The effect of long-term swimming program on glycemia control in 14–19-year aged healthy girls and girls with type 1 diabetes mellitus

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Key words: *type 1 diabetes mellitus, long-term physical activity, glycosylated hemoglobin, glycemia.*

Summary. *The aim of this study was to evaluate the effect of long-term physical activity in the water on glucose control.*

Material and methods. Altogether, 19 girls with duration of diabetes of 8.1±0.9 years and 28 healthy girls aged 14–19 years participated in the study. The participants with type 1 diabetes mellitus were questioned; glycosylated hemoglobin was measured before and after long-term swimming program for the participants with type 1 diabetes mellitus. Glycemia control was assessed by blood glucose monitoring before and after every physical sessions. Training sessions (each lasted for 45 min) were held twice per week for 14 weeks. A total of 28 trainings were performed in the swimming pool. Workload intensity was corrected by pulse measurement before and after every session in the water.

Results. After a 14-week long-term physical program glycosylated hemoglobin level has decreased ($p<0.01$) in diabetic subjects (8.5±0.4 vs 7.8±0.3%). Hyperglycemia significantly decreased for all subjects, but its response to the physical exercises in the water was the highest in diabetics ($p<0.001$).

Conclusion. Long-term physical activity program in the water improved glycemia control for all participants.

Introduction

Type 1 diabetes is characterized by inadequate secretion of insulin by the β-cells of the pancreas. It has a sudden and dramatic onset and is diagnosed primary in children and adolescents (1). People with type 1 diabetes require exogenous insulin for survival. An insulin deficiency has drastic effects on carbohydrate, lipid, and protein metabolism (1–3).

Puberty is a period of rapid anatomical and physiological alterations expected to induce changes in metabolic rate and energy requirements (4). Treatment for type 1 diabetes is often difficult in adolescents because of their ability to participate in self-management of diabetes during growing and developing varies with changing motor development, cognitive abilities, and emotional maturation (5).

Exercises are the cornerstone of the management of type 1 diabetes mellitus (6). Regular physical activity can help to reduce blood glucose level and blood pressure, to control weight, increase insulin sensitivity, reduce risk of diabetes mellitus complications, and improve the quality of life (6–12). The association between increased levels of physical activity and reduced occurrence of long-term complications of diabetes suggested that regular physical activity has a protective role (7). Most important to overall is aerobic fitness or physical condition resulting from prolonged aerobic activities. One of such activities is swimming. This activity is mainly aerobic in nature. Swimming intensity, duration, timing, and starting blood glucose level have the best effect on blood glucose for all regiments (11).

The aim of the research was to assess the status of diabetes mellitus in girls with type 1 diabetes mellitus and to estimate the effect of regular physical activity in the water on the concentration of blood glucose among 14–19-year aged healthy girls and girls with type 1 diabetes mellitus.

Material and methods

Altogether, 28 healthy girls and 19 girls with type 1 diabetes mellitus (duration of diabetes 8.1±0.9 years)

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aged 14–19 years took part in long-term physical activity program in the water. The research duration was 14 weeks, and 28 trainings were done. The participants attended swimming trainings two times per week. One training in the swimming pool lasted for 45 minutes. The intensity of the training was always adjusted according to the pulse, which we did not want to get higher than 144–156 beats/min. Before and after training the capillary blood glucose concentration was measured. The trainings took place in a swimming pool, the length of which is 25 meters. At the beginning of the training a 15–20-minute exercise was done, and the remaining 30 minutes the participants swam breaststroke and crawl. At the beginning short swimming distances (up to 200 meters) with the breaks were chosen, which later on were increased to 400 meters with the short breaks. The trainings took place at 12 p.m.

Participants with type 1 diabetes mellitus were questioned before and after the long-term physical program in the water. The information about the duration of the disease, injected insulin type and dosage, self-management of diabetes mellitus has been gathered. After the physical program the participants with type 1 diabetes mellitus have been questioned about the effect of physical activity on their dosage of injected insulin.

