

# Diabetes Sports Camps for Individuals with Type 1 Diabetes Associated with Improved Glycemic Control and Self-Estimated Level of Knowledge

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## Abstract

**Purpose:** To evaluate the effect of a novel sports camp containing education and individualized feedback, on glycemic control and self-estimated level of knowledge in individuals with type 1 diabetes (T1DM).

**Method:** Participants with T1DM attended a three-day sports camp with education and individualized feedback on insulin and carbohydrate adjustments. Continuous Glucose Monitoring (CGM) and carbohydrate counting was used. A1c was assessed at baseline, 3 and 12 months after the sports camps. Questionnaires using Visual Analogue Scale (VAS) were used before and after the camp to estimate attitudes and knowledge regarding insulin and carbohydrate adjustments in relation to exercise.

**Results:** During eight sports camps 105 T1DM participants were included, 53% females, mean age 40.5 ± 10.0 years.

A1c was significantly reduced from 7.5 ± 3.0% (58.7 ± 9.2 mmol/mol) at baseline to 7.3 ± 2.9% (56.2 ± 8.1 mmol/mol), P<.005, after 3 months and maintained after 12 months 7.3 ± 2.9% (56.4 ± 8.1 mmol/mol), P<.005. Self-estimated level of knowledge was significantly improved in the area of insulin adjustments, P<.001 and carbohydrate intake, P<.001, in connection to exercise.

99% of the participants wanted to continue on CGM and 85% of the participants stated they would like to continue with carbohydrate counting after the sports camp.

**Conclusion:** Sports camps for adults with T1DM, was associated with improved glycemic control and increased self-estimated knowledge regarding insulin and carbohydrate adjustments in relation to exercise. This improvement in A1c, might be linked to the participants' increased level of knowledge but also to increased use of CGM and carbohydrate counting.

**Abbreviations:** A1c: Glycated Hemoglobin; BG: Blood Glucose; BMI: Body Mass Index; CGM: Continuous Glucose Monitoring; CHO: Carbohydrates; CSII: Continuous Subcutaneous Insulin Infusion; DSME: Diabetes Self-Management Education; IFCC: International Federation of Clinical Chemistry; IG: Interstitial Glucose; MDI: Multiple Daily Injections; NGSP: National Glycohemoglobin Standardization Program; PG: Plasma Glucose; PE: Physical Exercise; RPE: Rate of Perceived Exertion; SMBG: Self-Monitoring of Blood Glucose; T1DM: Type 1 Diabetes; VAS: Visual Analogue Scale.

## Keywords

A1c; Blood glucose; Carbohydrates; Continuous glucose monitoring; Diabetes sports camp; Diabetes mellitus type 1; Education; Insulin; Physical activity; Self-management

## Introduction

In type 1 diabetes individuals (T1DM) physical exercise (PE) has been shown to be associated with an increased incidence of both hypoglycemia and hyperglycemia especially during and after PE [1,2]. The induced increased glucose variability [3] related to PE has been pointed out as the primary reason for the fact that individuals with T1DM not reaching the glycemic treatment targets [4,5]. Moreover, the increased risk of hypoglycemia during and/or after the PE is regarded as the major barrier to PE [5]. Interestingly an improvement in the knowledge regarding insulin adjustments to minimize exercise-induced hypoglycemia during PE has been shown to reduce the barriers to PE [5]. This highlights the importance of education within this area.

To achieve good glycemic control with intensive insulin treatment and to combine this with regular PE could be challenging. Therefore a high degree of self-management support is required, and thus also supported by most education programs [6]. Diabetes self-management education (DSME) is the ongoing process of facilitating knowledge, skills, and abilities necessary for diabetes self-care.<sup>7</sup> Education and increased self-perceived knowledge in the field of diabetes have shown to have a major impact on the individual's ability to manage their diabetes [6]. Poor self-management has also been shown to be associated with poor glycemic control, defined as an A1C>8.5% (>69 mmol/mol) [6]. However, most patients with insufficient glycemic control have actually received education, but then not implemented this into their daily self-management regimen. This behavior may be due to a lack of motivation

to achieve better glycemic control and/or reflect a fear of hypoglycemia by keeping glucose levels generally higher. This emphasizes the importance of both education and strategies to increase motivation in order to achieve good glycemic control [7].

