24hr glycemic changes after peer group exergaming and step goal activities among adolescents with type 1 diabetes

James Lukasik[1], Laura M. Nally[1], Sangchoon Jeon[1], Alvaro Granados[1], Stuart A. Weinzimer[1], Garrett I. Ash[1,2]

[1]Yale University, [2]Veterans Affairs Connecticut Healthcare System

INTRODUCTION

- Physical activity (PA) is known to be metabolically beneficial and decrease cardiovascular risk. This has a heightened importance in individuals with type 1 diabetes (T1D) due to the inherently increased risk of cardiovascular complications[1]. However, PA has unpredictable acute effects on glucose which are just beginning to undergo study in real-world settings[2,3].
- Two pragmatic ways for individuals to engage in PA are videogames involving gross motor movement (exergames) and daily step goals. These activities have been shown to modestly increase time in glycemic target range (TIR) among individuals with T1D. However, the samples were mostly restricted to those with average glucose levels within clinical recommendations, PA levels exceeding recommendations, and non-Hispanic white background[4-6].
- Adolescents are an age group of the T1D population in especial need of PA guidance as they take greater responsibility for personal care, manage insulin effects of puberty hormones, and face social barriers to PA like self-management logistics, fear, distress, and stigma in group settings. Adolescents have the highest A1c levels of any age group with T1D[7] and have the most potential to gain from increased PA and TIR[8].
- We previously addressed these gaps with a peer support intervention containing group exergaming and step-counting goals for adolescents with T1D. The intervention proved highly feasible and acceptable a cohort of adolescents with a diversity of HbA1c levels and demographic backgrounds.

PURPOSE

Identify relationships between 24hr continuous glucose monitoring (CGM) changes and step counts following the intervention's biweekly exergaming sessions.

METHODS

Design: This project was a longitudinal observational post-hoc analysis of a clinical trial previously described[9] in which adolescents with type 1 diabetes wore a CGM and Fitbit for 6 weeks while receiving a virtual peer group exergaming and PA goal-setting intervention (NCT05163912).

Participants: Age of 14-19 years, diagnosis of T1D for ≥6 months, not achieving recommended PA targets (i.e., <4 days/wk with 60+ min moderate-to-vigorous PA self-reported), and lack of physical limitations that would prevent them from engaging in the activity.

CGM: Sensors estimating blood glucose based upon interstitial glucose including Dexcom G6 (n=12 participants) and Abbott Libre 2 (n=3 participants). Both have been previously validated as <10% mean absolute relative difference to venous blood glucose. Values were extracted at 5min intervals and for purposes of this post-hoc analysis averaged across each hour. Clinical guidelines for T1D management recommend working toward increasing the amount of time with CGM values in a target range of 70-180 mg/dL[10].

Smartwatch: Fitbit Inspire 2 contains an accelerometer for step counts and photoplethysmography sensor for heart rate. No published studies to our knowledge have validated this specific model of Fitbit. The Fitbit brand in general has been found to underestimate steps (-3 steps/minute)[11] and heart rate (-3 beats per minute)[12]. Also, of great importance, among five validation studies capturing skin tone two reported that darker was associated with less accurate Fitbit heart rate[13]. It was chosen for the study due to its popularity and affordability (80 USD).

ANALYSIS

- Two-level linear model for continuous dependent variable of hourly average glucose
- Two-level logistic model for categorical dependent variable of hourly average glucose within clinical target range.
- Independent variables for both models
  - Within-person: exergaming in past 24 hours, hourly step count, hourly average heart rate
  - Between-person: demographic covariates (age, HbA1c)

RESULTS

•Data collation
- •14 of the 15 participants shared data.
- •Exergaming sessions held biweekly (85% attendance, yielding 117 person-sessions)
- •Glucose readings taken every 5 minutes (75% complete, yielding ~136,000 readings)
- •Fitbit readings aggregated every minute (71% complete, yielding ~644,000 readings)
- •In total 8,638 person-hours of data with all variables were compiled from a possible 15,120 over the 6-week intervention (57%).

•Periods of sustained moderate-to-vigorous PA (i.e., 10 consecutive minutes of Fitbit steps >100 steps/min[14] or Fitbit heart rate >55% age-predicted maximum[15]) were extremely rarely detected (<5 total cases) apart from the exergaming sessions.

•Higher average Fitbit steps were associated with lower hourly glucose and higher probability of being in the glucose target range (Tables 1, 2).

•Lower average Fitbit heart rate values were associated with lower hourly glucose and higher probability of being in the glucose target range (Tables 1, 2).

•24hr periods following exergaming in comparison to the subsequent 24hr periods had
- •Lower hourly average glucose (Δ = 7 mg/dL, Figure 1, Table 1)
- •Higher probability of hourly average glucose being in the clinical target range (odds ratio = 1.18, Figure 2, Table 2).

Table 1. Demographics. Mean±SD for normally distributed variables, median (interquartile range) for others.

