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Brief Communication

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A mobile app identifies momentary psychosocial and contextual factors related to mealtime self-management in adolescents with type 1 diabetes

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ABSTRACT

Effective diabetes problem solving requires identification of risk factors for inadequate mealtime self-management. Ecological momentary assessment was used to enhance identification of factors hypothesized to impact self-management. Adolescents with type 1 diabetes participated in a feasibility trial for a mobile app called MyDay. Meals, mealtime insulin, self-monitored blood glucose, and psychosocial and contextual data were obtained for 30 days. Using 1472 assessments, mixed-effects between-subjects analyses showed that social context, location, and mealtime were associated with missed self-monitored blood glucose. Stress, energy, mood, and fatigue were associated with missed insulin. Within-subjects analyses indicated that all factors were associated with both self-management tasks. Intraclass correlations showed within-subjects accounted for the majority of variance. The ecological momentary assessment method provided specific targets for improving self-management problem solving, phenotyping, or integration within just-in-time adaptive interventions.

Key words: diabetes, pediatric, ecological momentary assessment, precision medicine, self-management, context

INTRODUCTION

Diabetes problem solving is dependent upon obtaining information that points to specific and actionable influences on self-management. Processes important for self-management problem identification, such as pattern recognition and causal inference, are often based on unreliable and incomplete patient recall of events. Dependence on recall may lead to identification of factors that are salient but not correlated with self-management. Psychosocial and contextual factors have been related to diabetes self-management.[1] However, greater accuracy and specificity regarding which, when, and how often psychosocial and contextual barriers occur and their relationship to self-management are needed for effective self-management problem solving. Ecological momentary assessment (EMA) utilizes repeated sampling of behavior in real-time within the natural environment. It provides a valuable method to examine relationships between events that are proximal in nature. EMA has been shown to be more accurate and reliable compared with traditional questionnaire methods.[2–4] Momentary assessment studies have rarely been conducted in diabetes.[5,6] To improve inferences regarding potential risk factors for missed self-management, we assessed momentary psychosocial and contextual factors and related those to self-monitored blood glucose (SMBG) and insulin administration in adolescents with type 1 diabetes. The MyDay mobile app development process, feasibility, and engagement patterns have been reported previously.[7,8]

MATERIALS AND METHODS

Inclusion criteria in the mobile app study included patients 1) treated in the Vanderbilt Eskind Pediatric Diabetes Clinic over 12 years of age, 2) diagnosed with type 1 diabetes for at least 6 months, 3) able to speak and read English, 4) in possession of an Android or iOS smartphone, and 5) who were willing to use a Bluetooth blood glucose meter for 1 month. Recruitment occurred via clinic flyers and clinician referral. Parent consent and adolescent assent were obtained before research procedures commenced. Momentary data were collected using a mobile application for iOS/Android called MyDay.

The dependent variables in this study were missed mealtime blood glucose monitoring (1 = missed, 0 = completed) and missed mealtime insulin administration (1 = missed, 0 = completed). Momentary psychosocial and contextual factors were assessed at each self-reported mealtime and included stress, energy, mood, location, people, and situational barriers. Stress, energy, and mood were assessed using a "slider" interface and could range from 0 to 100 in value. Stress and energy had high (value = 100) and low (value = 0) and mood had bad (value = 100) and good (value = 0) labels as anchors for the sliders. Options for locations included home, school, friend's house, work, restaurant, on the road, and other. Multiple responses could be selected for who the adolescent was with at the mealtime ("people") and included the options of no one, parent(s), sibling(s), close friends, casual friends, strangers, and boyfriend or girlfriend, or other. Participants could select (yes/no) multiple contextual barriers associated with mealtime self-management behaviors: rushing, with people, hungry, busy, having fun, tired, without supplies, meter or pump issues, and nothing. Participants selected either breakfast, lunch, or dinner for the assessment. Snacks were not assessed. Data could be entered up until midnight of that day. The time gap between reported mealtime and momentary assessment data submission varied by meal but was consistently within 1 hour, except for lunchtime, which was delayed approximately 2 hours due to school attendance.[7] Bluetooth iHealth meters were used to passively obtain SMBG frequency and self-report was used for insulin administration.

