Education and individualized support regarding exercise and diabetes improves glucose control and level of physical activity in type 1 diabetes individuals

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Abstract

Background: Physical activity is advocated in all individuals with diabetes. However, good glycemic control can be difficult to achieve due to exercise induced glucose excursions.

Objective: To evaluate the impact on glucose control of a structured diabetes education concerning physical activity, delivered via the web/internet together with telemedical care (individualized feedback by phone).

Methods: Eighty-two individuals with type 1 (T1D) were included in the pre-race intervention and randomized into two groups: intervention (I) (n=48) and control (C) (n=48). Both groups received web-based training of sports and nutrition in relation to diabetes. The intervention group also received structured and individualized feedback on two different occasions. HbA1c was measured at baseline, after 3 and 6 months when a 45 km cross-country skiing race (the HalvVasa) was performed. Only the individuals attending the skiing race were eligible to be included in the study. Level of Physical Activity (LPA), Multidimensional Health Locus of Control (MHLC) and Confidence In Diabetes Self-care (CIDS) were assessed at baseline and after 7 months.

Results: HbA1c at start was 58.5 ± 10.0 (I) respectively 60.7 ± 9.5 (C) mmol/mol. At 3 months 56.7 ± 8.7 (I) respectively 61.0 ± 9.6 (C) mmol/mol and at 6 months 55.7 ± 8.1 (I) respectively 60.3 ± 9.7 (C) mmol/mol. A significant in (I) at 3 months: 2.2 ± 3.8 mmol/mol (0.7-3.7, 95% CI), (p<0.05) and after 6 months: 2.8 ± 5.5 mmol/mol (0.5-5.0, 95% CI), (p<0.05). No reduction was seen in (C). However between the two groups no difference was noted. The LPA was increased in 52% of the participants in (I) respectively 7% in (C), a significant difference, p<0.05. No differences were seen regarding HbA1c or LPA in the control group.

Conclusion: Education and individualized feedback, delivered via telemedicine, to physical active individuals with T1D resulted in improvements in glycemic control within the intervention group and improved level of physical activity and locus of control when compared to the control group.

ABBREVIATIONS

CIDS: Confidence In Diabetes Self-care; CSII: Continuous Subcutaneous Insulin Infusion; DKA: Diabetes Ketoacidosis; LPA: Level of Physical Activity; MDI: Multiple Daily Injections; MHLC: Multidimensional Health Locus of Control; PG: Plasma Glucose; PE: Physical Exercise; T1D: Type 1 Diabetes

INTRODUCTION

Besides insulin and dietary management physical exercise is one of the cornerstones in glucose regulation. Besides the many positive effects by physical exercise, there are still conflicting results regarding the effects on long-term glucose control. While lower HbA1c was associated with exercise in the pediatric [1] and adult female population [2] however later systematic reviews have not found replication of these findings in youth [3] and in adult [4] populations. Good glucose control could be hard to achieve in relation to exercise, as it is associated with hypoglycemia as well as hyperglycemia in individuals with T1D.
Fear of hypoglycemia can change strategies of diabetes self-management and thus affects the possibility of reaching an optimal glucose control [7]. Education has been shown to have a positive impact in several different skills including carbohydrate intake, reduced frequency of hypoglycemia and increased physical exercise one year after introduction and was associated with improved glycemic control [8]. In diabetes education is an ongoing matter and repetition is of great importance as the disease itself progresses and the individual deals with multiple challenges of diabetes self-management. Education can be delivered on a one to one basis but also in groups where web-based training can be effective. Telemedical care has been shown to reduce the number of hypoglycemic events, improve glycemic control [9] and potentially change behavior enabling the patients better to achieve good glycemic control [10]. However, although life-style interventions and nutrition advice and physical activity have also been shown to affect glycemic control [11] the efficacy of providing this type of training via telemedicine has not been proven.

This randomized controlled study evaluated the effect of education on T1D subjects’ self-management of glucose monitoring, and insulin and carbohydrate adjustments during exercise. This was followed by individualized feedback after analyses from glucose meters and insulin pumps were downloaded remotely. The aim of the study was to evaluate the outcomes of telemedical care in terms of glycemic control, related to the level of physical activity (LPA), health related locus of control and self-efficacy in physically active T1D individuals. In order to generate a highly motivating and challenging environment for the participants in the study it was decided to use an endurance race as the test environment. Sport and particularly endurance sports such as marathon running and long-distance skiing races has become a popular feature of our culture. Many diabetes patients would like to participate in these activities. However, current advice is to be careful due to the problems of glycemic control. Therefore, in order to demonstrate the feasibility of sports performance for people with T1D diabetes the 45 km HalvVasa skiing race was chosen as the test environment.

