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# Establishing the incidence and timing of hypoglycemia at a residential diabetes camp

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ABSTRACT

*Aims:* To establish the incidence and timing of hypoglycemia at a week-long residential diabetes camp for children. We hypothesized that hypoglycemia would occur more frequently during the first two days of camp and following evening all-camp games.
*Methods:* 225 children (mean age 12.0 ± 2.3 years, 56% female, mean hemoglobin A1c 8.4% [71.6 mmol/mol]) had blood glucose (BG) levels obtained before meals, at bedtime, and as needed to detect hypoglycemia. Insulin adjustments were made by medical staff according to camp protocol and at the discretion of medical staff during camper check-in.
*Results:* Mild hypoglycemia (BG 50–69 mg/dL [3.9 mmol/L]) occurred ≥ 1 time in 90% of campers while 43% had ≥ 1 episode of BG < 50 mg/dL (2.8 mmol/L). No episodes of hypoglycemia requiring glucagon occurred. More campers experienced ≥ 1 overnight hypoglycemia event during the first 48 hours of camp compared to later in the week ($p = 0.01$). Evening all-camp games did not impact hypoglycemia rates overnight.
*Conclusions:* Nocturnal hypoglycemia occurred more frequently during the first two nights, establishing this period as high risk and supporting implementation of a standard protocol to lower insulin doses. Rates of hypoglycemia were unaffected by all-camp games, indicating current practices are effective at minimizing hypoglycemia.


## 1. Introduction

For over ninety years, diabetes camps have provided a traditional summer camp experience for children with type 1 diabetes mellitus. American Diabetes Association camps host over 6,000 children with Type 1 diabetes mellitus annually. The primary goal of camp is to allow children with diabetes an opportunity for safe, full participation in camp activities while preventing blood glucose (BG) extremes. This can be challenging given the increased activity level experienced by some children at camp compared to home [1].

It is well established that adjustment of basal and/or bolus insulin doses may be necessary to prevent hypoglycemia if mild to moderate endurance exercise occurs within one hour

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after a meal [2], and that late-onset hypoglycemia can occur up to 12 hours (h) after physical activity [3]. Campers and medical staff must work together at camp to adjust basal and bolus insulin doses throughout the day, as necessary, to account for carbohydrate intake, upcoming physical activity, and corrections to the current BG level. Automated systems such as closed-loop insulin pumps may help eventually alleviate the burdens of manual adjustment [4–7], but such systems are not yet approved for all pediatric age ranges, and many campers choose to take a "pump holiday" during their week of camp, switching to multiple daily injections instead. Thus, insulin dose adjustments in preparation for camp activity are necessary for avoidance of hypoglycemia, particularly at night, and camp protocols should be established to account for this possibility.

The primary aim of this study was to establish the incidence and timing of hypoglycemia during a week-long residential camp for children with type 1 diabetes mellitus. We hypothesized that hypoglycemia was more common: (1) during the first 48 h of camp, before most campers' basal insulin doses were adjusted; and (2) during and after all-camp evening games, when exercise is increased for all campers. A secondary aim was to examine how individual medical staff insulin dose adjustment patterns impacted rates of hypoglycemia.

## 2. Materials and methods

### 2.1. *Participant recruitment*

BG levels from 225 children with type 1 diabetes mellitus, aged 8–16 years, attending one week of a residential diabetes camp in August 2015 were used in analysis. Nineteen percent (n = 42) of campers had celiac disease. Most campers spent 7 days and 6 nights at camp (n = 203), while a few spent 4 days and 3 nights (n = 22). Demographic data collected for each camper included age, sex, and most recent hemoglobin A1c (HbA1c), as reported by campers' primary diabetes care providers. This study was deemed exempt from Institutional Review Board (IRB) review by the University of Minnesota IRB under federal guidelines 45 CFR Part 46.101(b) category 4.