Mixed-effects logit models were used to assess the associations of the momentary variables with mealtime self-management behaviors. The most prevalent responses for momentary question options were analyzed and defined as responses endorsed by at least 10% of the sample. Analyses were conducted via the maximum likelihood adaptive Gauss-Hermite quadrature estimation and logit-link function as implemented in the STATA "xmelogit" procedure (version 14; StataCorp, College Station, TX). Exponentiation of the fixed estimates resulted in the between-subjects odds ratios controlling for within-subjects autocorrelation. Within-subjects random effects odds ratios were also calculated. Analyses provide the likelihood of a missed self-management task in the presence of a risk factor relative to the likelihood without that factor. Breakfast served as the referent for mealtime and home was the referent for the location factor. With the exception of location and mealtimes, each of the momentary factor categories were dichotomous (eg, family yes/no, rushing, yes/no) resulting in a single between-subjects and respective within-subjects odds ratio. However, location and mealtime had mutually exclusive categories. Given that a single individual can only have one location or mealtime (of the 3 mutually exclusive categories) for a specific momentary assessment, only a single pooled within-subjects odds ratio could be calculated for those 2 factors. Intraclass correlations were calculated to quantify within-subjects variability in self-management behaviors.

RESULTS

One participant from the pilot study was not included in the current analyses as there was no data available after week 1. The sample (n = 30) was on average 15.40 ± 1.52 years of age, 53% were girls, and 90% were non-Hispanic white. Duration of diabetes was on average 5.96 ± 4.41 years, 73% used an insulin pump, 13% used continuous glucose monitoring, and the mean hemoglobin A1c was 8.0 ± 1.16%.

Of the 1472 mealtime assessments with reported meals, there were 4% (n = 57) self-reported missed insulin boluses (median 2.26) and 28.0% (n = 412) missed SMBG (median 38.19) from the Bluetooth meter. Average levels of momentary factors were as follows: stress (mean 25.23 ± 11.81; median 24.20 [range, 0-100]), energy (mean 46.81 ± 13.63; median 44.85 [range, 0-100]), and mood (mean 68.88 ± 16.24; median 72.01 [range, 0-100]). Locations reported most frequently at mealtimes were home (62.80%), school, (20.10%), and restaurant (10.60%). Social contexts reported most frequently were with family (60.00%), with friends (25.50%), and alone (17.50%). Situational barriers were reported for 57.41% of assessments. The most frequently reported situational barriers were fatigue (32.70%), hunger (26.27%), having fun (13.10%) and rushing (12.87%).

Figure 1 shows the between- and within-subjects odds ratios and 95% confidence intervals for associations between momentary factors and missed mealtime SMBG. The between-subjects factors "with family," "with friends," school, restaurant, and lunch and dinnertimes were related to more missed SMBG. Within-subjects random-effects odds ratios indicated that all momentary factors were significant for SMBG. Figure 2 shows between- and within-subjects odds ratios and 95% confidence intervals for associations between momentary factors and mealtime insulin. Stress, energy, mood, and fatigue were associated with more missed insulin. Variables with odds ratios less than 1 indicate less missed insulin. Dinnertime and having fun were associated with less missed insulin. Within-person random effects odds ratios indicated that all momentary factors were associated with more missed insulin. Intraclass correlation coefficients indicated between 63.3% and 77.8% within-person variability for SMBG and between 63.2% and 74.7% within-person variability for insulin.

DISCUSSION

The current study utilized EMA to identify psychosocial and contextual risk factors important for understanding and improving adolescent diabetes self-management. Using this in vivo method, unique temporal relationships were documented among contextual variables, subjective experiences, and critical mealtime self-management behaviors.

The results of the study should be interpreted in context of the between-subjects and within-subjects analyses. Between-subjects analyses identified associations relevant for the sample, and by inference, the population. The within-subjects analyses identified association based on the variability of individuals and the degree to which individuals within the sample varied on a given factor. The relevant between-subjects factors for missed SMBG or insulin administration were stress, energy, mood, having fun, fatigue, mealtime, social influences, and location. In within-subjects analyses all momentary factors were associ-

