Use of a Smartphone Application for Prompting Oral Medication Adherence Among Adolescents and Young Adults With Cancer

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OBJECTIVES: To explore the feasibility and acceptability of use of a smartphone medication reminder application to promote adherence to oral medications among adolescents and young adults (AYAs) with cancer.

SAMPLE & SETTING: 23 AYAs with cancer from a Children's Oncology Group–affiliated children's hospital and a National Cancer Institute–designated comprehensive cancer center in Salt Lake City, UT.

METHODS & VARIABLES: Participants were asked to use the application for eight weeks. Data on application usage were obtained from a cloud-based server hosted by the application developers. Weekly self-report questionnaires were completed. Feasibility was assessed through participants' usage and responses. Acceptability was assessed through participants' perceived ease of use and usefulness.

RESULTS: Almost all participants used the application at least once. More than half reported that they took their medications immediately when they received reminders. Participants also reported that the application was easy to set up and use, and that it was useful for prompting medication taking.

IMPLICATIONS FOR NURSING: Nurses could continue to test the efficacy of integrating e-health modalities, such as smartphone applications, into efforts to promote medication adherence.

KEYWORDS medication nonadherence; adolescent; young adult; e-health; oral medications

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During the past 30 years, adolescents and young adults (AYAs) with cancer have experienced less improvement in survival than children or older adults with cancer (Albritton & Bleyer, 2003; Bleyer, 2002; Bleyer, Viny, & Barr, 2006). Suboptimal adherence to oral cancer therapy medications has been cited as a key contributor to adverse cancer outcomes, such as disease relapse (Bhatia et al., 2012, 2014; McGrady, Brown, & Pai, 2016).

Rates of medication nonadherence are significant among AYAs, with a reported incidence of 27%–63% across studies (Butow et al., 2010; Kondryn, Edmondson, Hill, & Eden, 2011; Landier, 2011; Partridge, Avorn, Wang, & Winer, 2002). In addition, rates of nonadherence are higher among AYAs compared with younger children (Bhatia et al., 2012). Reported reasons for nonadherence to oral medications include factors related to medications themselves (e.g., side effects, frequent or complex dosing), as well as factors particularly relevant to AYAs, such as forgetting, having lifestyle disruptions, and lacking physical and social support for medication taking (Hall et al., 2016; Hullmann, Brumley, & Schwartz, 2015; McGrady et al., 2016; Verbrugghe, Verhaeghe, Lauwaert, Beeckman, & Van Hecke, 2013; Wood, 2012). Medication nonadherence among AYAs is a particularly salient issue for nurses who may be among the first on the multidisciplinary team to recognize nonadherence or factors contributing to it. With their frequent direct contact with patients, nurses are well positioned to intervene with strategies to encourage adherence (Winkeljohn, 2007).

The development of interventions to promote oral medication adherence among AYAs with cancer is an urgent priority because they are scarce and limited data exist to support their clinical use (Burhenn

& Smudde, 2015; Butow et al., 2010; Gupta & Bhatia, 2017; Landier, 2011). The only published study of a computer-based intervention promoting adherence in this age group demonstrated that use of a video game intervention improved medication adherence among AYAs aged 13–29 years (Kato, Cole, Bradlyn, & Pollock, 2008). Ideally, interventions for AYAs should not only support them through their cancer treatment experience but also promote success in the unique developmental tasks of this age group, including working toward independence in personal care and decision making, preparing for careers, exploring romantic relationships, and establishing families and independent households (Albritton, Barr, & Bleyer, 2009; Butow et al., 2010; Evan & Zeltzer, 2006). For example, interventions could help AYAs take medications independently, without reminders from a caregiver.

A growing body of literature demonstrates the feasibility of implementing e-health interventions (e.g., to monitor symptoms) for AYAs with cancer and other serious illnesses (Baggott et al., 2012; Kock et al., 2015; Macpherson et al., 2014; Rodgers, Krance, Street, & Hockenberry, 2014; Wesley & Fizur, 2015). New adherence interventions may have the greatest chance of success if they integrate tools or platforms that AYAs already use, such as smartphone technologies. An estimated 92% of young adults aged 18–29 years own a smartphone (Pew Research Center, 2016). E-health interventions (Eysenbach, 2001), including ones enabled by the Internet and mobile phones, have been used successfully to deliver health-promoting interventions to AYAs with chronic health conditions, such as diabetes and asthma (Cushing & Steele, 2010) and to promote medication adherence (Linn, Vervloet, van Dijk, Smit, & Van Weert, 2011).

