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Association between Fear of Hypoglycemia and Physical Activity in Youth with Type 1 Diabetes: the SEARCH for Diabetes in Youth Study

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Abstract

Background: Youth with type 1 diabetes (T1D) are encouraged to participate in physical activity (PA). Studies have identified fear of hypoglycemia (FOH) as a barrier to participating in PA.

Objectives: To examine 1) PA patterns in youth with T1D by age group and 2) the relationship between both parental and youth FOH and youth PA.

Methods: A cross-sectional analysis from the SEARCH cohort study visit of youth ages 10-17 years with T1D (n=1,129) was conducted. Linear regression models estimated the association between self-reported number of days of vigorous PA (VPA) and moderate PA (MPA) and both youth- and parent-reported FOH. Multivariable models were adjusted for age, sex, race, duration

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of T1D, HbA1c, use of continuous glucose monitoring (CGM), recent severe hypoglycemia, primary insulin regimen, and BMI.

Results: Participants were 52% female, had mean (sd) age 14.4 (4.2) years, diabetes duration 7.5 years (1.8), HbA1c 9.2% (1.7). Older youth were less likely to engage in VPA ($p<.01$), or sports teams ($p<.01$), but more likely to engage in MPA ($p<.01$). Higher youth FOH (behavior subscale) was associated with increased levels of VPA (β (se) 0.30 (0.11), $p=.01$) but not significantly associated with MPA ($p=.06$). There was no statistically significant association between parental FOH and youth PA.

Conclusions: In SEARCH participants with T1D, VPA and team sports participation declined with age, while MPA increased. We observed that higher scores on the youth FOH behavioral subscale were associated with increased VPA levels, suggesting that FOH may be less of a barrier to PA than previously thought.

Introduction:

Youth with type 1 diabetes (T1D) are encouraged to participate in physical activity (PA) for improved cardiovascular function (1, 2), psychosocial benefits (3), and positive effect on glycemic control (4, 5). National recommendations in the United States are that all children participate in at least 60 minutes of moderate-to-vigorous physical activity daily (6, 7). International Society for Pediatric and Adolescent Diabetes (ISPAD) and American Diabetes Association (ADA) guidelines (8, 9) reinforce the importance of PA in people with T1D and strongly recommend regular PA with appropriate precautions related to the demonstrated increased risk for glycemic excursions around exercise (10). Clear consensus guidelines exist to mitigate the risk of hypoglycemia around exercise and promote safe and regular PA in T1D (11).

Exercise may be associated with hypoglycemia and hyperglycemia, depending on the type of activity and associated counter-regulatory hormone milieu (12, 13). Additionally, hypoglycemia can occur several hours following the exercise period, especially overnight, as increased insulin sensitivity and replenishment of glycogen stores occur (14, 15). Increased glucose monitoring and insulin dose adjustments before, during, and following exercise may mitigate this risk and are often indicated to maintain euglycemia (16–19). Many youth with T1D are not performing appropriate glucose monitoring or insulin dose adjustments around exercise (20), potentially perpetuating the association of increased PA with hypoglycemia.

While only 33% adults with T1D achieve recommended daily exercise targets (21), a subset of youth with T1D in the SEARCH for Diabetes in Youth Case-Control Study reported exercise rates comparable to peers without diabetes with 82% of youth with T1D meeting PA recommendations (22). With the important beneficial impact that exercise can have on disease-related outcomes, a focused effort to increase PA and address barriers is important.

Studies in youth and adults with T1D report fear of hypoglycemia (FOH) as a primary barrier to adequate exercise in all age groups (23–25). Brazeau et. al administered a diabetes-specific measure to determine significant barriers to PA in adults with T1D and found FOH to be the strongest reported barrier in their study (26). Jabbour et. al. reached a similar conclusion in youth; FOH was a significant barrier, though other factors cited included loss of control of diabetes, work schedules, external temperature, and low fitness levels (24). Furthermore, greater parental support was associated with lower barrier scores to PA (24). These aforementioned studies assessed perceived barriers to PA via questionnaires but did not objectively evaluate PA levels and how they may relate to FOH. While some FOH may be appropriate and adaptive given the risks of severe hypoglycemia (27, 28), excessive FOH may be maladaptive and associated with decreased quality of life (29), permissive hyperglycemia and poorer glycemic control (30). Additionally, FOH may contribute to disordered eating behaviors in T1D as well as difficulty with healthy weight management (31).