Individuals with T1DM tend to participate in a variety of different types of physical activities, with differences in duration and intensity. The duration may vary from a few seconds (weight lifting and sprints), to minutes during intervals (ice hockey), and to several hours during prolonged PE (marathons, triathlons and cross-country ski races) [8]. To achieve good glucose control during different sports of different durations and intensities entails high demands on insulin adjustments and a customized carbohydrate intake, depending partly on the exercise itself and also to the intensity and the duration of the exercise. In order to manage this, the T1DM individual needs education and training on exercise physiology, carbohydrate intake and insulin adjustments [9]. Guidelines regarding diabetes management during prolonged PE or exercise of high intensity for longer duration than 60 min is insufficient. In the absence of guidelines for prolonged physical activity, the individuals themselves therefore have to adopt a “trial-and-error” approach based on past experience of their blood glucose responses to similar activities [10,11].

Diabetes camps have shown to be a valuable contribution for children and adolescents to learn diabetes self-management skills [12]. Diabetes camps provides excellent opportunities to combine both theory and practice. Despite this, diabetes camps are nevertheless uncommon in adults with T1DM.

There is no published study that has evaluated the effect of diabetes sport camps on self-perceived knowledge and glycemic control in adults with T1DM. The aim of this study was to evaluate the effectiveness of a three-day long diabetes sports camp on long-term glycemic control, and self-perceived level of knowledge about the necessary carbohydrate and insulin adjustments in connection to PE.

## Methods

### Research design

A prospective intervention study design was used to evaluate whether participation in a diabetes sports camp during three consecutive days was associated with an improvement in long-term glycemic control and self-perceived knowledge in T1DM subjects. Informed consent was collected prior to study start. The study was approved by the local ethics committee in Uppsala, Sweden.

### Study population

Individuals with T1DM were recruited through advertisements. Inclusion criteria were individuals diagnosed with type T1DM, aged between 16 and 70 years, and performing regular exercise  $\geq 3$  workouts/week. Exclusion criteria were known proliferative retinopathy and known macrovascular complication.

### Intervention

A week before the sports camp all subjects were requested to keep a diet diary and conduct 7-point self-monitoring of blood glucose (SMBG), before-, two hours after meals and at bedtime, as well as to register all administered insulin doses. This information provided a foundation for the first individual counseling regarding appropriate adjustments of insulin and diet associated with exercise. A Visual Analogue Scale (VAS) questionnaire was used before and directly after the camp to estimate the participants' self-perceived knowledge regarding insulin and carbohydrate adjustments in relation to exercise. In the same questionnaire knowledge/attitudes towards continuous glucose monitoring (CGM) as well as carbohydrate counting was evaluated.

During the camp, all participants received the same education by two physicians and a dietician. The education focused on how to adjust insulin doses and to consume appropriate amounts of carbohydrates, before, during and after PE. After each training session, the participants received individualized feedback based on downloaded data from both CGM and insulin pumps.

During all meals, the participants practiced carbohydrate counting in order to select an appropriate dose of insulin to the amount of carbohydrates consumed.

The participants exercised 1-2 times per day in various types of sports such as running, cycling, cross-country skiing, circuit training, etc. All participants used CGM throughout the camp. The participants using CSII were taught how to adjust the basal insulin levels before, during and after PE to improve glycemic control. The participants who used MDI had to learn how to reduce mealtime insulin before the PE and in the same way, how to reduce the long-acting insulin before the night.