### 2.2. *Camp policies and data collection*

A OneTouch® UltraMini® glucometer (Lifescan Inc.) was distributed to each camper and used to measure all BG levels at camp. Glucometer use was performed by the camper, trained counselors, and/or medical staff, depending on the age of the child. BG levels were then transcribed in real-time from the glucometer to the individual cabin log. Each camper was listed in individual cabin logs where scheduled BG levels were recorded and maintained by medical staff. All campers performed scheduled BG checks a minimum of five times per day: before meals, at afternoon snack, and at bedtime per camp protocol. Campers were also required to check a BG level anytime they experienced symptoms of hypo- or hyperglycemia. For the purposes of this analysis, all BG checks performed between 6 am and 7 pm were categorized as daytime glucose values, and those performed after 7 pm through 6am were categorized as overnight glucose values. Camp policy requires all BG levels checked during camp to be recorded real-time in individual cabin logs by medical staff, as recommended by the American Diabetes Association (ADA) [1]. Trained medical staff recorded and reviewed all BG levels with campers before meals and evening snack, making insulin adjustments as necessary. In addition to the cabin log maintained by medical staff, counselors were provided an additional logbook (counselor camp log) to record BG checks performed during non-scheduled times. Individual cabin logs and counselor camp logs were used as source data for this study. Campers were permitted to use continuous glucose monitors (CGM) during camp, but these campers were required to check BG using glucometer at all scheduled times and these values were recorded on their individual cabin logs. Since a limited number of campers were using this technology, these data were not used in the analysis. Campers using CGM who experienced hypoglycemia were required to verify the reading by glucometer and used the glucometer BG level in the individual camper and counselor camp logs.

Hypoglycemia was defined for all age groups as mild if BG 50–70 mg/dL (2.8–3.9 mmol/L), moderate if BG < 50 mg/dL (2.8 mmol/L) and the camper did not require intervention from medical staff for administration of glucagon or oral glucose, and severe if BG < 50 mg/dL (2.8 mmol/L) and medical staff intervened. Documented hypoglycemia events were coded by camper age, sex, type of insulin administration (CSII: continuous subcutaneous insulin infusion or MDI: multiple daily injections), date, and time.

Overnight, camp policy required counselors to check BG levels at bedtime on all campers, and if bedtime BG was < 100 mg/dL (5.5 mmol/L), additional BG checks were performed at 2300 and again at 0200 (if BG remained < 100 mg/dL (5.5 mmol/L)) per ADA recommendations [1]. Documented BG 50–70 mg/dL (2.8–3.9 mmol/L) was treated with 15 g of glucose or simple carbohydrates, and BG was rechecked 15 min later. When necessary, oral treatment was repeated. Campers with BG < 50 mg/dL (2.8 mmol/L) were treated with 30 g of glucose or simple carbohydrates, rechecked in 15 min and treatment repeated if necessary. Glucagon and glucose gel were available for hypoglycemia events complicated by seizures or altered consciousness. Children with persistently elevated BG or ketonemia were brought to medical staff for immediate evaluation. All overnight values were reviewed with medical staff each morning and adjustments to insulin doses were made as necessary.

All insulin doses were adjusted and administered with approval by trained medical staff. Current camp policy recommends considering a decrease to basal insulin individually during camper check-in but not universally for all campers. This decision was made by individual medical staff based on baseline glycemic control, prior camper history of consistent or severe hypoglycemia while at camp, baseline physical activity at home, and/or parental preference.

Mealtime insulin bolus doses were calculated together by the camper and medical staff using intended carbohydrate intake, individualized insulin-to-carbohydrate ratios, individualized correction scale (if necessary), and anticipated physical activity following meals. Registered dietitians created well-balanced meal menus with carbohydrate counts, in

grams, that were distributed to the campers to use for meal calculations. Campers with celiac disease were provided equivalent gluten free options with separate carbohydrate counts. Insulin calculations for protein and fat in the meals were not performed. Mealtime insulin boluses were administered approximately 0–15 min prior to the meal, depending on the pre-meal BG.