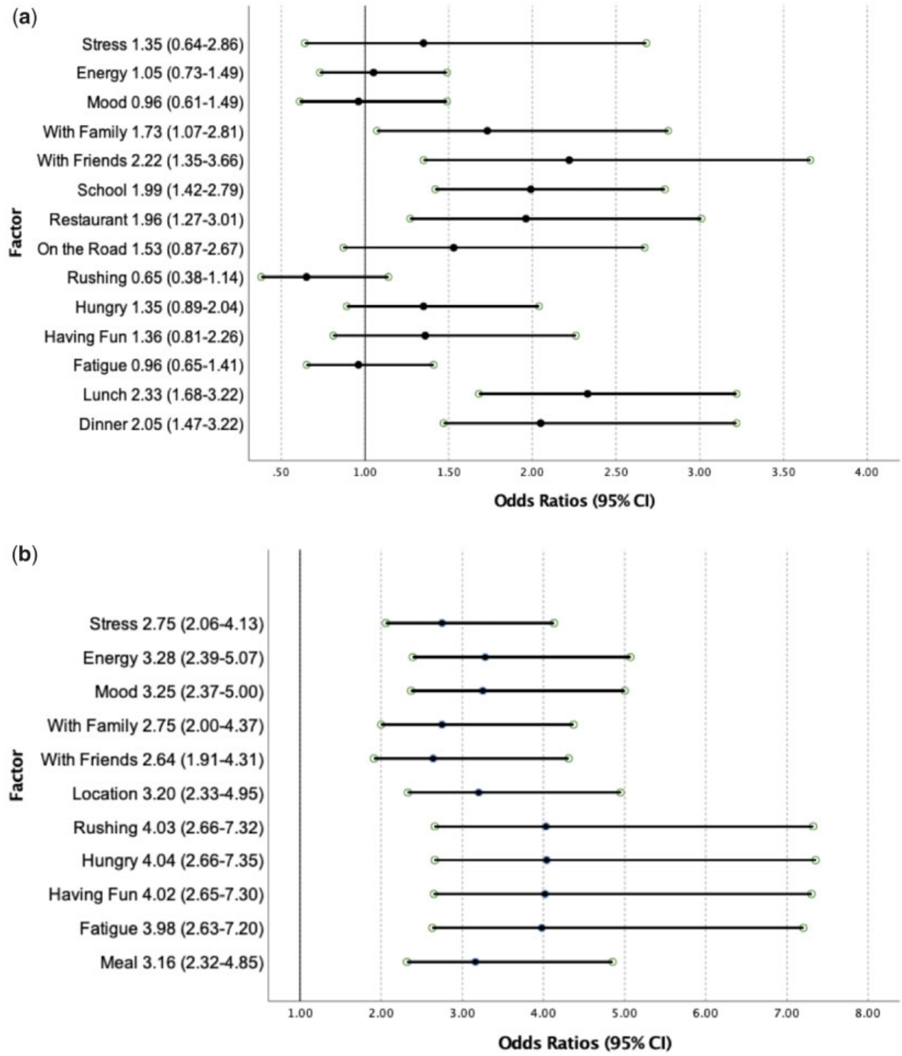

Figure 1. (A) Between- and (B) within-subjects associations of momentary factors with missed mealtime self-monitored blood glucose. CI: confidence interval.

ated with both SMBG and insulin. Additionally, based on intraclass correlations, it appears that the relative majority of variability in self-management was due to within-subjects. The within-subjects results underscore the need to study individual-level patterns of risk factors to inform precision behavioral interventions and clinical practice.

The momentary factors included in this study were selected based on their documented associations with self-management using traditional assessment methods or hypotheses regarding potential impact. Previous research has largely documented self-management barriers based on retrospective patient perceptions of influences and used questionnaires that aggregate multiple self-management behaviors.[9–11] EMA allowed the aggregation and quantification of specific instances when the actual presence of a risk factor negatively impacted a specific self-management behavior. For example, previous research has shown that adolescents perceive peers can have a negative influence on their self-management[11,12]; here, between-subjects results indicated that being in the presence of friends was associated with 2× greater chance of missing a blood glucose check compared with being alone.

Similarly, while meals or food in general have been identified as general risk factors for problems in self-management,[13,14] we were able to identify that on average school and restaurants were associated with 2× greater risk for missed SMBG compared with being at home. In addition to enhancing our understanding of previously identified self-management risk factors, the current study identified novel risk factors. Research to date has few studies focused on protective factors related to self-management with notable exceptions focused on resilience.[15,16] The between-subjects results uniquely identified dinnertime and "having fun" as protective factors related to insulin administration, and being in the presence of family as a risk factor for missed SMBG.

While advancing our understanding of momentary influences on health behavior and providing novel targets for intervention, the current study has limitations. The ultimate goal for research and clinical practice is to obtain accurate and actionable patient-generated data using the most feasible and objective methods. EMA typically depends on self-report of experiences and response burden is a valid concern regarding feasibility for clinical use. While mobile location services provide valuable geographic data and will be used in this system moving forward, objective passive data streams are not currently available for many experiences or behaviors such as mood, persons present, or nutritional intake. Current interest in wearable devices and personal health tracking will facilitate the