### Study devices

CGM was calibrated by measuring plasma glucose (PG) before breakfast, lunch and dinner, and performed by healthcare professionals. Plasma glucose was measured by HemoCue Glucose 201 RT (HemoCue, Ångelholm, Sweden), glucose measuring range 0–24.6 mmol/L and coefficient of variation (CV) 1.8%. Each individual was randomized to use CGM, Dexcom G4 Platinum (Dexcom, San Diego, CA), or Medtronic Guardian REAL-Time (Medtronic MiniMed, Inc., Northridge, CA). The sensors were inserted according labelling. The CGM devices were downloaded via CareLink (Medtronic MiniMed, Northridge, CA) and Diasend (Diasend AB, Gothenburg, Sweden) downloading system.

### Outcome measures

Hemoglobin A1c was collected at baseline and 3 respectively 12 months after the camp. All A1c samples were analyzed using a Tosoh G8 (Tosoh Biosciences, San Francisco, CA). The participants' self-reported knowledge about exercise, and the associated adjustments of insulin dose and carbohydrate intake related to PE was assessed using a VAS questionnaire, before- and after the camp. The respondents were asked to place a line perpendicular to the 100 mm VAS line at the point that represents their answers. The score was determined by measuring the distance by a ruler on the 100 mm line between the “very little” anchor and the patient's mark, providing a range of scores from 0–100. Mean and standard deviation values were calculated for each answer and accordingly presented along the scale including descriptive terms.

Moreover, attitude towards using CGM and carbohydrate counting was collected in the multi-choice closed questionnaires which provided frequencies and percentages of each response option.

### Statistical analysis

The statistical package for the social sciences (SPSS) version 17.0 (SPSS Inc., Chicago, IL, USA) was used for statistical analysis. A paired t-test was used for comparison of A1c levels before, 3 respectively 12 months after the sports camp. A Chi-Square Test was used to compare gender differences and glycemic control. Group mean and standard deviation were calculated for each answer in the questionnaires. As we did not assume normally distributed answers, we used the non-parametric Wilcoxon signed-rank test for comparison.

A  $P < .05$  was considered significant. Values presented are mean  $\pm$  standard deviation unless otherwise indicated.

## Results

### Demographics

A total of 105 individuals (53% females and 47% males) with T1DM participated in the eight sports camps. The mean age of the individuals was  $40.5 \pm 10.0$  years and the mean A1c at start was  $7.5 \pm 3.0\%$  ( $58.7 \pm 9.2$  mmol/mol). The majority of the participants, 61%, used insulin pump (CSII) and 39% were treated with Multiple Daily Injections (MDI). Baseline characteristics of the participants are described in table 1.

### Glycemic control

A complete A1c data set at start, 3 and 12 months, was collected in 95 individuals. A1c was significantly improved from  $7.5 \pm 3.0\%$  ( $58.7 \pm 9.2$  mmol/mol) at baseline to  $7.3 \pm 2.9\%$  ( $56.2 \pm 8.1$  mmol/mol),  $P < .005$ , after 3 months and maintained after 12 months  $7.3 \pm 2.9\%$  ( $56.4 \pm 8.1$  mmol/mol),  $P < .005$  (Figure 1). No significant difference in A1c was seen between 3 and 12 months.

### Glycemic control and insulin regimen

The CSII group had a more profound improvement in A1c compared to the MDI group. In the CSII group A1c was significantly improved from  $7.6 \pm 3.0\%$  ( $60.1 \pm 9.3$  mmol/mol) at baseline to  $7.4 \pm 2.9\%$  ( $57.2 \pm 7.7$  mmol/mol),  $P < .005$ , after 3 months and maintained after 12 months  $7.4 \pm 2.9\%$  ( $57.1 \pm 7.7$  mmol/mol),  $P < .005$  (Figure 2).