In addition to daytime physical activity, all campers participated in all-camp games (moderate to high intensity exercise) from 1830 to 2000 on nights 2 through 5. During the year of the study, night games were cancelled on 2 of 4 nights due to weather. Medical staff supervised these activities while assessing and treating hypoglycemia events as they occurred. BGs checked during these activities were recorded in a separate game log. While no policy existed for adjustments prior to all camp games, medical staff are encouraged to adjust insulin doses and/or allow for uncovered carbohydrate consumption prior to the games at the evening meal.

Camp medical staff were surveyed after camp about their practices to prevent hypoglycemia at camp check-in, within the first 24 h of camp, and before all-camp games. Results were coded by years of experience and correlated with their campers' rates of hypoglycemia.

### 2.3. Statistical analysis

Descriptive statistics were used to summarize the camper demographics and characteristics. Fisher's exact test was used to test for the association between hypoglycemia and HbA1c level. Generalized estimating equations (GEE) models were used to compare the hypoglycemia rates between time periods. These models allow for modeling of repeated measures data. Statistical analysis was performed using SAS V9.3 (SAS Institute Inc., Cary, NC).

## 3. Results

### 3.1. Baseline characteristics and BG analysis

Baseline camper characteristics are summarized in Table 1. The majority of campers were using CSII, and campers using MDI were using either insulin glargine or detemir as their basal insulin. Fewer than one quarter of campers were in optimal glycemic control with HbA1c $\leq$ 7.5% or 58 mmol/mol (n = 41; 17.8%). A total of 6,117 BG levels were recorded (mean of 4.7 per camper per day). The mean BG level for all measurements was 167 mg/dL (9.3 mmol/L) with a standard deviation of 96 mg/dL (5.3 mmol/L). A higher mean BG level was noted on the 1st day of camp (194 mg/dL (10.8 mmol/L)) with a reduction by day two that remained unchanged for the rest of the week (range of daily mean values 158–166 mg/dL (8.8–9.2 mmol/L), as detailed in Table 2.

**Table 1 – Camper characteristics.**

| | |
|---|---|
| Total number of campers | 230 |
| Campers with BG Data | 225 (98%) |
| Mean age in years ± sd (range) | 12 ± 2.3 (8–16) |
| **Gender** | |
| Male | 98 (44%) |
| Female | 127 (56%) |
| **Insulin delivery method** | |
| Multiple daily injections | 75 (33%) |
| Continuous subcutaneous insulin infusion | 147 (65%) |
| Both | 3 (1%) |
| Mean HbA1c ± sd (range) | 8.4% ± 1.3 (6.0–14.0) |
| *n = 192 campers* | [72 mmol/mol (42–130)] |

### 3.2. Frequency of hypoglycemia events

Mild hypoglycemia accounted for 13.1% of all BG levels and moderate hypoglycemia an additional 3.0%. No camper experienced a severe hypoglycemia event.

Most campers (90%) had at least one episode of hypoglycemia (any BG < 70 mg/dL (3.9 mmol/L)), and just under half (43%) of those campers had at least one moderate hypoglycemia event. The mean number of hypoglycemia events per camper for the week was 3.6 (range 0–14). Most campers (69.5%) experienced $\leq$ 4 mild hypoglycemia events over the course of the week, and almost all (98%) had $\leq$ 4 moderate events (Table 3). Campers with a lower baseline HbA1c < 9.0% (74.9 mmol/mol) had a higher rate of any hypoglycemia events compared to those with a baseline HbA1c $\geq$ 9.0% (92% v. 80%; p = 0.03). There were similar rates of hypoglycemia events ($\geq$1) between campers using MDI (95%) and those using pump therapy (87%; p = 0.10).

