed the same. Is it like the same questions? I'd like to change a little bit." G1 QK-C "It was like ask me questions start back over ask me the same question. And I will be thinking like I answered this question two weeks ago. But I still answer it anyway."*

4.4. Comparison of Data for Participants with Public and Private Insurance

Thirty participants were simultaneously enrolled in each of two cohorts (private insurance and public insurance). Initially there were the same number of males and females in each of the three groups: ***Control (C)***, ***Knowledge*** (***K***) and ***Symptoms and Knowledge*** (***S&K***, see Table 3). The attrition in both groups was the same --- 9 participants dropped out in each cohort. In both cohorts, patients were more likely to drop out if they were in the control group. Table 4 shows that the ICT utilization was very similar among participants that had private medical insurance and those that had public medical insurance.

Table 3. Patient Characteristics

	Public Insurance (Pri, N=21*)			**Private Insurance (Pri, N=21*)**		
	C	K	S&K	C	K	S&K
Attrition	4	3	2	4	2	3
Female	2	3	4	4	5	3
Male	4	4	4	2	3	4
Total N	6	7	8	6	8	7
Age* M **SD**	11.5 .8	13.0 .7	14.7 .7	12.3 .7	14.0 .7	12.0 .7

National data indicate that low-SES individuals are likely to have more severe asthma as their middle SES counterpart. We conducted an analysis of the initial pulmonary measure (FEF25-75%) for the public- and private- insurance cohorts. Results indicate that the participants with public insurance had lower lung function over all (t (40)=2.21, p= .017) compared to their private insurance counter parts. Given that this was the case one would hypothesize that the intervention would be more effective for the low-SES counter part because this group had a greater opportunity to improve their lung function (more statistical power in this group). In order to compare the effectiveness of the intervention between patients with public insurance and patients with private insurance, we compared the effect sizes across the studies [29]. Table 5 show larger effect sizes (as measured by both Cohen's d and r) for the public insurance vs. the private insurance cohorts. This indicates that the intervention was more powerful for children with public versus private insurance.

Table 4. Characteristic of Patient ICT Usage

(N=21 per group)	Public	Private
Internet Usage Time in hours	2.18	1.7
Use of Internet for Asthma Management (N)	2	3
Mobile Data Plan	11	13
Use of SMS for Asthma Management (N)	2	0
Daily SMS Users (N)	20	18
>300 text messages a month (N)	9	6

Table 5. Comparison of effect sizes of the FEF25-75% data in intervention vs. control outcomes

	Public Insurance	Private Insurance
Knowledge	Cohen's d = 1.34 effect-size r = .56	Cohen's d = .57 effect-size r = .28
Symptoms & Knowledge	Cohen's d = 1.02 effect-size r = .46	Cohen's d = .85 effect-size r = .39

5. DISCUSSION AND FUTURE RESEARCH

We conducted a random control study with low SES children with asthma. Our results indicate that we affirmatively answered the questions: "Do children with public insurance benefit from a text-based intervention?" and "Do individuals from different SES backgrounds reap different benefits?" We now discuss these findings in detail and provide future steps for researchers in this area.

5.1 Discussion

We investigated the role that income plays in pediatric asthma patient's adoption of an SMS intervention. We used public insurance as a proxy for low income because in the US children must meet a designated Federal Poverty Level in order to get public insurance. We showed that pediatric participants with asthma from low-income households benefit from a text-message based intervention to improve their physical health and some of their psychological outcomes. Specifically, we found that patients in the intervention groups that received either daily text messages (***Symptoms & Knowledge, S&K)*** or a ***Knowledge (K)*** message on alternate days had improved lung function (FEF25-75%).

Beyond the physiological improvements, we also found that being in the interventions improved children with public insurance's knowledge about asthma and communication about asthma with their family. An intriguing finding is that the intervention also improved their affective connection to their pulmonologist. They were more likely to respond affirmatively to questions about whether their doctor valued them and respected them. An improved interpersonal connection can improve a patient's willingness to communicate. This is a promising finding because the literature indicates that communication between patient and caregiver can lead to improved chronic care management [31]. We also found that after three months of receiving daily texts messages, there was a correlation between participants' perception of their asthma severity and their actual lung function (which is quantitative measure of the current asthma status). The latter provides some evidence for the positive effect that awareness has on behavior change [8, 24].

Taken together these results replicate and extend the results from previous studies [5, 6]. In previous studies, over a 3-4 month period, participants in the ***S&K*** condition had health outcome benefits [5,6], but not in the ***K*** condition [6]. Unlike the present cohort, the patients in previous studies also showed improvement in the quality of life measure. However, patients in the previous studies were largely from middle-income households (as indicated by their private insurance status). This may underlie the fact that physiological and psychological factors may be differently correlated for patients from different economic backgrounds. This is echoed in a study that showed that asthma severity, socioeconomic status, and racial/ethnic group explained 67% of the variance of quality of life [32]. Our present findings underscore the fact that low income is associated with poor quality of life and that a three to four month intervention is not enough for quality of life improvements for patients with public insurance. This was despite the fact that they experienced clinically significant improvements in pulmonary function.