Tables 1: Baseline characteristics

Number (n)	105
Gender (female/male), number (percent, %)	56 (53%)/49 (47%)
Age (years), mean (range)	$40.5 \pm 10.0$ (16-68)
Treatment regimen (CSII/MDI), number (percent, %)	59 (61%)/46 (39%)
Total Insulin per day (U/kg), mean (range)	0.53 (0.1-1.2)
Use of carbohydrate counting, number (percent, %)	31 (30%)
Use of CGM, number (percent, %)	64 (61%)
A1C, pre-camp (IFCC, mmol/mol), mean (range)	58.7 (41-96)
A1C, pre-camp (NGSP, %), mean (range)	7.5 (5.9-10.9)

**Abbreviations:** CSII: Continuous Subcutaneous Insulin Infusion; IFCC: International Federation of Clinical Chemistry; MDI: Multiple Daily Injections; NGSP: National Glycohemoglobin Standardization Program.

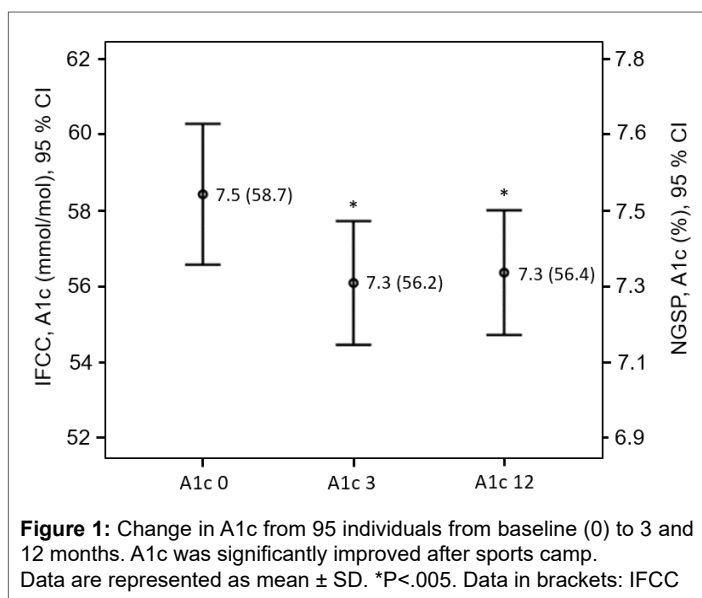


Figure 1: Change in A1c from 95 individuals from baseline (0) to 3 and 12 months. A1c was significantly improved after sports camp. Data are represented as mean  $\pm$  SD. \* $P < .005$ . Data in brackets: IFCC