The primary aims of this study were to examine PA by age in the SEARCH youth T1D population, and how FOH in youth and parents impacts moderate-intensity physical activity (MPA) and vigorous-intensity physical activity (VPA) levels. We hypothesized that 1) overall PA in youth with diabetes declines with age, 2) FOH is associated with lower PA levels, and 3) parental FOH does not impact PA levels in youth.

Methods:

Study population

Youth with diabetes diagnosed before 20 years of age were identified through a population-based incident registry network at five U.S. sites starting in 2002 by the SEARCH for Diabetes in Youth Registry Study (32). Cases with a clinical diagnosis of T1D in 2002-2006 or 2008 (based on medical record or referring physician (32)), a baseline SEARCH visit and at least 5 years of diabetes duration were recruited into the cohort study. This analysis presents cross-sectional data collected at the cohort study visit. Cohort study visits were conducted between 2010 and 2015.

Cohort study visits

Anthropomorphic measurements were taken and body mass index (BMI) was defined as weight (kilograms) divided by height (meters^2) and converted to an age and sex-adjusted Z score (33, 34). Participants and/or their parents completed surveys including insulin regimen (pump vs. multiple daily injections), insulin daily dose, and mode and frequency of glucose monitoring. Participants' race, ethnicity, parental education and household income were self-reported by participants or parents.

Laboratory measures

HbA1C was measured at the central laboratory (35) (Northwest Lipid Metabolism and Diabetes Research, Seattle, WA).

Type of diabetes

Diabetes type was extracted from the participants' medical record. Only those participants with a clinical diagnosis of T1D were included in this analysis.

Measurement of key variables

All self-report variables were assessed at the cohort study visit between 2010 and 2015. Youth ages 10-17 years with T1D who participated in the SEARCH cohort study visit and who completed both the FOH (Child and Parent) and PA questionnaires (N=1,129) were included; those with missing questionnaires (n=75) were excluded. Of note, those ages 18 and older did not have parental FOH questionnaires and thus were not included in this study. FOH was assessed using the Child Hypoglycemia Fear Survey and Parent Hypoglycemia Fear Survey – previously published surveys that have been shown to have good internal consistency and validity (30). These surveys are scored as an item average (each of the 25 items on a 0-4 scale, 4 indicating more fear). A total average score, as well as behavior and worry subscale average scores were generated. For each tool, there are 10 items in the Behavior subscale and 15 items in the Worry subscale. The Behavior subscale score relates to engagement in behaviors to avoid hypoglycemia. The Worry subscale score measures how often the youth or parent worries about concerns related to hypoglycemia. These surveys have demonstrated adequate reliability, in that the Child Hypoglycemia Fear Survey had Cronbach's αs of 0.85 (Total), 0.70 (Behavior), and 0.89 (Worry) (30). The Parent Hypoglycemia Fear Survey had Cronbach's αs of 0.86 (Total), 0.70 (Behavior), and 0.89 (Worry) (30).

PA was assessed via a questionnaire that asked the youth to report VPA participation as follows: "On how many of the past 7 days did you exercise or participate in a physical activity for at least 20 minutes that made you sweat and breathe hard, such as basketball, soccer, running, swimming laps, fast bicycling, fast dancing, or similar aerobic activities?". They were then asked about participation in MPA: "On how many of the past 7 days did you exercise or participate in a physical activity for at least 30 minutes that did **not** make you sweat and breathe hard, such as fast walking, slow bicycling, skating, pushing a lawn mower, or mopping floors?" They were also asked, in the past 12 months, how many sports teams they participated in. These questions were taken from the Centers for Disease Control and Prevention's 1999 Youth Risk Behavior Survey (YRBS)(36). Reliability of the YRBS for MPA is moderate, with an Intraclass Correlation Coefficient (ICC) of 0.51 and an ICC of 0.46 for VPA (37). Severe hypoglycemia was self-reported for the prior 6 months and defined as a "very low blood sugar that required you to get help".