Published reports exploring the use of application interventions for supportive care in patients with cancer are limited. These studies focused on nutrition, monitoring of symptoms and pain, documentation of the symptom experience, and promotion of medication taking (Wesley & Fizur, 2015). Only one study, which included children and adults aged 6–87 years, sent automated medication reminders and allowed users to create a list of their prescribed medications and to receive medication-taking reminders (Becker et al., 2013). Therefore, despite the widespread availability of medication reminder applications on the market (Wesley & Fizur, 2015), a dearth of literature documenting the feasibility and acceptability of smartphone-enabled interventions to promote adherence among AYAs with cancer still exists.

The goal of the current study was to explore the feasibility and acceptability of use of a smartphone medication reminder application to promote adherence to oral medications among AYAs with cancer (Bowen et al., 2009). The authors sought to characterize the use of the medication reminder application among AYAs, as well as the AYAs' perceptions of the application's ease of use and usefulness. In investigating the application's perceived ease of use and usefulness, the authors drew from the technology acceptance model (Venkatesh & Bala, 2008), which posits that whether an individual engages with technology is predicted by his or her behavioral intention, which, in turn, is predicted by the technology's perceived usefulness and ease of use.

Methods

This 12-week study used a pre-/post-test, single-group design. The first four weeks served as an initial monitoring period prior to introducing the smartphone medication reminder application. Participants then were asked to use the application for eight weeks.

Sample and Setting

Individuals were eligible to participate in the 12-week study if they were aged 15–29 years, were receiving treatment for any type of cancer (either primary or recurrent/relapsed disease), and were receiving at least one outpatient scheduled oral chemotherapy (e.g., 6-mercaptopurine) or supportive care (e.g., sulfamethoxazole-trimethoprim) medication related to their cancer. Individuals had to have completed at least one month of cancer therapy at the time of enrollment, with therapy anticipated to continue for at least three months following study enrollment. Individuals were eligible to participate if they had a smartphone device (either iOS or Android) and were willing to use a specific smartphone medication reminder application while they were enrolled in the study. Individuals were excluded from participation if they had prior experience using a smartphone medication reminder application, did not speak English, or had cognitive or physical limitations that prevented them from using a smartphone medication reminder application. Participants were recruited from two sites that provide cancer care for AYAs at a Children's Oncology Group–affiliated children's hospital, Primary Children's Hospital, and a National Cancer Institute–designated comprehensive cancer center, Huntsman Cancer Institute, both in Salt Lake City, Utah.

Smartphone Application

Following the four-week preintervention monitoring period, participants were asked to use the Dosecast mobile application, which is available on Android and iOS platforms as a free version or as a paid, enhanced version (i.e., Dosecast Pro Edition). Participants were provided with a code to allow them access to the Dosecast Pro Edition for one year. The authors contracted with Dosecast so that participants were provided with the enhanced version of the application at no cost to them. The authors paid Dosecast for their services using research funding. This enhanced version of the application includes visual and audible medication reminders and a log of responses to those reminders. Study personnel held brief (10-minute) one-on-one sessions to teach participants how to enter their medications (medication name, dosage, schedule) into the application to receive medication reminders. Study personnel then demonstrated the features of the application and how to use it. Dosecast provided visual and audible reminder notifications on the participant's phone based on the individual medication dosing schedules entered by the participant. When participants received a medication reminder, they were offered the option of selecting "take dose now," "postpone," or "skip," and the reminder was adjusted accordingly. If participants chose to postpone the dose, they were prompted to enter the number of minutes until the medication reminder, and response options were provided again.

Measures

At the baseline study visit, participants were asked to provide demographic information, including age, gender, race/ethnicity, marital status, educational attainment, household income, employment status, and individual(s) with whom they live. They also were asked to provide information on their cancer type, date of cancer diagnosis, and whether they were being treated for a relapse of their disease.