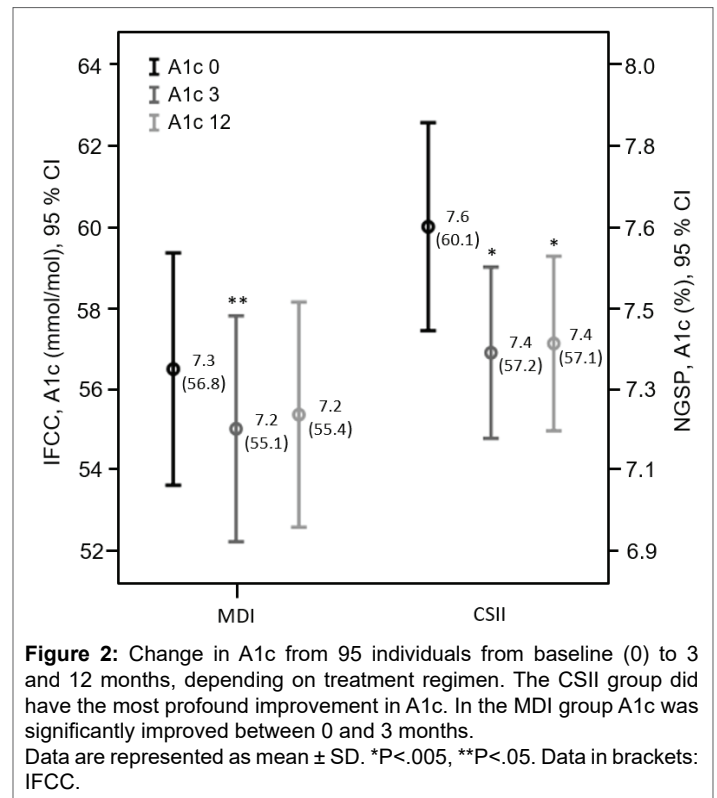


Figure 2: Change in A1c from 95 individuals from baseline (0) to 3 and 12 months, depending on treatment regimen. The CSII group did have the most profound improvement in A1c. In the MDI group A1c was significantly improved between 0 and 3 months. Data are represented as mean  $\pm$  SD. \* $P < .005$ , \*\* $P < .05$ . Data in brackets: IFCC.

In the MDI group A1c was significantly improved from  $7.3 \pm 2.9\%$  ( $56.8 \pm 8.7$  mmol/mol),  $P < .05$ , at baseline to  $7.2 \pm 2.9\%$  ( $55.1 \pm 8.4$  mmol/mol),  $P < .05$ , after 3 months. No difference was seen when A1c was compared at baseline with the value at 12 months  $7.2 \pm 2.6\%$  ( $55.4 \pm 8.6$  mmol/mol),  $P = .23$  (Figure 2). The group using CSII started with a A1c on a higher level at baseline  $7.6 \pm 3.0\%$  ( $60.1 \pm 9.3$  mmol/mol) compared to the MDI group  $7.3 \pm 2.9\%$  ( $56.8 \pm 8.7$  mmol/mol).

### Glycemic control and gender

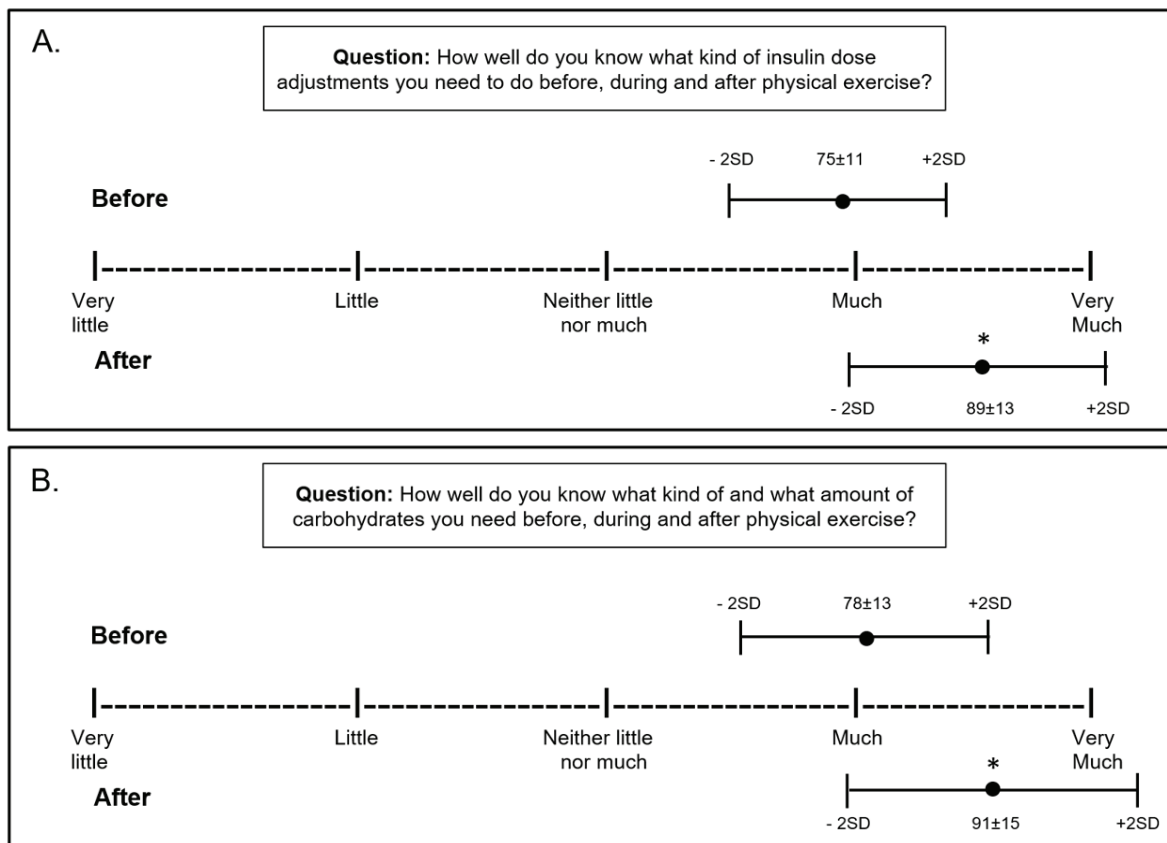
A gender difference was seen when A1c was analyzed. The females showed the most profound improvement and A1c was significantly improved from  $7.5 \pm 3.0\%$  ( $58.3 \pm 9.5$  mmol/mol) at baseline to  $7.2 \pm 2.9\%$  ( $55.5 \pm 8.7$  mmol/mol),  $P < .05$ , after 3 months and maintained after 12 months:  $7.2 \pm 2.9\%$  ( $55.6 \pm 7.7$  mmol/mol),  $P < .05$ . The male group significantly improved A1c from  $7.6 \pm 3.0\%$  ( $59.1 \pm 8.8$  mmol/mol) at baseline to  $7.4 \pm 2.8\%$  ( $57.1 \pm 7.3$  mmol/mol),  $P < .05$ , after 3 months. A1c comparison between baseline and 12 months  $7.4 \pm 2.9\%$  ( $57.3 \pm 8.5$  mmol/mol), did not reach significant difference.