Before the beginning of the long-term swimming program and right after it, the analysis of glycosylated hemoglobin of venous blood was performed for the participants with type 1 diabetes mellitus. This analysis was done using fast ion-exchange resin separation method. The recommended norm of glycosylated hemoglobin (HbA1C) for the subjects with type 1 diabetes mellitus is up to 7.0% (13). In such a case, the control of diabetes mellitus is estimated well. If the value of HbA1C exceeds 7.0% the control of diabetes mellitus is estimated as satisfactory. When the value of HbA1C exceeds 9.5% it is estimated badly (13).

The concentration of glucose was measured before every training in the water and right after it. To measure the glucose concentration in blood, the capillary blood was taken from the finger; some drops of it were dripped on the stripe which was inserted into the device "AccuTrend GCT," and after 12 seconds the results were received in millimoles per liter of blood. The norm of capillary blood glucose concentration for healthy person is 3.33–5.55 mmol/l, whereas for people with type 1 diabetes mellitus – up to 6.5 mmol/l (13).

Descriptive data are presented as mean±SD. To check the hypothesis of the quantitative variable, the criteria of Student's t-test were used. The groups (healthy persons and diabetics) were compared with a two-way analysis of variances (ANOVA). Pearson's correlation coefficient was used for the quantitative values. Statistical significance of all tests was set at $p<0.05$.

Results

After a 14-week physical program in the water the participants with type 1 diabetes mellitus insignificantly reduced the total daily insulin dose ($p>0.05$). After the long-term physical activity the decrease in the dose of short-acting and long-acting insulin was observed too. However, only the decrease in the dose of short-acting insulin (before the long-term physical activity it was 26.44±1.82 units, after it – 25.00±1.81 units) was statistically significant ($p<0.01$). Less than three-fourths (73.7%) of girls with type 1 diabetes mellitus reduced the total daily insulin dose while participating in a 14-week physical training program, and only 26.3% did not change it. More than half (57.9%) of the respondents with type 1 diabetes mellitus reduced short-acting insulin dose, whereas 42.1% of the respondents with type 1 diabetes mellitus did not change it. More than one-third (36.8%) of the participants with type 1 diabetes mellitus reduced long-acting insulin dose, while 63.2% of diabetic girls did not change the dose.

The total daily-injected insulin dose before and after the long-term physical activity did not correlate with the duration of diabetes mellitus in diabetic girls participating in our research.

Good diabetes control means a properly chosen dose of injected insulin, well-balanced nutrition, and physical load. Only 5.3% of the respondents of our questionnaire-based survey control their illness only with the help of insulin. Less than half (42.1%) of the respondents control diabetes mellitus with the help of insulin and diet, and 52.6% of the respondents in order to compensate hyperglycemia constantly apply regular physical activity, diet, and insulin.

Before the long-term physical training in the water, the mean HbA1C value of type 1 diabetes mellitus subjects was 8.5±0.37%, and it exceeded the recommended norm. Therefore, the control of diabetes mellitus is estimated as satisfactory (13). After long-term physical activity program (Fig. 1), the average value of HbA1C significantly decreased to 7.8±0.28% ($p<0.01$), nevertheless it still remained above the recommended norm for diabetics (13).