Feasibility of using the application was assessed through participants' use of it. Usage was measured using two methods. The first method used data downloaded by the study personnel from a cloud-based server, hosted by the developers of Dosecast. The second method entailed an online, self-report questionnaire that participants were asked to complete (via an email prompt) each week they used the application. Participants were asked about the percentage of time they received medication reminder prompts from the application and how they responded to the prompts (e.g., took the medication immediately, ignored the reminder and did not take the medication at all). Responses could vary from 0%–25% of the time to 76%–100% of the time. Participants also were asked whether they had

TABLE 1. Sample Characteristics (N = 23)

Characteristic	n
Gender	
Male	14
Female	9
Race	
White	21
Asian	1
Native American or other Pacific Islander	1
Ethnicity	
Not Hispanic or Latino	21
Hispanic or Latino	2
Marital status	
Never married	17
Married	3
Prefer not to answer	2
Member of an unmarried couple	1
Highest level of school completed	
Some high school	10
High school or GED	6
Some college, university, or technical school	5
Four-year college or university	2
Employment	
Student	11
Unable to work	6
Employment for wages	2
Out of work for less than one year	2
Out of work for more than one year	2
Living situation[a]	
With parents	18
With significant other or spouse	3
With roommates or friends	2
Alone	1
Cancer type[b]	
Leukemia	8
Lymphoma	4
Sarcoma	4
Other solid tumors	7

[a] Participants could choose more than one response.
[b] Based on self-report, verified by medical record review

reprogrammed their reminders in the prior week because of medication changes (responses included yes; no, my medications did not change; and no, my medications changed but I did not reprogram the application).

Drawing from the technology acceptance model (Venkatesh & Bala, 2008), investigator-developed items were used to assess the participants' perceived ease of use of the application (six items, Cronbach alpha = 0.84) and perceived usefulness of the application (seven items, Cronbach alpha = 0.95) at the conclusion of each individual's participation in the study. Item responses were rated on a five-point Likert-type scale ranging from not at all easy to very easy.

Procedures

All study procedures were approved by the University of Utah's institutional review board. Based on medical record review and consultation with patients' healthcare teams, 64 AYAs were approached at their clinic appointments for assessment of their eligibility for and interest in the current study (i.e., five-minute recruitment conversation). Of the 64 approached, 54 were deemed eligible. Twenty-two AYAs who were eligible declined to participate, with reasons for declining including time limitations (e.g., too busy, not able to spend time completing study visits) and preference for using a pill box. In total, 32 AYAs (59% of all eligible patients) enrolled in the study. Informed consent was obtained from patients who were 18 years of age or older. For patients 15–18 years of age, a parent or legal guardian provided written permission and the patient provided written assent. Recruitment occurred during a 13-month period.

The study included three in-person visits: baseline, at 4 weeks, and at 12 weeks. At the first study visit, participants were given electronic pill bottles to use for the duration of the study to track use of their scheduled oral medications (results to be reported elsewhere).

Participants completed self-report questionnaires during each week of study participation. Participants completed questionnaires during their scheduled study visits. Outside of the three in-person visits, participants received weekly email links to complete the questionnaires. All patient-entered questionnaire data were collected and managed using REDCap electronic data capture tools hosted at the University of Utah (Harris et al., 2009).

At the second study visit (following week 4 of the study period), study personnel helped participants download Dosecast onto their smartphone and taught them how to program medication reminders. Participants were asked to begin using the application immediately for the eight-week period, culminating at their third (last) study visit.

One participant dropped out of the study before completing any study measures because of not wanting to wait four weeks to begin using Dosecast. Of the 31 participants who completed the first study visit, 8 dropped out before the second study visit (reasons included preference for using a pill box, time limitations, and unanticipated discontinuation of medications). Twenty-three participants (72% of all enrolled patients) completed study measures at the

TABLE 2. Self-Reported Use of the Dosecast Application

	0%–25% of the Time		26%–50% of the Time		51%–75% of the Time		76%–100% of the Time	
Measure	**n**	**%**	**n**	**%**	**n**	**%**	**n**	**%**
When I received medication reminders this week, I took my medication immediately.	22	13	15	9	33	20	95	58
When I received medication reminders this week, I ignored the reminder and did not take my medication at all.	150	91	3	2	6	4	6	4
When I received medication reminders this week, I used "remind me later" and then took my medication later.	122	74	15	9	10	6	18	11
When I received medication reminders this week, I used "remind me later" and then ignored the reminder and did not take my medication at all.	160	97	3	2	1	1	1	1

Note. Participants completed self-report questionnaires during each week of study participation, for a total of 165 responses for 23 participants.
Note. Because of rounding, percentages may not total 100.

second and third visits and were included in the current analyses.

The 23 AYAs who completed the study were, on average, 19.7 years old (SD = 4.3), with a range of 15–29 years. Their median household income was $60,000–$79,000, with the entire range being $20,000 or less to $100,000 or more. Mean time since diagnosis was 1.9 years (SD = 2.2), with a range of 23 days to six years. Five participants experienced relapse of disease. Table 1 contains a summary of the participants' demographic characteristics.