Analysis

Summary measures were used to describe the sample, both overall and by age group (10-13 years, 14-17 years). Initial tests for differences between age groups were done using exact tests for categorical variables and either a t-test or a Kruskal-Wallis test, depending on the distribution of the variable of interest. Linear regression was used to model the association between FOH and days of VPA and MPA; and, generalized linear models with a log link and assuming a negative binomial distribution were used to estimate the association between FOH and sports team participation. FOH was examined by total score, as well as behavior and worry subscale scores when generating models. The multivariable models were adjusted for age at visit, sex, race, duration of T1D, HbA1c, severe hypoglycemia history, continuous glucose monitor (CGM) use, insulin regimen and BMI. To account for multiple comparisons in the multivariable models, a p value of 0.006 was considered significant. Age was included as a continuous variable when examining PA patterns by age, and dichotomized into 10-13 years and 14-17 years age groups when examining relationships with FOH. Spearman's Rank Correlations were used to assess the unadjusted relationship between FOH and HbA1C, PA and HbA1C, and self-reported FOH scores and parent-reported FOH scores.

Results:

Participant characteristics are presented in Table 1. Of the 1,129 participants in the study sample, 52% were female, their mean (SD) age was 14.4 (2.2) years, diabetes duration was 7.5 years (1.8), and their mean HbA1c was 9.2% (1.7%) at the cohort study visit. One third (34%) had a BMI in overweight or obesity range, defined as 85^{th} percentile or greater.

PA patterns

Mean (SD) days of ≥20 minutes of VPA was 3.5 (2.2) and days of ≥30 minutes of MPA was 2.8 (2.3). Mean (SD) number of sports teams participated in during the past year was 1.1 (1.2). VPA declined with age (p<.01), while MPA levels increased with age (p<.01) (Table 1 and Figure 1). Sports team participation decreased with age (p<.01). A history of severe hypoglycemia was associated with increased VPA (p=.01) but not MPA or sports team participation.

FOH measured in youth and PA

Youth-reported FOH scores did not differ across age groups (10-13 yrs, 14-17 yrs) (Table 1). The mean item Youth FOH total scores were [median(Q1,Q3)] 1.2 (0.9;1.5), behavior scores were 1.8 (1.3;2.2), and worry scores were 0.7 (0.5;1.1). In the multivariable models (Table 2), a higher youth-reported FOH behavior subscale score was associated with increased days of VPA (β (se) 0.30 (0.11), p=0.005), but not significantly associated with MPA (p=0.06) or sports team participation (p=0.008)(Table 2). Sports participation and PA were not associated with youth-reported FOH worry or total FOH scores.

FOH in parents of youth with T1D and PA

The mean item Parental FOH total scores were [median(Q1,Q3)] 1.4 (1.0;1.8), behavior scores were 2.0 (1.5;2.4), and worry scores were 1.1 (0.6;1.6). Parents of youth ages 10-13 years scored higher on the behavior subscale (p <.01), worry subscale (p=.03), and total score (p <.01) for FOH, compared to parents of older youth (Table 1). Parental-reported FOH was not associated with youth PA levels or sports team participation overall, nor in any age group (Table 2). Parental FOH scores correlated with youth FOH scores (Table 3).

FOH, Activity and HbA1c

Youth-reported FOH worry scores demonstrated a positive correlation with HbA1c; higher worry scores were associated with higher HbA1c (r_s=0.07, p=.02) (Table 3). Parent FOH behavior and total scores were negatively correlated negatively with HbA1c (behavior, r_s= −0.15, p<.01; total, r_s= −0.07, p=.02). More days of VPA and higher number of sports teams were both inversely associated with HbA1c (r_s= −0.08, p=.01, r_s= −0.14, p<.01 respectively).