### 3.3. Timing of hypoglycemia events

Just over 1/3 of all hypoglycemia events occurred at night (1900 to 0600) (Fig. 1). There were significantly more nighttime hypoglycemia events per camper during the first 48 h of camp as compared to the rest of the camp period (p = 0.01). There were no differences in frequency of hypoglycemia readings following nights that included all-camp games (n = 2; 24% of night 2 and 16% of night 5 recorded BG values) compared to nights without all-camp games (n = 4; 22% of night 1, 19% of night 3, 21% of night 4 and 15% of night 6 recorded BG values, p = 0.80).

### 3.4. Relationship of hypoglycemia events to insulin adjustments

Pre-emptive insulin dose adjustments were made in 21 of 225 campers (9.3%), at baseline or within the first twelve hours of camp arrival. In addition, a total of 45 campers (20%) required insulin dose adjustments within the first 24 h and 98 campers (44%) within the first 48 h. Of the campers who required insulin dose changes in the first 48 h, 92% had a reduction in basal insulin dose, and the mean reduction in dose was 11%. Only two medical staff reported lowering basal rates by an average of 10–25% for their campers at check-in. Campers who had basal rates adjusted at start of camp (within 12 h of check-in) had the same rate of hypoglycemia within the first 48 h compared to those that did not (57% vs. 55%, p = 1.0).

**Table 2 – Mean daily blood glucose levels.**

| | Day of Camp | | | | | | |
|---|---|---|---|---|---|---|---|
| | Sun | Mon | Tues | Wed | Thurs | Fri | Sat |
| Number of tests | 991 | 1168 | 1069 | 1066 | 1020 | 993 | 235 |
| Mean BG ± SD (mg/dl) | 194 ± 97 | 166 ± 95 | 157 ± 93 | 163 ± 96 | 159 ± 95 | 166 ± 96 | 162 ± 82 |
| Mean BG (mmol/L) | 10.8 | 9.2 | 8.8 | 9.1 | 8.9 | 9.2 | 9.0 |

**Table 3 – Distribution of hypoglycemia[†] events.**

| Frequency of events (total number during camp) | Campers with any hypoglycemia event[*] n (%) | Campers with at least one moderate hypoglycemia event n (%) |
|---|---|---|
| 0 | 23 (10) | 128 (57) |
| 1–4 | 134 (60) | 93 (41) |
| 5–9 | 60 (27) | 4 (2) |
| 10+ | 9 (4) | 0 (0) |

[†] Hypoglycemia defined as blood glucose less than 70 mg/dl (3.9 mmol/L) and moderate hypoglycemia as less than 50 mg/dl (2.8 mmol/L).
[*] Includes all mild or moderate hypoglycemia events. No severe events (BG < 50 mg/dl or 2.8 mmol/L requiring medical staff intervention) occurred.

## 4. Discussion

This study takes a novel approach to analyze the frequency and patterns of hypoglycemia at diabetes camp. Although overall rates of hypoglycemia were comparable to prior studies [8,9], this is the first study to describe the timing of hypoglycemia events. Hypoglycemia occurred more frequently overnight in the first 48 h of camp, suggesting it is essential to make empiric insulin dose reductions for all campers at the beginning of camp to prevent hypoglycemia. Our current strategies for managing glycemic levels during and after planned all-camp games at least prevented any increases in hypoglycemia, though rates remain unacceptably high. Thus, ongoing efforts to prevent hypoglycemia during anticipated increases in activity levels are warranted. Overall daytime rates of hypoglycemia continued to increase during the first five days of camp (Fig. 1), suggesting that daytime management strategies during the beginning of camp may need to be more aggressive to prevent daytime hypoglycemia.