Analytic Plan

Descriptive statistics (i.e., mean, standard deviation, and frequencies) were calculated to summarize participant demographic characteristics. For feasibility, frequencies and proportions were calculated from Dosecast usage data downloaded from the application developer and participant self-reported responses regarding their usage. Sample means and standard deviations for usage data were calculated after first averaging responses for each participant across his or her weeks of application use. Descriptive statistics (means, standard deviations, frequencies) were used to summarize responses to items relating to acceptability, including perceived ease of use and perceived usefulness of the application.

Feasibility

Twenty-two participants used Dosecast at least once during the current study, based on usage data recorded by the application. The usage data indicated that, on average, participants responded to their initial medication reminder prompts 90% of the time (SD = 0.3).

Table 2 summarizes participants' self-reported responses to the reminders about taking their medications across the weeks during which they used the application. Ninety-five (58%) responses indicated that AYA participants took their medications immediately upon receiving reminders 76%–100% of the time. Another 33 (20%) responses indicated that medications were taken immediately upon receiving reminders 51%–75% of the time. In contrast, only 15 (9%) responses indicated that participants ignored reminders more than 25% of the time. About one-fourth of responses indicated that AYAs used the feature to delay their medication dose more than 25% of the time. Seven (4%) responses indicated that the participants reprogrammed their medication reminder that week because their medication changed; 144 (87%) responses showed that the participants did not change their reminder

TABLE 3. Smartphone Application Acceptability (N = 23)

Question	n	$\bar{X}$	SD
How clear were setup instructions?		**4**	**1.1**
5 (very clear)	10		
4	4		
3 (clear)	7		
2	2		
1 (not at all clear)	–		
How easy was following application instructions?		**4.2**	**1**
5 (very easy)	12		
4	6		
3 (neutral)	3		
2	2		
1 (not at all easy)	–		
How do you feel about how long setup took?		**4.4**	**1.2**
5 (OK amount of time)	16		
4	2		
3 (neutral)	3		
2	1		
1 (too long)	1		
How easy was programming your medication reminders into the application?		**4.2**	**1**
5 (very easy)	12		
4	4		
3 (neutral)	6		
2	1		
1 (not at all easy)	–		
How easy was entering that you had taken a medication when you received a reminder?		**4**	**1.2**
5 (very easy)	11		
4	5		
3 (neutral)	4		
2	2		
1 (not at all easy)	1		
How easy was entering that you wanted to be reminded later when you received a reminder?		**3.9**	**1.1**
5 (very easy)	9		
4	4		
3 (neutral)	8		
2	2		
1 (not at all easy)	–		
How useful were the application graphics?		**3.7**	**1**
5 (very useful)	6		
4	5		
3 (neutral)	11		
2	–		
1 (very poor)	1		

Continued on the next page

because their medication did not change. Fifteen (9%) responses indicated that the participants' medication did change, but they did not reprogram their reminder.

TABLE 3. Smartphone Application Acceptability (N = 23) *(Continued)*

Question	n	$\bar{X}$	SD
How useful were the application's alert sounds?		**3.7**	**1.1**
5 (very useful)	7		
4	3		
3 (neutral)	12		
2	–		
1 (not at all useful)	1		
Overall, how useful was the application to you?		**3.9**	**1.3**
5 (very useful)	11		
4	4		
3 (neutral)	5		
2	1		
1 (not at all useful)	2		
Receiving reminders helped me take my scheduled oral medications as prescribed.		**3.9**	**1.1**
5 (strongly agree)	8		
4 (agree)	9		
3 (neither agree nor disagree)	3		
2 (disagree)	2		
1 (strongly disagree)	1		
The application helped increase my independence in taking scheduled oral medications.		**3.9**	**1.1**
5 (strongly agree)	8		
4 (agree)	8		
3 (neither agree nor disagree)	4		
2 (disagree)	2		
1 (strongly disagree)	1		
I would be interested in using a reminder application even if it were not part of this study.		**3.7**	**1.1**
5 (strongly agree)	7		
4 (agree)	7		
3 (neither agree nor disagree)	6		
2 (disagree)	2		
1 (strongly disagree)	1		
I would recommend using a reminder application to others my age with cancer.		**4.1**	**0.9**
5 (strongly agree)	8		
4 (agree)	12		
3 (neither agree nor disagree)	1		
2 (disagree)	2		
1 (strongly disagree)	–		

Acceptability

In terms of perceived ease of use of the application, participants reported, on average, that Dosecast was easy to set up and that it was easy to respond to medication reminder prompts (see Table 3). Participants endorsed that the application was useful overall (65% of participants) and that individual features of the application were useful (43%–48% of participants). Seventy-four percent and 70% of AYAs agreed in study questionnaires that the application helped them to take oral medications as prescribed and increased their independence in taking medications, respectively. The majority (61%) of participants reported interest in using a medication reminder application even outside the context of a research study, and 87% of participants stated that they would recommend medication reminder applications to peers with cancer.