### Glycemic control depending on low or high A1c at baseline

Participants who had higher A1c before camp,  $A1c \geq 7.5\%$  ( $\geq 58.0$  mmol/mol) had the greatest improvement in glycemic control. A1c was significantly improved from  $8.1 \pm 2.6\%$  ( $65.0 \pm 5.1$  mmol/mol) at baseline to  $7.7 \pm 2.7\%$  ( $60.0 \pm 5.6$  mmol/mol),  $P < .005$ , after 3 months and maintained after 12 months  $7.7 \pm 2.7\%$  ( $60.9 \pm 6.4$  mmol/mol),  $P < .005$ . Participants who had an  $A1c \leq 7.4\%$  ( $\leq 57.0$  mmol/mol) before camp showed no significant reduction in A1c at 3- respectively 12 months after the camp.

### Self-estimated knowledge

The questionnaire revealed that the participants experienced a significant improvement of their self-estimated knowledge in the area of insulin adjustments to implement,  $P < .001$  and adjustments of a carbohydrate intake,  $P < .001$ , in connection to PE (Figure 3).



**Figure 3:** The participants' self-reported knowledge about exercise associated insulin dose adjustments and carbohydrate intake was assessed using a VAS questionnaire, before- and after the camp. The respondents were asked to place a line perpendicular to the 100 mm VAS line at the point that represents their answers. The participants experienced that the sports camps gave a significant improvement of their self-estimated knowledge in the area of insulin adjustments to implement (Figure 3A), and adjustments of a carbohydrate intake (Figure 3B) in connection to PE. Minimum score 0, maximum score 10. P values from Wilcoxon signed ranks test. Data are represented as mean ± SD. \*P<.001.

### Attitudes towards the use of CGM and carbohydrate counting

The questionnaire also showed that the attitudes were positive regarding the use of CGM in connection with PE. 64 participants out of 105 (61%) had experience of using CGM before the camp. After the sports camp 104 out of 105 participants wished to continue to use CGM.