MATERIALS AND METHODS

Announcement of the study was done via the web and sports magazines. Individuals diagnosed with T1D, aged 17-70 yrs. With duration of diabetes more than 1 year, and willingness to conduct the HalvVasa were eligible for inclusion. Exclusion criteria included; HbA1c >75 mmol/mol (9% NGSP), known cardiovascular disease, known proliferative retinopathy, or known hypoglycemic unawareness. Eligible individuals were matched and randomized into an intervention group or a control group during a pre-race intervention phase.

All participants received two lectures

1) exercise and diabetes, and 2) diabetes, diet and exercise. The intervention group additionally received individualized feedback based on downloading of data from home glucose meters and insulin pumps (CSII) together with a discussion on self-management. Furthermore carbohydrate counting was introduced in the intervention group where feedback also was provided [12]. This feedback was conducted by phone on two different occasions (max duration 15 minutes) and included advice on insulin doses/diet in relation to physical exercise. The control group was recommended to seek advice from their ordinary diabetes teams (standard feedback).

Subjects

A prerequisite for inclusion in the study was to commit to be present at the starting line of the HalvVasa. Eighty two adults with T1D were included in the pre-race intervention whereof 40 completed the race. Table 1 shows the baseline characteristics of the study population who completed the study.

A large number of study drop-outs occurred during the pre-race intervention phase -16/41 (39%) in the intervention group and 26/41 (63%) in the control group prior to attending the start of the HalvVasa skiing race. The results from the participants who completed the study and the race are presented. The cross-country skiing race was completed by all the participants who attended the starting line of the race.

Study protocol

The study protocol is illustrated in (Figure 1).

Patient questionnaires were completed at baseline and repeated after 7 months which was one month after the HalvVasa. Three questionnaires were included: A. Level of Physical Activity (LPA) [13], B. Multidimensional Health Locus of Control (MHLC) [14,15], and C. Confidence In Diabetes Self-care (CIDS) [16].

HbA1c was assessed at 0, 3 months and at 6 months coinciding with the skiing race. The HbA1c was analyzed at an accredited university hospital laboratory using the BioRad assay, Life Science, CA. HbA1c is presented as HbA1c IFCC mmol/mol and as HbA1c NGSP %.

Downloads of home glucose meters and insulin pumps (CSII) were performed using Accu Chek SmartPix™ (Roche Diagnostics, Mannheim, Germany) and Diasend™ (Diasend, Gothenburg, Sweden) in home settings at 2 and 4-5 months, both occasions before the individualized feedback was provided by telephone. The feedback was provided to the intervention group only. The participants in the control group were instead referred to their normal diabetes team for advice. Co-working study personnel (diabetes consultant and dietician) provided the intervention feedback. Each telephone session conducted with the individual was of approximately 15 minutes duration.

Questionnaires

The Level of Physical Activity (LPA) questionnaire concerns the individual’s total physical activity: duration, frequency and intensity. The individual chooses the alternative, which in the best way corresponds to their LPA during the last week. Six different levels of activity can be chosen, see (Table 2). When the six different levels were aggregated into three levels, these have been validated with total amount of activity measured as counts/min per day in an adult population [13]. In this study the questionnaire was used at baseline and end of the study (7 months). Answers were then categorized in increased/tie/decreased physical activity.

The Multidimensional Health Locus of Control (MHLC)

Table 1: Baseline characteristics of those completing the study.

<table>
<thead>
<tr>
<th></th>
<th>Intervention group (n=25)</th>
<th>Control group (n=15)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Age, years (mean ± SD, range)</td>
<td>37.8 ± 12.3 (17 – 64)</td>
<td>43.7 ± 8.2 (29 – 62)</td>
</tr>
<tr>
<td>Diabetes duration, years (mean ± SD, range)</td>
<td>19 ± 11 (2 – 43)</td>
<td>18 ± 12 (1 – 40)</td>
</tr>
<tr>
<td>Gender (female/male)</td>
<td>12/13</td>
<td>5/10</td>
</tr>
<tr>
<td>Treatment model (MDI/CSII)</td>
<td>17/8</td>
<td>13/2</td>
</tr>
<tr>
<td>Insulin total daily dose (mean ± SD, U/kg)</td>
<td>0.73 ± 0.24</td>
<td>0.78 ± 0.20</td>
</tr>
<tr>
<td>BMI (mean ± SD, kg/m²)</td>
<td>25.5 ± 4.4</td>
<td>25.9 ± 4.3</td>
</tr>
<tr>
<td>HbA1c (mean ± SD, NGSP,%)</td>
<td>7.6± 0.9</td>
<td>7.8± 0.9</td>
</tr>
<tr>
<td>HbA1c (mean ± SD, IFCC, mmol/mol)</td>
<td>58.5 ± 10.0</td>
<td>60.7 ± 9.5</td>
</tr>
</tbody>
</table>