Discussion

The current study documents the feasibility of using a commercially available smartphone application to foster oral medication adherence among AYAs with cancer. Participants reported that Dosecast was acceptable in terms of ease of use (e.g., programming medication reminders) and perceived usefulness (e.g., helping remind the patient to take medications). These results support previous reports on the use of electronically delivered health promotion interventions in pediatric and AYA populations with diseases other than cancer (Cushing & Steele, 2010) and AYAs with cancer (Becker et al., 2013; Wesley & Fizur, 2015).

E-health interventions are a promising format for supportive care interventions targeting patients with cancer, and multiple authors have discussed their potential to address unmet needs relating to medication adherence, cancer- and health-related knowledge, and guidelines for recommended follow-up care (Bateman & Keef, 2016; Odeh, Kayyali, Nabhani-Gebara, & Philip, 2015). The vast majority of participants in the current study stated that they would recommend use of Dosecast to peers with cancer, supporting the development of additional e-health applications for use by the AYA cancer population. As data accumulate on e-health interventions among AYAs with cancer, documenting health-related outcomes associated with the interventions and defining characteristics of patients and interventions that moderate the effectiveness of the interventions will be important.

The current study had notable strengths and limitations. One strength was that application usage data were downloaded directly from the application server;

the study did not rely solely on patient self-report of application use. Because the study was designed to assess initial feasibility and acceptability of the medication reminder application, the sample size was limited and involved participants from a single geographic area. Additional studies should recruit larger and more ethnically diverse samples from multiple treatment sites. Before larger-scale testing of e-health interventions for medication adherence is initiated, obtaining qualitative feedback from AYAs who have used such interventions about how they could be improved would be helpful. Future work also could examine whether application use leads to measurable changes in long-term medication adherence, as well as the mediators and moderators of adherence changes (e.g., changes in self-efficacy associated with application use). Additional studies also could examine potential differences in adherence to chemotherapy versus supportive care medications. As healthcare technologies, such as alerts (i.e., automated emails and telephone calls), become standard practice and continue to evolve, such resources also could be leveraged and integrated into e-health interventions.

Implications for Nursing

Nurses are well positioned to support treatment adherence among patients with cancer, including among AYAs with cancer (Winkeljohn, 2007). For example, previous studies have reported interventions by nurses to promote adherence for adults with lung and gastrointestinal cancer (Boucher, Lucca, Hooper, Pedulla, & Berry, 2015; Sommers, Miller, & Berry, 2012). If smartphone application interventions, such as the one examined in the current study, are found to increase oral medication adherence among AYAs with cancer, nurses could introduce the use of such an application to patients as part of routine clinical care for this population. Given the high value that AYAs place on peer influences and recommendations (Prinstein, Boergers, & Spirito, 2001; Wilks, 1986), nurses who share with AYAs that their peers find medication reminder applications useful could significantly influence patient willingness to consider their use. In addition, nurses could interface with other members of an AYA's multidisciplinary healthcare team, such as social workers or behavioral health providers, to communicate concerns about adherence that are not resolved through interventions such as use of a smartphone application.

Conclusion

In the current study, AYAs with cancer were willing to use a commercially available medication reminder application on their smartphones. They found the application acceptable in terms of its perceived usefulness and ease of use. E-health platforms, such as smartphone applications, present a promising strategy for facilitating adherence in this patient population, potentially improving cancer survival and quality of life (Atkinson et al., 2016; McGrady et al., 2015).

KNOWLEDGE TRANSLATION

- Use of smartphone applications prompting medication adherence is feasible among adolescents and young adults (AYAs) with cancer.
- AYAs with cancer perceive the smartphone medication reminder application used in the current study as an acceptable resource to prompt medication adherence.
- E-health strategies to promote medication adherence among AYAs with cancer could augment existing clinical strategies to optimize medication adherence in this patient population.

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Wu, Linder, Macpherson, and Johnson contributed to the conceptualization and design and provided the analysis. Wu, Linder, Kanokvimankul, Fowler, and Parsons completed the data collection. Wu, Linder, and Fowler provided statistical support. All authors contributed to the manuscript preparation.

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