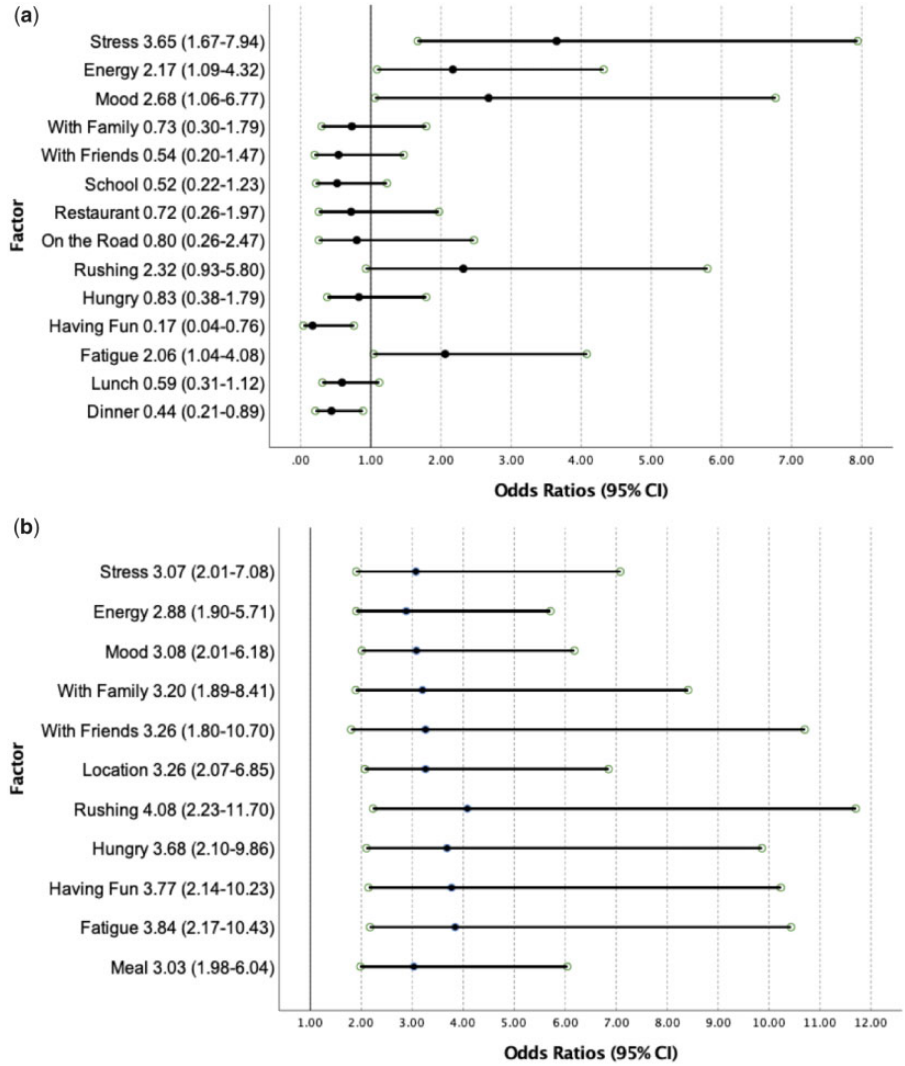

Figure 2. (A) Between- and (B) within-subjects associations of momentary factors with missed mealtime insulin. CI: confidence interval.

integration of patient-generated data into health care.[17,18] Ideally, both passive sensor data and self-report EMA should be integrated to maximize behavioral and clinical insights.

Although both SMBG and insulin administration are both important for mealtime self-management, results identify unique patterns of momentary factors for each. We are not aware of studies that have directly compared momentary factors associated with multiple self-management behaviors within one sample. While the natures of the 2 tasks do differ, it is not clear behaviorally why these specific differences in momentary factors may exist. One possible methodological explanation is the use of Bluetooth meters for SMBG and self-report for insulin administration. Future researchers could limit sampling to individuals using insulin pumps for objective data, although this would negatively impact generalizability as approximately 50% of adolescents use insulin pumps.[19,20]

The methods and results of this study have implications for integration of patient reported outcomes to tailor problem solving and clinical care,[21] development of more specific and accurate behavioral risk profiles or phenotypes,[22,23,24] and integration into just-in-time adaptive interventions in diabetes.[25] To utilize EMA in just-in-time adaptive interventions or health care, these results will need to be documented in a larger sample where the reliability of the associations over time may be established, feasibility enhanced, and clinical cost-benefit ratio established.

CONCLUSION

EMA provided valuable insights into the association of momentary psychosocial and contextual influences on pediatric diabetes self-management. While integration with passive sensor data streams and further confirmation of the reliability and robustness of the relationships are needed, the method may be instrumental in advancing behavioral interventions and support of self-management problem solving.

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AUTHOR CONTRIBUTIONS

All authors contributed to the conceptualization and implementation of the design and scientific evaluation of the mobile momentary assessment app. SAM, SV, DS, MSD, LL, and KKH helped draft and/or revise the manuscript.

ETHICS APPROVAL

The Vanderbilt University Human Subjects Committee reviewed and approved this research.

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CONFLICT OF INTEREST STATEMENT

None declared.

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