**Abbreviations:** T1D: Type 1 Diabetes; SD: Standard Deviation; MDI: Multiple Daily Injections; CSII: Continuous Subcutaneous Insulin Infusion; NGSP: National Glycohemoglobin Standardization Program; IFCC: International Federation of Clinical Chemistry

Table 2: Questionnaire on the Level of Physical Activity (LPA).

<table>
<thead>
<tr>
<th>Level</th>
<th>Description</th>
<th>Definition</th>
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<tbody>
<tr>
<td>1</td>
<td>Sedentary</td>
<td>&lt; 2 hours/week</td>
</tr>
<tr>
<td>2</td>
<td>Moderate physical activity</td>
<td>&lt; 2 hours/week, sometimes with perspiration</td>
</tr>
<tr>
<td>3</td>
<td>Moderate, regular physical activity</td>
<td>1–2 times/week, at least 30 min each time and with perspiration</td>
</tr>
<tr>
<td>4</td>
<td>Regular physical activity and training</td>
<td>3-4 times/week, at least 30 min each time and with perspiration</td>
</tr>
<tr>
<td>5</td>
<td>Extended regular physical activity and training</td>
<td>5-6 times/week</td>
</tr>
<tr>
<td>6</td>
<td>Extensive regular physical activity and training</td>
<td>≥7 times/week</td>
</tr>
</tbody>
</table>

Figure 1: The HahVasa study protocol.
Scale, using a 6-point scale ranging from strongly disagree -1- to strongly agree -6-, was used to evaluate the individual’s sense of control over his or her life choices [14]. The MHLC has acceptable internal consistency a (α=0.65-0.75) [15].

The individual’s self-efficacy was assessed using the Confidence In Diabetes Self-care scale (CIDS). In this questionnaire patients rate each item on a 5-point Likert scale, ranging from “No, I am sure I cannot” to “Yes, I am sure I can”. The CIDS has high internal consistency (α=0.86-0.90) [17].

Statistics

The statistical package for the social sciences (SPSS) version 17.0 (SPSS Inc Chicago, Illinois, USA) was used for statistical analysis. Comparisons were made between the intervention group and the control group regarding glucose control/HbA1c, level of physical activity (LPA), locus of control and self-efficacy. Data for comparison were gathered at 0 months, at 3 months and at 6 respectively 7 months (stop) (Figure 1). Levene’s test was used to evaluate homogeneity of variances in the different samples. The intervention and control group were matched according to HbA1c, age, duration and gender. In within groups’ analysis each subject acted as his or her own control; comparisons were also made between the groups. Analyses for paired data were made using paired t-test and Wilcoxon signed rank test. Analysis of variance between the intervention and control group was performed by repeated measurements of variance (ANOVA). A p < 0.05 was considered significant. Values presented are mean ± standard deviation unless otherwise indicated.

The study was conducted in accordance with the Declaration of Helsinki [17], with approval granted by local ethical review board. Each participant provided informed consent prior to study start.

RESULTS

Glycemic control

Glycemic control (HbA1c) was improved in the intervention group but not in the control group. The results are illustrated in (Figure 2). HbA1c in the intervention group: at 0 months; 58.5 ± 10.0 mmol/mol (7.5 ± 3.2 %), at 3 months; 56.7 ± 8.7 mmol/mol (7.3 ± 2.9 %) and at 6 months/HalvVasa; 55.7 ± 8.1 mmol/mol (7.2 ± 2.7 %). The difference from 0 months until 3 months was 1.8 ± 3.5 mmol/mol (0.34-3.26, 95% CI), (p<0.05) and from 0 months until the 6 months/HalvVasa 2.8 ± 5.4 mmol/mol (0.56-5.04, 95% CI), (p<0.05). The HbA1c in the control group was: at 0 months; 60.7 ± 9.5 mmol/mol (7.7±3.0 %), at 3 months; 61.0 ± 9.6 mmol/mol (7.7 ± 3.1 %) (NS) and at 6 months/HalvVasa 60.3 ± 9.7 mmol/mol (7.7 ± 3.1 %) (NS). No difference was seen regarding HbA1c change from baseline in the control group. However repeated measures analysis of variance indicated no significant effect between the intervention and control group for HbA1c.