Discussion:

VPA and sports team participation among youth with T1D from the SEARCH for Diabetes in Youth study were less frequent in older youth, and higher scores on the youth-reported FOH behavior subscale were associated with increased levels of VPA. Parental FOH correlated with youth FOH, but was not associated with PA level or sports team participation.

A decline in PA with age is consistent with data on the general population from NHANES which demonstrated that 59.3% of youth ages 6-11 years meet PA guidelines (60 min of PA daily), while only 27.5% of adolescents 12-15 years meet PA guidelines (38). This is an especially important finding, given that the adolescent period is associated with insulin resistance of puberty and poorer glycemic control (39). Studies suggest that exercise has a beneficial impact on HbA1c in youth (40). Therefore, efforts focused on preserving (and increasing) PA levels as youth emerge into adolescence and young adulthood with maintenance of healthy lifestyle are key. Prior studies have identified specific barriers to PA among youth with T1D ≥12 years old including external temperature, loss of control of diabetes, low fitness levels, and fear of hypoglycemia(24).

FOH is self-reported as the primary barrier to PA (24, 26) in individuals with T1D. Additionally, antecedent exercise has been shown to be a leading risk factor for severe hypoglycemia in youth(41). Thus, we hypothesized that higher FOH would be associated with decreased PA levels. Our data, however, suggest the relationship between FOH and PA may be more complex. Youth that participate in more VPA reported higher FOH scores on the behavior subscale, suggesting more active avoidance of hypoglycemia. VPA is likely to result in glycemic excursions and delayed hypoglycemia if insulin modifications are not made (42). Additionally, more VPA was associated with a history of severe hypoglycemia. Thus, youth who participate in more VPA may be more acutely aware of the potential for glycemic excursions with exercise, or have received education from providers on hypoglycemia prevention strategies. An alternative interpretation is that those most active have previously experienced more hypoglycemia and thus utilize more strategies to prevent it. This study suggests that opportunities exist for improved education on exercise management for youth with T1D. Research has shown that increased in-clinic education on safe exercise is desired by parents and youth with T1D (43), and models of care to effectively incorporate exercise education into diabetes clinic have been recently published(44).

Parent FOH was not significantly associated with PA or sports team participation in this cohort of youth with T1D ages 10-17 years. This is consistent with other FOH literature which suggests that parental FOH does not impact other constructs such as HbA1c in adolescents (45). This suggests that, for youth 10 years or older, education on safe exercise and mitigating hypoglycemia risk should primarily focus on the child/adolescent rather than parents. This relationship has not been examined in the younger age group (<10 years old). The parental role in supervising activity levels and sports participation, as well as in diabetes management, is likely more significant in those who are <10 years old, and relationships between parental FOH and PA would likely exist in a younger cohort. The relationship between parental FOH and PA in young children could be examined in future studies.

In the SEARCH cohort study, we found that higher youth FOH worry scores were correlated with a higher HbA1c and thus worse glycemic control. This is consistent with studies that demonstrate less in-target glucose values and more glycemic variability with higher fear as well as studies that demonstrate an association between higher youth FOH and higher HbA1c (25, 29). In contrast, some studies show no relationship between FOH and glycemic control(46). The present study is a larger sample size than any previous FOH study cohort and thus we may have more power to better detect an association with glycemic control as measured by HbA1c.

Conversely, higher parental FOH total and behavior scores have the opposite relationship, correlating with lower HbA1c. Though an association between higher parental FOH and higher HbA1c has been seen in studies of younger children (47), parental FOH in other studies has not been found to correlate with glycemic control (48).. Our average participant age was 14 years, and thus it is not surprising that a direct correlation between parental FOH and HbA1c was not seen. With our adolescent cohort, the inverse relationship found may reflect parental concern that tighter glycemic control may result in a higher risk for hypoglycemia. More VPA and sports participation were associated with lower HbA1c, suggesting that the most active youth in our cohort had the best glycemic control. This is consistent with a 2014 meta-analysis which demonstrated that interventions to increase PA and reduce sedentary time in youth with T1D are associated with a reduction in HbA1c(40).

