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Lower objectively measured physical activity is linked with perceived risk of hypoglycemia in type 1 diabetes

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ABSTRACT

Aims: Compare physical activity (PA) levels in adults with and without type 1 diabetes and identify diabetes-specific barriers to PA.
Methods: Forty-four individuals with type 1 diabetes and 77 non-diabetic controls in the Coronary Artery Calcification in Type 1 Diabetes study wore an accelerometer for 2 weeks. Moderate-to-vigorous physical activity (MVPA) was compared by diabetes status using multiple linear regression. The Barriers to Physical Activity in Type 1 Diabetes questionnaire measured diabetes-specific barriers to PA, and the Clarke hypoglycemia awareness questionnaire measured hypoglycemia frequency.
Results: Individuals with type 1 diabetes engaged in less MVPA, fewer bouts of MVPA, and spent less time in MVPA bouts per week than individuals without diabetes (all $p < 0.05$), despite no difference in self-reported PA ($p > 0.05$). The most common diabetes-specific barrier to PA was risk of hypoglycemia. Individuals with diabetes reporting barriers spent less time in MVPA bouts per week than those not reporting barriers ($p = 0.047$).
Conclusions: Individuals with type 1 diabetes engage in less MVPA than those without diabetes despite similar self-reported levels, with the main barrier being perceived risk of hypoglycemia. Adults with type 1 diabetes require guidance to meet current PA guidelines and reduce cardiovascular risk.

1. Introduction

Cardiovascular disease (CVD) is the leading cause of death in individuals with type 1 diabetes, is a common complication of type 1 diabetes, and presents at significantly higher rates and earlier in life in individuals with type 1 diabetes than in individuals without diabetes.[1,2] In people under 40 years of age, the CVD mortality rate is 9 times higher in men and 40 times higher in women with type 1 diabetes as compared to men and women without diabetes,[3] and CVD prevalence continues to rise.[4] Glycemic dysregulation is associated with increases in CVD risk and weight gain, both of which have become more prevalent in individuals with type 1 diabetes along with obesity[5–7]; thus, glycemic and weight control are important to prevent future cardiovascular and microvascular complications and to improve overall health in individuals with type 1 diabetes.[1,8]

The American Heart Association and the American Diabetes Association both recommend physical activity (PA) for optimizing blood glucose control in individuals with type 1 diabetes.[9,10] PA is known to reduce risk of CVD and to aid in the management of diabetes complications,[9] and higher levels of PA are associated with better glycemic control, lower levels of obesity, and a decrease in cardiovascular risk factors in individuals with type 1 diabetes.[11,12]

Previous studies have identified barriers to PA that are specific to diabetes and prevent individuals with diabetes from engaging in consistent PA,[13] suggesting that PA may be lower in this population due to unique barriers. Additionally, studies have shown that self-reported PA levels often differ from objective measures of PA.[14–16] The primary aim of this study was to compare planned leisure-time PA levels in adults with and without type 1 diabetes using objective data measured by an accelerometer. In addition, we examined diabetes-specific barriers to PA and explored how barriers and hypoglycemic episodes impacted PA in people with type 1 diabetes.

2. Materials and methods

2.1. Study population

We collected data on PA from 121 adults between the ages of 35 and 76 who initially enrolled in the Coronary Artery Calcification in Type 1 Diabetes (CACTI) study between March 2000 and May 2002.

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Participants were followed for 15 years and provided data at follow-up study visits occurring between May 2014 and June 2016. A total of 44 adults with type 1 diabetes and 77 adults without diabetes agreed to wear an accelerometer to collect PA data for a period of two weeks at the follow-up visit and were included in these analyses. All participants provided informed consent at baseline and follow-up visits, and all protocols were reviewed and approved by the Colorado Multiple Institute Review Board.

2.2. Physical activity

Study participants wore an Actigraph wGT3X-BT triaxial accelerometer on the hip for the two-week period (mean wear time 14.4 ± 3.6 days). The accelerometer was worn at all times except during water activities. Activity counts, calculated as a function of the frequency and intensity of acceleration on the X, Y, and Z axes,[17] were collected at 1-min intervals. Participants additionally logged their PA for the full two-week period and completed a validated questionnaire[18] capturing self-reported sports and leisure PA. Participants reported approximate weekly and yearly occupational and leisure periods of PA, and we calculated level of activity based on energy expenditure algorithms specific to each activity.[19]

Wear time validation was conducted in ActiLife version 6.13 to remove periods of non-wear from further analysis. The algorithm proposed by Choi et al. was chosen to identify periods of wear and non-wear time.[20] Only participants wearing the accelerometer for a total of at least 4 days, with at least 1 weekend day, were included in the analysis to ensure representative data were captured.