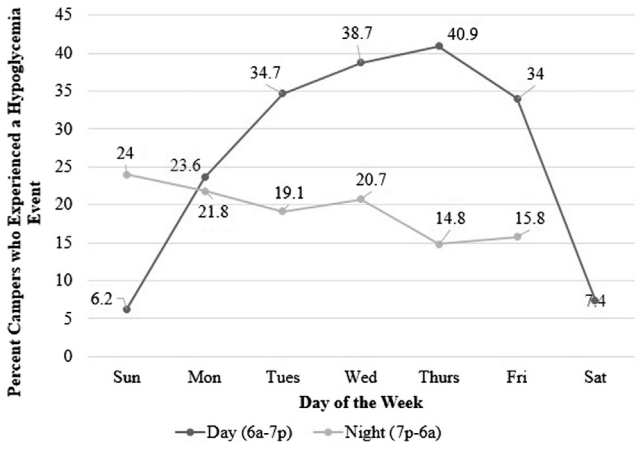


**Fig. 1 – The percent of campers who experienced at least one hypoglycemia event at night (grey line) was significantly higher during the first two nights compared to all nights thereafter (p = 0.01).**

The ADA recommends considering insulin dose reduction in anticipation of increased activity but does not provide specific guidelines. An empiric 10% reduction in basal insulin at the beginning of camp has been proposed, but hypoglycemia remains common despite this intervention [9]. Other studies have proposed a basal insulin reduction of 20% empirically [8,10–13]. Based on the increased frequency of nocturnal hypoglycemia during the first 48 h of camp, our data also support a standard reduction in basal insulin at the start of camp. Nocturnal hypoglycemia rates continued to decrease as the week progressed, presumably in accordance with later adjustments to basal insulin doses, suggesting basal insulin dose reductions at the start of camp will reduce overall frequency of nocturnal hypoglycemia.

For this analysis, reductions in insulin within the first 48 h at our camp were not standardized and were dependent on individual health care personnel. Although not powered to definitively answer this question, we found the rate of hypoglycemia to be the same for campers who had basal rates adjusted in the first 12 h of camp compared to those who did not. This suggests that the reductions made during camp (mean reduction of 11%) may have been inadequate to prevent hypoglycemia in campers that were identified by some medical staff as high risk during the check-in process. Therefore, greater reductions of basal insulin in the range of 15% or higher may be necessary to make a meaningful reduction in hypoglycemia rates. After the first day, mean daily BG for all campers remained stable and lower than the first day of camp, implying that lower basal insulin doses do not adversely result in hyperglycemia. In addition to basal insulin dose adjustments, medical staff often provide carbohydrates without insulin coverage for meals or bedtime snack, depen-

dent on activity, rather than adjusting the prescribed insulin-to-carbohydrate ratio, which may have impacted rates of hypo- or hyperglycemia further. Hyperglycemia correction scales and insulin-to-carbohydrate ratios may also have been adjusted to prevent hypoglycemia, and further studies are necessary to establish the best guidelines for these adjustments.

While universal reductions may reduce overall hypoglycemia during the start of camp, our data also support efforts at identifying campers at highest risk for hypoglycemia. We identified smaller subsets of campers who experienced a high frequency of hypoglycemia events (31% with $\geq 5$ mild events) who should be further characterized as primary prevention targets. Though there was an overall increased rate of hypoglycemia among campers with pre-camp HbA1c < 9.0% (74.9 mmol/mol) as compared to those with HbA1c $\geq$ 9.0% (74.9 mmol/mol), this should not serve as the sole source of risk stratification because a very high proportion of both groups experienced hypoglycemia (92% and 80%, respectively). Campers with celiac disease represent an additional population to study as a high-risk group in the future. Lastly, we did not perform routine height and weight measurements nor calculate body mass indices (BMI) at the start of camp, and these could serve as useful data to collect for future analyses in determining campers at highest risk for hypoglycemia.

