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A Pilot Randomized Trial of Text-Messaging for Symptom Awareness and Diabetes Knowledge in Adolescents With Type 1 Diabetes

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Adolescents with type 1 diabetes typically receive clinical care every 3 months. Between visits, diabetes-related issues may not be frequently reflected, learned, and documented by the patients, limiting their self-awareness and knowledge about their condition. We designed a text-messaging system to help resolve this problem. In a pilot, randomized controlled trial with 30 adolescents, we examined the effect of text messages about symptom awareness and diabetes knowledge on glucose control and quality of life. The intervention group that received more text messages between visits had significant improvements in quality of life.

CHILDHOOD TYPE 1 diabetes mellitus (T1D) is growing worldwide, with the incidence peaking at puberty and affecting 1 out of 400 adolescents (SEARCH for Diabetes in Youth Study Group et al., 2006; Writing Group for the SEARCH for Diabetes in Youth Study Group et al., 2007). Adolescents with type 1 diabetes (T1D) have to be constantly aware of their condition to maintain optimal glucose control. Self-management that determines glucose control is a complex process, encompassing administration of daily insulin, glucose testing, dietary modification and exercise along with symptom awareness. The responsibilities that these adolescents face, coupled with their goals of increasing independence that are negotiated with parents and other family caregivers, often contribute to struggles with adherence to T1D care plans. Biological changes of puberty further complicate and frustrate attempts to manage T1D. These include insulin resistance induced by rising sex steroid hormone levels and psycho-developmental factors that may contribute to a decline in self-management adherence (Amiel, Sherwin, Simonson, Lauritano, & Tamborlane, 1986; Rausch et al., 2012) and affect awareness of dysglycemic symptoms (Nurick & Johnson, 1991; Ryan, Dulay, Suprasongsin, & Becker, 2002).

Therefore, it is important for adolescents to consciously link symptoms with low or high blood glucose readings and associated self-management behaviors related to diet, insulin, activity level and emotional well-being. For example, how many episodes of hypoglycemia such as feelings of shakiness or diaphoresis did the adolescent have in the past week? What time of day did the symptom occur, and what self-management behaviors occurred prior to the event?

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What actions are needed to remedy the symptom based upon glucose level? Although this type of information is assessed by the health care provider during periodic checkups, adolescents are often unreliable historians. Adolescents and their primary family caregivers may report diabetes-related events that occurred over the past week, rather than provide comprehensive information for the entire past 3 months between visits (American Diabetes Association, 2014). As a result, these valuable symptoms and acute event records are often lost in the hectic lives of adolescents, limiting their ability to link their awareness of symptoms to check their blood glucose or take other therapeutic responses.

Additionally, adolescents must learn a large amount of information about their condition including long-term effects of TID, treatment adjustment for sick days, and co-morbidities if present, such as celiac disease and thyroiditis. This information is commonly presented in both written and verbal instructions with the health care providers and diabetes educators at the time of diagnosis. However, with the limited amount of encounter time in the clinic, it is unclear how much information is transferred and retained. Depending on the age at diagnosis, varying amounts of diabetes education may have been provided directly to the patient. As adolescents begin to assume greater shared responsibilities for diabetes management, review of key principles of diabetes management is warranted. An alternative solution may be to present the information to the adolescent using readily available technology via mobile phones, delivering content bit by bit on a daily basis using the process of microlearning (Hug, 2007). Microlearning emphasizes that learning content in small amounts within short periods of time, in this case, the information about symptom awareness and knowledge of diabetes management via text-messaging.

The value of creative self-management interventions is enhanced when one employs a communication approach focusing on technology familiar to adolescents. According to a recent Pew Survey (Lenhart, 2012) approximately 77% of American teens own mobile phones and at least 63% report texting daily. The study also found that mobile phone usage, specifically texting, is their favorite mode of communication. Texting using mobile devices presents opportunities to enhance diabetes management by extending health interventions beyond traditional care. Mobile technology makes it possible for patients to share relevant data at any time, not just at the time of a clinic visit, strengthening best evidence for optimal treatment.

Background Literature

Text messaging has been used extensively in supporting the communication and education of adults and adolescents with diabetes. Text messaging has been used to send blood glucose levels (Ferrer-Roca, Cárdenas, Diaz-Cardama, & Pulido, 2004) and general questions to providers (Rotheram-Borus et al., 2012), and to transmit educational materials (Arora, Peters, Agy, & Menchine, 2012; Foreman et al., 2012; Franklin, Waller, Pagliari, & Greene, 2006; Wangberg, Arsand, & Andersson, 2006), motivational messages (Arora et al., 2012; Franklin et al., 2006), and reminders to patients (Arora et al., 2012; Fischer et al., 2012; Franklin et al., 2006; Hanauer, Wentzell, Laffel, & Laffel, 2009). Few studies have investigated the effectiveness of using a text messaging system to improve glucose control (HbA_{1c}). For the ones that did (Benhamou et al., 2007; Franklin et al., 2006; Hanauer et al., 2009), no significant improvements for HbA_{1c} were obtained.

There are several systems that send questions to patients with diabetes to collect information, similar to the text messaging system previously designed by members of our research group for adolescent patients with asthma (Yun & Arriaga, 2013; Yun et al., 2012). These systems have been designed to send questions to inquire about hypoglycemic events (Tasker, Gibson, Franklin, Gregor, & Greene, 2007), adherence to healthy lifestyle behaviors (Rotheram-Borus et al., 2012), and blood pressure measurements (Fioravanti, Fico, Arredondo, & Leuteritz, 2011). Furthermore, Harris et al. (2010) took a different approach in providing feedback to patients on their reported blood glucose values by asking the patients why they thought their glucose values were high and asked follow-up questions based on the response (Harris et al., 2010). Unfortunately, none of the systems in these studies measured glycemic control.

One of the earliest text messaging systems specifically designed for youth with T1D was developed in Scotland, named *Sweet Talk,* with the intent to provide education and motivation for better self-management. These researchers designed a large text-messaging database to motivate adolescents to engage in four major activities: insulin injections, blood-glucose testing, healthy eating and exercise (Franklin et al., 2006). The system was rigorously evaluated with a yearlong randomized controlled trial of 92 participants enrolled in three arms of the study: conventional therapy, conventional therapy with *Sweet Talk,* and intensive therapy with *Sweet Talk.* Glycemic control (HbA_{1c}) did not change in patients on conventional therapy without or with *Sweet Talk*, but improved in patients randomized to intensive therapy and *Sweet Talk* ($P < 0.001$). Although *Sweet Talk* alone when included with conventional therapy did not affect glycemic control, the program was associated with improvement in diabetes self-efficacy ($P = 0.003$) and self-reported adherence ($P = 0.042$). Eighty-two percent of youth reported that *Sweet Talk* had improved their diabetes self-management, and 90% wanted to continue receiving messages (Franklin, Greene, Waller, Greene, & Pagliari, 2008).

In a pilot trial of a mobile text-messaging intervention to improve diabetes adherence in adolescents, Mulvaney, Anders, Smith, Pittel, and Johnson (2012) designed messages according to individually-reported barriers to diabetes self-care (Mulvaney et al., 2012). After 3 months, system users rated the content, usability and experiences with the system as very favorable. Intervention and control groups had similar HbA_{1c} levels at baseline. After 3 months, the mean HbA_{1c} level in the intervention group was unchanged (8.8%), but the mean level in