Our comparative analyses of the present and past [6] intervention data show that this text-message based system is effective among a wide demographic group. These analyses are valid because the two cohorts were recruited from the same clinic during the same time period. Our comparative study mirrored national trends where the low-SES cohort had more severe asthma (as measured by lunch function) compared to the middle-SES cohort [33]. The comparative analysis showed that both cohorts had the same completion rate. The sample size at the end of the study was exactly the same (N=21) and the participants most likely to miss follow-up visits were those assigned to the control group. We found that the ICT use was basically the same for both cohorts as well.

The most provocative finding from the comparative analyses is that public insurance patients seemed to garner greater physiological benefits from the intervention (as indicated by greater effect sizes). Patients with public medical insurance showed improved pulmonary function in both the ***S&K*** and the ***K*** condition, unlike patients with private medical insurance who only showed improvements in the ***S&K*** condition [5, 6]. We present possible reasons for this finding later in the discussion.

In order to be eligible to participate in the study children had to have a phone plan with unlimited text messaging. This could be seen as introducing a sampling bias. We opted for this because we did not want to have the additional confound of introducing a new technology. Our data indicates that the greater benefits that accrued for the public insurance group compared to the private insurance group did not come from difference in technology utilization between the groups. The comparative study found that the technology utilization (access to the Internet, data plans and texting habits) were very similar between the two cohorts. Further, type of insurance was not associated with either different recruiting success or attrition rates. This suggests that the promise that technology can help improve health outcomes across demographics can be actualized.

There are two other possible reasons why the low SES cohort had improved outcomes compared to the middle SES cohort. One is concrete and the other more speculative. The pragmatic reason for this result can be explained statistically. The low SES cohort had greater asthma severity, and therefore it had greater opportunity for health improvements. The more speculative reason is that the increase in affective connection with their pulmonologist led to greater medication compliance. More studies will need to be conducted to test the latter hypothesis.

5.2 Opportunities for Future Research

In this paper we sought to understand the role a simple ICT can play in promoting self-management in a group of asthmatic children with public insurance. We propose that having public insurance is a proxy for being low SES and hope to draw implications from these findings. However, there are a number of limitations that we need to consider. These limitations suggest opportunities for future research.

Future studies would do well to access low-income cohorts that are "at risk" for poor health outcomes. This would address a feature of the at-risk group, namely the over-reliance on acute care [15]. The participants in our study had very engaged caregivers that sought out specialized/continuous care for their child's asthma. This means that while our public insurance group is low-income it may not be representative of "high risk" groups usually discussed in the health literature. One idea is to recruit pediatric asthma patients in the emergency department rather than a private clinic.

Another study design implication that can be drawn from these results relates to lowering the attrition rate. We found that patients in the control group, in both the private and public insurance cohorts, were more likely to fail to show up to the second visit. In order to minimize attrition in the control condition, these patients could be allowed to utilize the intervention technology after they complete their second visit (the so called cross-over methodology).

Our research methodology has focused on short-term (3-4 months) controlled design studies with relatively small sample sizes. This limits our ability to draw conclusions about the long-term effects of the intervention and the generalizability of our findings. Future studies need to deploy the system for longer durations with larger sample sizes. We have seen successful ventures into this approach in the diabetes space [34] and we need do the same in other chronic care areas including asthma.

In the age of a multitude of mobile apps for asthma [35], the interview data shows that texting is an appropriate method for distributing information in the pediatric asthma population. However, we need to find a better strategy to provide personalized content. Interview data suggests that text content could be changed depending on the knowledge level of the participant at the beginning of the study. Interview data also suggests some design considerations for future long-term interventions. First, the action of receiving/answering the text messages worked as a reminder for some of the children. New experiments might investigate if explicitly tethering texts to a medication schedule can actually lead to improved medication adherence. Asthma knowledge increased in both intervention groups. Interview data suggests that this may be because the "knowledge" text triggered conversations with family on the topic. It would be interesting to try to quantify this systematically. Participant interview data also indicates that the increased asthma knowledge changed the quality of interaction with their doctors. Future research should also address this intriguing finding.

In conclusion, our study has bridged a gap in the health ICT space by focusing on children from low-income families. We moved away from the traditional education-based approaches to include raising the participant's awareness of the severity of their condition. Also, the technology intervention was included in the context of their daily practices (i.e., texting). This approach has proven to be beneficial. We have shown that public insurance patients (and those with private insurance) can have improved health outcomes with a short-term, SMS intervention. While designing for chronic-care management is a complex problem our findings show that simple, ubiquitous solutions can be a first step to psychological and physiological improvements in children with asthma from a broad demographic base.

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