Aside from describing one of the largest ADA camps, this analysis is unique in that it included all glycemic values throughout the course of camp including non-scheduled checks. This enhanced the opportunity to capture hypoglycemia events, particularly if they occurred at night. These data also described the greatest proportion of campers on CSII to date. The rates of hypoglycemia at our camp were comparable to other studies. The overall glycemic control on our population was poor and quite varied, consistent with type 1 diabetes registries in the US [14]. However, prior thresholds chosen for hypoglycemia were quite heterogeneous [8,9,15], making comparisons of glycemic management strategies across camps challenging. Our definitions were consistent with the ADA and our methodology for collecting BG data was comprehensive comparatively. Thus, our reported rate of 0.59 mild and 0.13 moderate hypoglycemia events per camper per day can serve as a baseline rate to determine effectiveness of future interventions. Given the heterogeneity of camp structures and experiences across the country and the globe, it is possible that particular activities at our camp may have differed from others. However, since a general principle of diabetes camp is to keep campers active and embrace the outdoors, the application of these findings is generalizable to all camps.

Given the nature of manual recordings of BG data, it is possible that some BG levels were unintentionally omitted or transcribed incorrectly, and this is a potential limitation of the study. Although downloading all meters to collect the data could have been performed, many meters were misplaced or damaged during camp and this data would otherwise have been lost without logbooks. The degree of discrepancy between self-reporting BG levels and glucometer downloads in the camp setting for adolescents has not been well studied. Two studies suggest that between 13 and 26% of self-reported BG levels are erroneous with the majority being omitted values or phantom values [16,17]. Campers in this study were observed during BG checks, making these errors less likely. Regardless, similar studies should be conducted at other diabetes camps across the country to evaluate glycemic patterns and establish protocols that ensure camper safety. Camp protocol calls for routine, mandatory testing at scheduled times during the day as opposed to testing based on BG thresholds and/or symptoms of hypoglycemia overnight. Thus, given the fixed difference in testing frequency between day and night periods, it is possible this may have biased our findings. Since this would likely bias the data towards increased hypoglycemia episodes detected during the day, we believe that our findings in the first 48 h remain valid if not underreported. Finally, we did not formally assess glycemic trends or hypoglycemia incidence using CGM technology. As some campers were using CGM during the study, a portion of potential hypoglycemia events may have been prevented, thus impacting overall rates. More CGM technology and sensor augmented insulin pump therapies have been approved for use within the United States since this study was conducted, so rates of CGM technology use at future camps will likely continue to increase. While future studies could use CGM data from campers to further define the patterns of hypoglycemia identified in this study, diabetes camp remains an opportunity for many campers to "disconnect" from technology. Therefore, even as CGM technology becomes more available, some campers may continue to choose to forgo its use during camp sessions.

In summary, our analysis identified the first 48 h of diabetes camp as a high-risk period for nocturnal hypoglycemia. Our data support the ADA recommendations of making reductions to basal insulin prior to the start of camp to reduce the risk of hypoglycemia, and we propose that basal insulin reductions of 15% or greater are necessary. Future studies should investigate the amount of reduction and whether it should be the same across all campers or tailored to target the highest risk groups.

## Author contributions

Elizabeth Mann conceptualized the study, collected the data, assisted in the analysis, wrote the manuscript, and approved of the final manuscript. Scott Lunos provided statistical guidance and analysis, reviewed the manuscript, and approved of the final manuscript. Elijah Carrel assisted in the analysis, reviewed the manuscript, and approved of the final manuscript. Trevor Omann assisted in the data collection and analysis, reviewed the manuscript, and approved of the final manuscript. Alyssa Halper assisted in data collection, reviewed the manuscript, and approved of the final manuscript. Anne Kogler assisted in the analysis, reviewed the manuscript, and approved of the final manuscript. Bradley Miller assisted in the data collection and analysis, reviewed the manuscript, and approved of the final manuscript. Muna Sunni assisted in the data collection and analysis, reviewed the manuscript, and approved of the final manuscript. Melena Bellin assisted in the data collection and analysis, reviewed the manuscript, and approved of the final manuscript. Bran-

don Nathan conceptualized the study, assisted in the data collection and analysis, wrote the manuscript, and approved of the final manuscript. There was no conflict of interest for any of the authors.

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