With regard to carbohydrate counting did 30% of the individuals use carbohydrate counting before the camp. After the sports camps 85% stated that they would like to continue to use carbohydrate counting.

### Discussion

Our sports camps were associated with improved glycemic control and increased self-estimated knowledge regarding insulin and carbohydrate adjustments in relation to exercise.

There is no published study about the effects of diabetes sports camps for adults with T1DM on metabolic control. That is surprising considering that diabetes camps are commonly used in children and adolescents [13]. Previously published studies on diabetes camps and the effect on metabolic control have shown somewhat mixed results, ranging from no effect on A1c [14,15] to significant improvement of glycemic control [16-19]. Overall a relatively short follow-up period, between 2 weeks to 3 months, was used in these studies. One study differs with a follow-up time of 1 year, but no improvements in glycemic control could be seen, despite increased level of knowledge [14]. The study we conducted was the

first sports camp for adults with T1DM where long-term glycemic control was assessed, showing improved A1C, 3 respectively 12 months after the camp.

Individuals with T1DM have been shown to be able to improve the glycemic control by short intensive educational interventions providing self-management skills [20,21]. The intervention in these studies was 5 days (Monday-Friday). Compared with a 2.5-day intervention that had no significant improvement on A1c [22]. In the present study, we showed an association with improved glycemic control after the camp even though the camp and the education lasted only 3 days. An explanation may be that the participants did get an integrated education, involving both theoretical and practical education (the actual exercise session). All participants received feedback from a physician and a dietitian after every workout. Any changes that the participants needed regarding insulin adjustments and diet (carbohydrates) was evaluated repeatedly, already at the next training session. It has been shown that diabetes patients experience deficiencies arising from the gap between the ordinary theoretical diabetes education and practical reality of implementing that theoretical knowledge [23]. In these sport camps the participants exercised 1-2 times per day, which indicates that the theoretical knowledge they receive directly have to be implemented in their own reality. An advantage was that physicians and a dietitian were in direct proximity to the participants throughout the camp, and even took part during the exercise sessions. This likely gives the participants a feeling of security, which enables the participants dare to



try new methods and behaviors. Diabetes camps carried out together with other participants who have T1DM and the presence of advisors has been shown to have a positive impact on the participant's attitude to their own diabetes self-management [24]. These conditions increase the possibilities that the participants will adopt more of a "can-do attitude". After the sports camps, the participants themselves created a Facebook group that was highly appreciated. This medium created a social support as well as an opportunity for the participants to continue their dialogue and learning in the area, sport and T1DM. It has been shown that the use of social media, like Facebook, allows individuals with T1DM to gain knowledge about diabetes, which in the end has improved the glycemic control [25].

In the present study participants treated with CSII showed the most profound improvements. A1c decreased significantly from baseline to 3 and 12 months after the camp. The CSII group, however, had a higher A1c at the start of the camp, in comparison to those treated with MDI. It has been shown that individuals with poor glycemic control achieve greater improvements in A1c during educational intervention than those individuals who already from the start did have a good glycemic control [12]. The use of CSII, however, has advantages over MDI in terms of greater opportunities to both raise and lower insulin doses in connection with PE, which also increases the possibilities of achieving good glucose control with CSII. During the present diabetes camp, the participants who used CSII received education on how to adjust the basal insulin levels before, during and after exercise in order to improve glycemic control. It has recently been shown that people with T1DM that regularly exercise and are on CSII treatment can be associated with a lower A1c than those who are sedentary [26].