Level of physical activity

The LPA was collected in questionnaire at baseline, 6 months prior to the HalvVasa, and at 7 months. The LPA was increased in 52% of the participants in the intervention group and in 7% of the control group. The differences in LPA are shown in (Figure 3). A significant improvement was shown in the intervention group compared with the control group, (p<0.005).

Health related locus of control and self-efficacy

The MHLC showed that the participants in both groups tended to be oriented towards internal locus-of-control at the start of the study. The higher the level of induced self-efficacy, the higher the performance accomplishment and the lower the emotional arousal. Higher self-efficacy means better coping behavior and ability of self regulation. There was a general trend towards improved locus-of-control and self-efficacy within the intervention group whereas the trend was the opposite within.
the control group. There was a significant reduced tendency to rely on chance in the intervention group, p<0.05.

Acute complications

Severe hypoglycemia was present in 3 cases during the pre-race intervention phase – 2 in the intervention group and 1 in the control group. DKA did not occur in any of the groups.

DISCUSSION

The results indicate a clear improvement in glycemic control, level of physical activity and locus of control when education about sports and nutrition was implemented in the form of training and individualized feedback. Therefore we believe that the active individual with diabetes do greatly benefit from this training. A recently published review and meta-analysis of exercise interventions in adults with T1D pointed out that well-designed studies showing the effects of exercise on HbA1c in individuals with T1D are missing [4]. We believe that our study show the combined effects of education and exercise on HbA1c.

Continuous glucose monitoring (CGM) was not included as a tool in this study however, CGM could be used for better adjustments of insulin doses and carbohydrate intake especially during prolonged exercise and during competition [18]. One limitation of the study is the number of drop-outs during the pre-race intervention phase, 39%/63% in the intervention respectively control group. Part of this drop-out is explained by the fact that the HalvVasa is a physically demanding race which is usually associated with a 30% drop-out frequency. In the study group other possible factors that could have added to this were that enrollment and education were done exclusively via the web/internet and participants met the study personnel for the first time at the start of the HalvVasa race, 6 months after the inclusion in the study. This may have an effect of reducing the feeling of commitment to the study that would have occurred if there had been personal contact from the beginning. Moreover, the start of the race is situated far away from any large cities creating a possible problem as transportation to the HalvVasa start line had to be covered at the participant’s own expense due to ethical rules concerning payment to study participants. Furthermore, drop-outs in the control group may be due to exercise related barriers and problems in achieving good glucose control during exercise as this group failed to show any improvements in HbA1c. However, we cannot be certain because sub-analyses could not be implemented due to the limited number of individuals in the study.

A majority of the adult individuals with or without diabetes fail to reach the recommendation of moderate-intensity aerobic physical activity for a minimum of 30 minutes five times a week or vigorous-intensity aerobic physical activity for a minimum of 20 minutes three days a week [19]. The importance of increased amount of physical activity is further reinforced by the fact that exercise should be included in combination with diet to elicit increased level of physical activity. This study indicates the importance of increased LPA as in this study, is of importance.

Individuals having poor locus-of-control have also been shown to have lower insulin treatment satisfaction and perceived health [21]. In a meta-analysis locus of control was not shown to be significantly correlated to glucose control but a weak correlation was shown between reliance on chance and glucose control [22]. This is supported by the results in our study as we noted a reduced tendency to rely on chance in the intervention group.

CONCLUSION

Education and individualized feedback regarding the self-management of diabetes in relation to exercise improves the outcomes in terms of glycemic control (reduced HbA1c) and increased level of physical activity. This study indicates the efficacy of web-based information and individualized feedback based on downloads of glucometers and insulin pumps in order to improve self-management of diabetes in physical active individuals with T1D. This illustrates that technology could be used to provide on demand support to the individual.

Further studies are needed in order to evaluate if there are differences depending on other factors such as; gender, type and duration of diabetes and treatment model. In the future it is important that guides on exercise and diabetes should promote exercise for people with diabetes and to do so in a safe context.

ACKNOWLEDGEMENTS

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Conflict of Interest

Peter Adolfsson is one of the founders and a board member of Diasend.

Johan Jendle and Peter Adolfsson have served as advisory board members for Roche diagnostics.

REFERENCES

prospective evaluation at one year of a therapeutic patient education programme. Diabetes Metab. 2002; 28: 287-394.


20. Clark JE. Diet, exercise or diet with exercise: comparing the effectiveness of treatment options for weight-loss and changes in fitness for adults (18-65 years old) who are overfat, or obese; systematic review and meta-analysis. J Diabetes Metab Disord. 2015;14: 31.