The strengths of this study include a large sample size with participants from multiple geographic regions, obtaining care from different diabetes providers. The limitations include that PA was self-reported, the cross-sectional design and that FOH was not assessed longitudinally. Additionally there may be some selection bias, for example, a large proportion of participants (63.7%) were on insulin pumps.

Overall, this study demonstrated that youth with T1D who are more physically active engage in more FOH-driven behaviors, as represented by youth FOH behavior subscale scores. This reinforces the need for education on safe exercise practices, particularly targeting the adolescents themselves. The decline in VPA and sports team participation with age observed in this study, alongside prior studies citing FOH as a barrier to PA (24), further supports the need to educate less active youth regarding the management and benefits of exercise.

However, given similar trends with regard to declining VPA with age in the general youth population, it would appear from these data that FOH in youth with T1D plays a minimal role in the age-related decline in VPA.

Conclusions

FOH in youth with T1D is important to recognize and address as a potential barrier to PA. However, in our study, FOH was not associated with lower levels of PA. Furthermore, we observed that PA attrition occurs in youth with T1D, as it does in the general population. Diabetes care teams should regularly review the importance of exercise with all patients, and target middle and older adolescents especially. Efforts to prevent a decline in VPA should be examined in future studies.

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Sites

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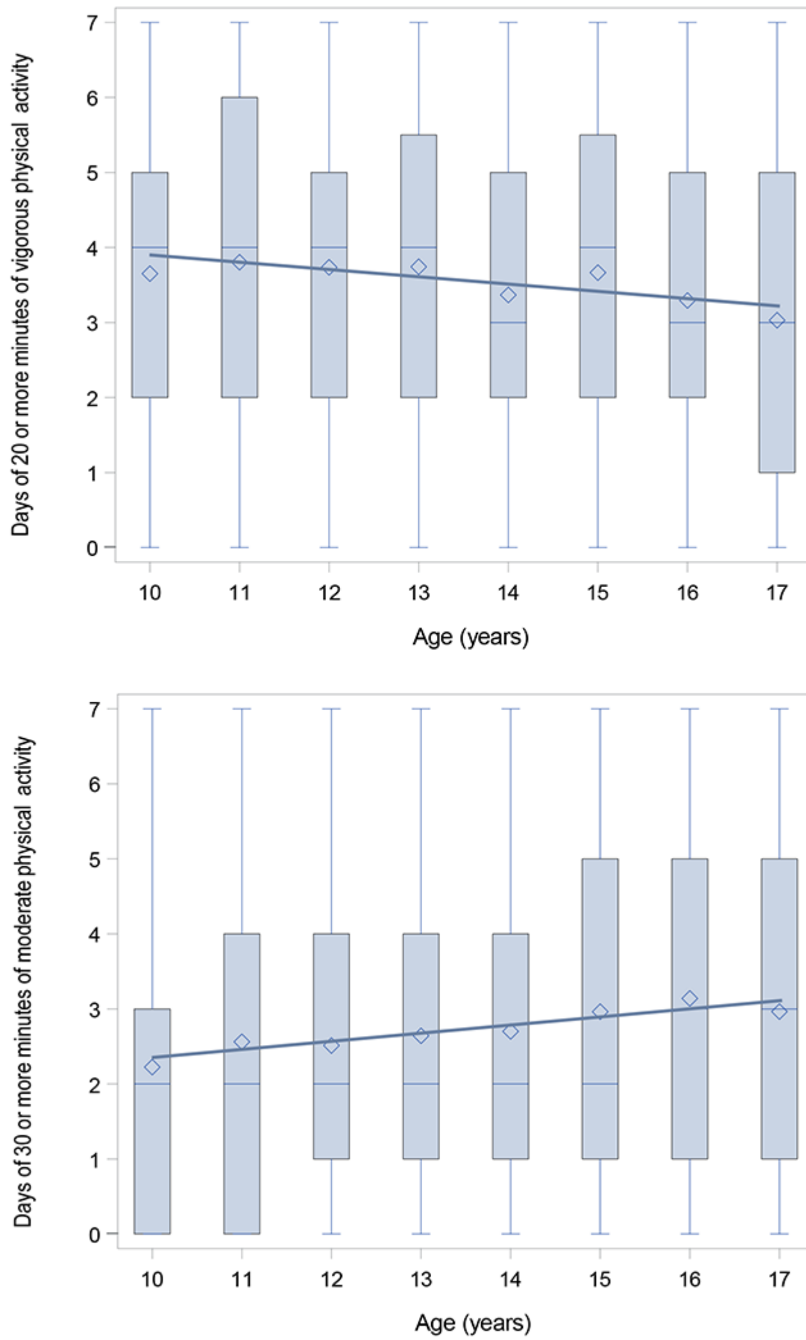