Activity levels were defined using Freedson adult definitions for sedentary, light, moderate, vigorous, and very vigorous activity based on the activity counts per minute.[21] Sedentary activity was defined as 0–99 counts per minute; light activity as 100–1951 counts per minute; moderate activity as 1952–5724 counts per minute; vigorous activity as 5725–9498; and very vigorous activity as >9499 counts per minute. Individuals were considered to be in extended bouts of moderate-to-vigorous PA (MVPA) if they engaged in moderate, vigorous, or very vigorous activity for at least 10 min with a maximum cumulative of 2 min of rest or inactivity that fell below the MVPA threshold. The bout definitions are intended to capture periods of planned activity and are the default in the ActiLife software. They are based on current guidelines and research regarding pauses in PA bouts.[21,22] Bouts of MVPA are comparable to the periods of planned PA described by the questionnaire used to capture self-reported PA. Non-bout periods of MVPA would include activity meeting the threshold for at least moderate activity but lasting fewer than 10 min, such as a brisk walk to catch a bus.

The MVPA outcomes assessed in the primary and secondary exploratory analyses were average weekly time spent in MVPA, including non-bout periods of MVPA; average weekly time spent in bouts of MVPA; and weekly number of MVPA bouts.

2.3. Barriers to physical activity

We administered the validated Barriers to Physical Activity in Type 1 Diabetes (BAPAD1) questionnaire[13] to all study participants: participants without diabetes completed a modified version of the BAPAD1 with diabetes-specific barriers removed. The questionnaire consists of 8 universal barriers to PA relevant to all study participants and 4 diabetes-specific barriers (Table 1). Participants were asked how likely each potential barrier is to prevent them from participating in PA using a Likert scale of 1 (extremely unlikely) to 7 (extremely likely). We defined individuals as having barriers if they assigned any potential barrier a score of 4 or greater. Scores <4 were not considered barriers as these were unlikely to prevent study participants from engaging in PA.

Table 1
Universal and diabetes-specific barriers measured by the BAPAD1.

Universal barriers	Diabetes-specific barriers
Fear of being tired	Loss of control over diabetes
Fear of hurting self	Risk of hypoglycemia
Fear of suffering a heart attack	Fact that you have diabetes
Low fitness level	Risk of hyperglycemia
Actual physical health status (excluding diabetes)	
Weather conditions	
Location of a gym	
Work schedule	

2.4. Hypoglycemia frequency

All study participants with type 1 diabetes completed the Clarke hypoglycemia awareness questionnaire[23] to assess their history of hypoglycemia. Participants self-reported past hypoglycemic episodes and the frequency of moderate hypoglycemic episodes in the prior six months. Moderate hypoglycemic episodes are those where the participant felt confused, disoriented, or lethargic and was unable to treat their hypoglycemia. We designated study participants as experiencing infrequent moderate hypoglycemia if they reported fewer than 2 occurrences in the previous 6 months, and frequent moderate hypoglycemia if they reported 2 or more occurrences in the previous 6 months.

2.5. Statistical analysis

All data analyses were conducted using SAS 9.4 (SAS Institute Inc., Cary, NC). Study participants' demographics, clinical and PA information were compared by diabetes status. Mean values and standard deviations of continuous characteristics were obtained and compared by diabetes status using two-sided *t*-tests. Proportions of categorical variables were obtained and compared by diabetes status using chi-squared tests for independence.

The three PA outcomes (average time in MVPA per week, average time in MVPA bouts per week, number of MVPA bouts per week) were compared between individuals with and without diabetes. We used multiple linear regression to model the mean outcomes for each exposure of interest. Because PA levels have been shown to differ between men and women, particularly among those with type 2 diabetes,[24,25] we tested the interaction between sex and the exposure of interest in all models. The final regression models were adjusted for age, sex, and accelerometer wear-time. If the interaction *p*-value between sex and the exposure variable was <0.10, this term was included in the model for the purpose of hypothesis generating regarding sex differences. For all other analyses, a relationship was considered significant at a p-value of 0.05.

3. Results

3.1. Physical activity

Characteristics of study population by diabetes status were compared (Table 2). Participants with type 1 diabetes were younger on average and had a more favorable lipid profile than participants without diabetes, as previously described.[26] There was no difference between the two groups in sex, BMI, or systolic blood pressure. Self-reported PA did not differ between groups: the number of participants reporting universal barriers to PA, the total scores on these universal barriers, and the time spent in planned MVPA per week did not differ by diabetes status. Based on accelerometer-measured objective PA data, individuals with type 1 diabetes spent significantly less time in MVPA bouts per week.

We compared differences in least-square means for the three MVPA outcomes in both participants with and without diabetes (Table 3). After adjustment for age, sex, and accelerometer wear-time, individuals

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