Age (yr)	15.4 (14.5 - 16.4)
Gender	6 female (40%) 2 non-binary (13%) 7 male (47%)
Race/Ethnicity	3 non-Hispanic black (20%) 4 Hispanic white (27%) 1 more than one race (7%) 7 non-Hispanic white (47%)
A1c (%)	7.8 (7.4 – 11.2)
Number of participants over 7%	12 (67%)
Number of participants over 10%	5 (33%)
Duration of type 1 diabetes (yr)	8.2±3.8
Household income	2 <$20,000 (13%) 5 $40,000-$59,999 (33%) 3 $80,000-$99,999 (20%) 4 >$100,000 (27%) 1 declined to respond (7%)
Type of CGM	12 Dexcom G6 (80%) 3 Abbott Libre 2 (20%)
Therapy	1 multiple daily injections (7%) 11 sensor-augmented pump (73%) 3 automated insulin delivery (20%)
Total daily insulin dose (U/kg)	0.9±0.3
Body mass index (%'ile)	75 (63, 87)
Baseline physical activity (days/wk with 60+ min moderate-to-vigorous PA)	2 (0±2)
Screen time (hours/day)	8.8±4.6

Table 2. Linear model for hourly average glucose in mg/dL (n=14 participants, k=8,638 person-hours)

	Coefficient	Standard Error	Degree of Freedom	T- Value	P-value
Within Subject					
Heart Rate	0.52	0.08	8640	6.52	<.0001
Steps	-0.65	0.11	8640	-6.06	<.0001
Exercise within 24hr	-7.74	1.90	8640	-4.07	<.0001
Between Subject					
A1c	17.29	2.65	8640	6.52	<.0001
Age (Baseline)	4.10	3.67	8640	1.11	.2651
	LS Mean	95% CI			
Exercise within 24hr	184.7	173.3, 196.1			
Exercise 24hr to 48hr	192.4	181.3, 203.6			
Difference	7.74	4.01, 11.47			<.0001

Table 3. Logistic model for odds of hourly average glucose being in clinical target range (70-180 mg/dL) (n=14 participants, k=8,638 person-hours)

	Coefficient	Standard Error	Degree of Freedom	T- Value	P-value
Within Subject					
Heart Rate	-0.012	0.002	8640	-5.20	<.0001
Steps	0.021	0.003	8640	6.26	<.0001
Exercise within 24hr	0.167	0.056	8640	2.98	.0029
Between Subject					
A1c	-0.333	0.067	8640	-5.00	<.0001
Age (Baseline)	-0.077	0.090	8640	-0.85	.3930
	Odds Ratio	95% CI			
Exercise within 24hr	1.18	1.06, 1.32			

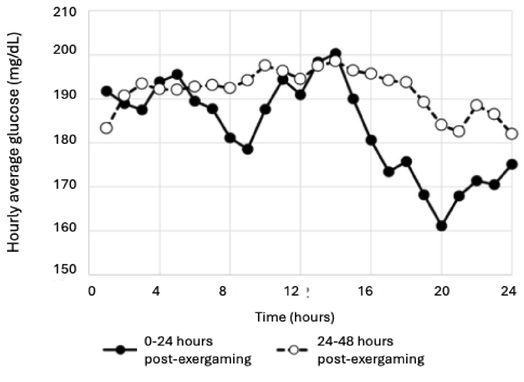

Figure 1. Hourly average glucose, compared between 24hr periods after exergaming versus no exergaming. n=14 participants, k=8,638 person-hours.

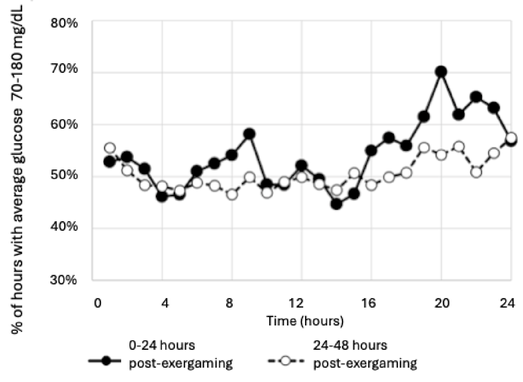

Figure 2. Proportion of hours with glucose averaging in clinical target range, compared between 24hr periods after exergaming versus no exergaming. n=14 participants, k=8,638 person-hours.

CONCLUSION

•Exergaming and Fitbit steps were both followed by glucose being lower and more often in the clinical target range, suggesting that these pragmatic strategies to increase PA may also aid in glucose management.

•Fitbit heart rate elevations, independent of PA, were associated with glucose elevation and time outside the target range and thus necessary to include in the models. These results may reflect effects of sympathetic nervous system activation (e.g., from mental stress) but should be interpreted cautiously due to questionable validity of Fitbit heart rate readings.

•A similar number of exergaming sessions as our study (~120) were evaluated in the T1DEXIP dataset and revealed glycemic time-in-range was 15% higher during these sessions compared to other exercise. However, this result may be due to differences in starting glucose (average 154 mg/dL for exergaming vs 163 mg/dL for other exercise)[4].

•We addressed this limitation by making comparisons over 24hr periods following exergaming versus no sustained moderate-to-vigorous PA, to mitigate the impact of hourly fluctuations unrelated to PA.

•We also extended the knowledge base by including a more diverse sample of adolescents with T1D.

•Further study is needed:
- •Examine time-in-range at the 5min instead of hourly level, to account for short hypoglycemic episodes
- •Examine other CGM metrics that are part of standard clinical trial reporting
- •Test dose response to various exergaming intensity, duration, and types
- •Refine the optimal time window duration after exergaming to observe glucose effects
- •Understand other contributors to glucose fluctuations in adolescents such as psychosocial and other external factors.

DISCLOSURE

S.A.W. receives grant support to his university from Abbott Laboratories. M.S. is employed as a product manager by Abbott Laboratories. L.M.N. began serving as a consultant for Medtronic after completion of the study. None of these entities supported the above study, and the authors conducted the research outside of their responsibilities and affiliations with these entities.

AKNOWLEDGMENTS

American Heart Association #852679 (G. Ash), Robert E. Leet and Clara Guthrie Patterson Trust Mentored Research Award, Bank of America, N.A., Trustee. G. Ash and L Nally were supported by the National Institute of Diabetes, Digestive, and Kidney Diseases of the National Institutes of Health under mentored research scientist development awards (K01DK129441, K23DK128560).