FIGURE 1.
Distribution and associations of age with days of moderate or vigorous physical activity

Table 1.

Characteristics of youth with T1D at the 2010-2015 Cohort visit for The SEARCH for Diabetes in Youth Study

		Age at Cohort Visit		
Characteristics	**All (N=1,129)**	**10-13 years (n=495)**	**14-17 years (n=634)**	**p-value**
Age at diabetes diagnosis (yrs) [mean(sd)]	6.8 (2.8)	4.7 (1.9)	8.4 (2.2)	<0.01
Age at study visit (yrs) [mean(sd)]	14.4 (2.2)	12.2 (1.1)	16.1 (1.2)	<0.01
Duration of diabetes (yrs) [mean(sd)]	7.5 (1.8)	7.4 (1.7)	7.6 (1.8)	0.23
Sex				0.67
Female	51.6%	52.3%	50.9%	
Race and Ethnicity				0.99
Non-Hispanic white	75.9%	75.5%	76.2%	
Non-Hispanic black	9.7%	9.9%	9.5%	
Hispanic	12.5%	62 12.6%	12.5%	
Other	2.0%	2.0%	1.9%	
Weight Status				<0.01
<85 percentile (normal or under)	66.4%	73.5%	60.8%	
85 to <95 percentile (overweight)	20.5%	16.0%	24.0%	
95+ percentile (obesity)	13.1%	10.4%	15.2%	
Primary Insulin Regimen Identified as Pump (vs. MDI)	63.7%	71.1%	57.9%	<0.01
Continuous glucose monitor (CGM) use	17.4%	17.6%	17.2%	0.87
Insulin Total Daily Dose (U/kg) [median(Q1,Q3)]	0.9 (0.7, 1.1)	0.8 (0.7, 1.0)	0.9 (0.7, 1.1)	0.05
Severe Hypoglycemia in last 6 months	6.3%	5.9%	6.6%	0.62
HbA1c (%) [mean(sd)]	9.2 (1.7)	8.9 (1.5)	9.3 (1.8)	<0.01
Health Insurance Type				0.57
Private	73.4%	73.0%	73.7%	
Public	23.7%	23.5%	23.9%	
Other/none	2.8%	3.4%	2.4%	
Parental Education				0.20
Less than high school graduate	3.9%	3.0%	4.6%	
High school graduate or higher	96.1%	97%	95.4%	
Child Hypoglycemia Fear Survey *				
Behavior subscale [median(Q1,Q3)]	1.8 (1.3; 2.2)	1.7 (1.3; 2.2)	1.8 (1.4; 2.2)	0.70
Worry subscale [median(Q1,Q3)]	0.7 (0.5; 1.1)	0.7 (0.5; 1.1)	0.7 (0.5; 1.1)	0.98
Total [median(Q1,Q3)]	1.2 (0.9; 1.5)	1.2 (0.9; 1.5)	1.2 (0.9; 1.5)	0.88
Parent Hypoglycemia Fear Survey *				
Behavior subscale [median(Q1,Q3)]	2.0 (1.5; 2.4)	2.1 (1.7; 2.5)	1.8 (1.4; 2.2)	<0.01
Worry subscale [median(Q1,Q3)]	1.1 (0.6; 1.6)	1.1 (0.7; 1.7)	1.0 (0.5; 1.5)	0.03
Total [median(Q1,Q3)]	1.4 (1.0; 1.8)	1.5 (1.2; 1.9)	1.3 (1.0; 1.7)	<0.01
Days of ≥20 min vigorous physical activity [mean(sd)]	3.5 (2.2)	3.7 (2.2)	3.3 (2.1)	<0.01
Days of ≥30 min moderate physical activity [mean(sd)]	2.8 (2.3)	2.5 (2.3)	2.9 (2.3)	<0.01
Number of sports teams in past 12 months [mean(sd)]	1.1 (1.2)	1.3 (1.3)	1.0 (1.1)	<0.01