The individual's level of knowledge is the basis to achieve diabetes self-management skills, but knowledge acquisition does not necessarily mean a change in behavior [27,28]. Diabetes knowledge has also been shown to be a significant predictor for attitudes towards their efforts to manage diabetes in everyday life [29]. Both attitude and knowledge can thus independently influence an individual's behavior and self-management. Improved personal attitudes and motivations have in some studies been shown to be even more effective than knowledge in improving glycemic control [22,30]. This may to some extent mean that educational programs are of limited value if they do not lead to permanent changes in attitudes and motivation, which are critical factors affecting long-term diabetic control. In the present study, we provided practical solutions to problems related to hypo- and/or hyperglycemia in connection with exercise likely to improve the participants' motivation and desire to continue the use of the newly acquired knowledge in their own diabetes self-management even after the camp.

One of the key components of a self-management behavior is that the individuals should be able to judge the content of carbohydrates in the food they consume, and thus increase the possibilities to choose an appropriate insulin dose accordingly [10]. In the current study 31 of 105 (30%) participants used carbohydrate counting before the camp, while it was a new tool for the rest. After the camp, 89 (85%) participants stated they would like to continue with carbohydrate counting. During the study the participants practiced carbohydrate counting at all meals. The participants were initially provided help to estimate their carbohydrate to insulin ratios (CIR), based on their total daily insulin requirement and body weight. Further refinement of CIR was made on an individual basis based on pre- and post-meal glucose testing. The participants answer to the questionnaire after the camp could be a sign that they considered carbohydrate counting as an important tool to achieve good glycemic control. No survey has been conducted in this study to investigate to what extent the participants have continued with carbohydrate counting.

PE can lead to rapid glucose changes compared to those seen during more sedentary activities in individuals with T1DM [31]. These rapid glucose changes represent for many T1DM individuals a barrier to physical activity. The use of CGM can thus provide extra security during and after PE. A study investigating CGM and its benefits on glycemic control suggested that the CGM even may have an important educational effect in terms of glycemic control [32]. The experience of this camp was that CGM provides very good opportunities to combine theory, practice and feedback. Studying glucose curves from previous exercise sessions provides a base for discussions on how to correct the choice of insulin doses and carbohydrate intake directly after the specific event. The proportion of the participants at this camp who had used CGM before the camp was 39%. After the sport camp 99% would like to continue using CGM. The use of CGM during the camp and in some cases even after the camp could contribute to the improvement in A1C.

### Limitations

A limitation of this study is that it is an observational study without control group making it difficult to evaluate the causality of study effects. Selection bias could also exist since the participants were not randomly selected from the T1DM population. The participants themselves announced their interest to participate in the camp. Thus, the participants in this study may not be a representative sample of adult subjects with T1DM who regularly practice physical activity in general. This design was chosen for the reason that it facilitated the process of obtaining enough candidates that passed the inclusion criteria. The inclusion criteria were that the participants would exercise  $\geq 3$  workout sessions/week, which probably yielded a relatively homogeneous group of participants who were determined to improve glycemic control. This has probably influenced the study results. A further limitation may be the patient's management after the camp ended. Post-camp each participant was treated by his or her regular diabetes team. The knowledge of the healthcare givers in the field of T1DM and exercise will vary between different hospitals. The support each individual will receive is dependent upon the knowledge and experience of the health-care providers'. After the camp, we have not carried out any controls in beyond the A1c. This means that we have no control over circumstances that may affect the participants' glycemic control i.e. switching from MDI to CSII and vice versa, concurrent diseases etc.

### Conclusion

Sports camps in type 1 diabetic subjects were associated with an improvement in glycemic control measured as a reduction in A1c 3 and 12 months after the camp. The improvement in A1c seen after the camp, could be associated to the participants' increased knowledge in terms of improved self-management skills in areas such as insulin adjustments, carbohydrate counting, carbohydrate intake, as well as the active use of both CGM and CSII. This association has to be confirmed in further specifically designed trials. Diabetes sports camp that combines theory, practice and immediate feedback via CGM provides an excellent environment for education, empowerment and learning, which in the end may increase the possibilities to improve the individual's self-management behavior and glycemic control.

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### Conflict of Interest

No conflict of interest exists.

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