Characteristics	All (N=1,129)	Age at Cohort Visit		p-value
		10-13 years (n=495)	14-17 years (n=634)	

p- values are either exact tests (categorical measures) or Kruskal-Wallis or t-test depending on the distributions (continuous measures) and are comparing the two age groups (10-13 vs 14-18).

*survey total of 25 items, 10 Behavior, 15 Worry. Each item scored 0-4. Scores represent average scores for all items in subscale or total, with possible reported range 0-4.

Table 2.

Multivariable linear models of relationship between FOH and measures of PA (Outcomes)

	Outcomes					
Exposures	**Vigorous physical activity**		**Moderate Physical activity**		**Team Sports Participation**	
	Beta (se)	**p-value**	**Beta (se)**	**p-value**	**Beta (se)**	**p-value**
Child Hypoglycemia Fear Survey						
Behavior	0.30 (0.11)	0.005	0.22 (0.11)	0.060	0.14 (0.05)	0.008
Worry	−0.03(0.12)	0.82	−0.004 (0.13)	0.97	−0.02 (0.06)	0.73
Total	0.18 (0.14)	0.19	0.14 (0.15)	0.34	0.08 (0.07)	0.25
Parent Hypoglycemia Fear Survey						
Behavior	−0.02 (0.11)	0.86	0.17 (0.12)	0.16	0.09 (0.05)	0.11
Worry	−0.10 (0.09)	0.30	−0.05 (0.10)	0.61	0.01 (0.05)	0.77
Total	−0.10 (0.12)	0.39	0.03 (0.13)	0.83	0.05 (0.06)	0.36

Each of the 18 models is adjusted for child's age at visit, sex (Female, Male), and race/ethnicity (non-Hispanic white, non-Hispanic Black, Hispanic, Other), duration of diabetes, hbA1c, bmi z-score, use of CGM (Yes, No), primary insulin regimen (Pump, Other), and recent severe hypoglycemia event (Yes, No). Vigorous and moderate physical activity are modelled using linear models, team sports participation is modelled using a generalized linear model with a negative-binomial distribution.

Table 3:

Spearman correlations between HbA1C and FOH and between Parent and Child FOH scores

HbA1C Correlations		
Child Hypoglycemia Fear Survey	**Spearman Correlation**	**p-value**
Behavior	0.009	0.78
Worry	0.07	0.02
Total	0.05	0.14
Parent Hypoglycemia Fear Survey		
Behavior	−0.15	<0.01
Worry	−0.02	0.61
Total	−0.07	0.02
Days of ≥20 min vigorous physical activity	−0.08	0.01
Days of ≥30 min moderate physical activity	−0.02	0.56
Number of sports teams in past 12 months	−0.14	<0.01
Parent and Child FOH Correlations		
Behavior	0.26	<0.01
Worry	0.25	<0.01
Total	0.28	<0.01