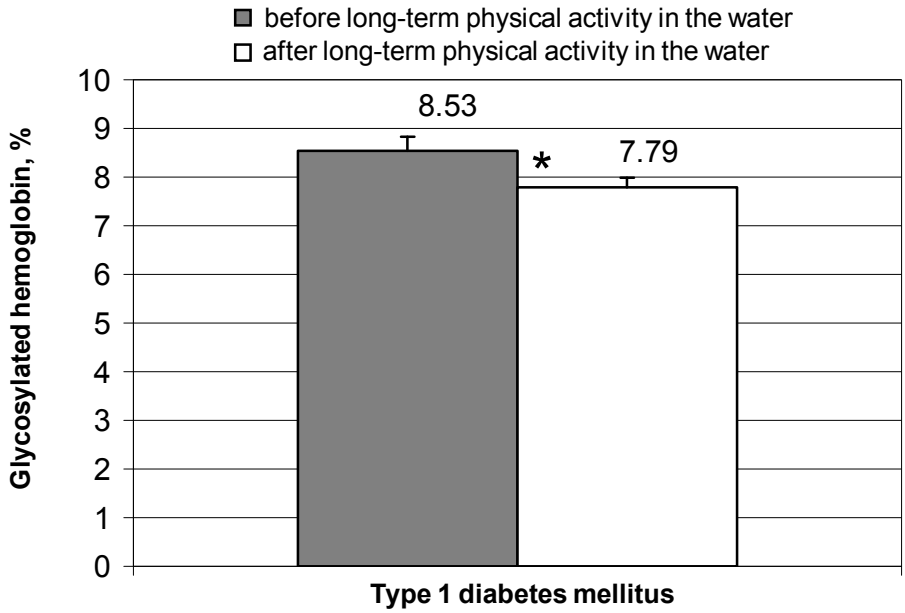

Fig. 1. **Glycosylated hemoglobin (%) of the girls with type 1 diabetes mellitus before and after the long-term physical activity in the water**

* – $p<0.01$.

Table. **Blood glucose (GL) concentration and heart rate (HR) of the healthy girls and type 1 diabetes mellitus subjects before and after trainings 1, 14, and 28 in the water**

Training	Group	Physical activity	GL (mmol/l)	p_{GL}	HR (beats/min)	p_{HR}
1	healthy	before after	5.3±0.7 4.6±0.8	0.001	94.0±2.9 145.3±3.9	0.001
	type 1 diabetes mellitus	before after	9.6±0.5 6.6±0.4	0.001	88.7±1.9 143.3±3.1	0.001
	p_1	before after	0.001 0.001	–	0.132 0.711	–
14	healthy	before after	5.1±0.7 4.3±0.7	0.001	88.9±2.4 154.3±2.2	0.001
	type 1 diabetes mellitus	before after	9.0±0.8 6.3±0.9	0.001	89.5±2.4 159.8±2.8	0.001
	p_2	before after	0.001 0.001	–	0.487 0.255	–
28	healthy	before after	4.9±0.7 4.4±0.9	0.001	90.0±2.5 150.4±1.9	0.001
	type 1 diabetes mellitus	before after	8.1±0.7 5.6±0.6	0.001	91.9±3.1 152.2±3.3	0.001
	p_3	before after	0.001 0.042	–	0.807 0.478	–

p_{GL} – significance level of mean glucose concentration within group before and after long-term 14-week physical activity in the water; p_{HR} – significance level of mean heart beat rate within group before and after long-term 14-week duration physical activity in the water; p_1 – significance level of the first training between healthy and type 1 diabetes mellitus groups; p_2 – significance level of training 14 between healthy and type 1 diabetes mellitus groups; p_3 – significance level of training 28 between healthy and type 1 diabetes mellitus groups.

When comparing heart rates between the groups, the mean heart rate of healthy girls was higher than type 1 diabetes mellitus subjects before the first training (94.0±2.86 *vs.* 88.7±1.98 beats/min), but this difference was not statistically significant ($p>0.05$). The mean heart rate between the groups after the first training in the water was not statistically different too ($p>0.05$). No statistically significant differences were found in mean heart rates between the groups of healthy girls and type 1 diabetes mellitus subjects before training 14 and after it as well as before and after training 28 ($p>0.05$).

The differences in blood glucose concentration between the healthy and diabetic groups during trainings 1, 14, and 28 were statistically significant. After the first training, the mean blood glucose concentration between the groups differed statistically significantly ($p<0.001$). Healthy subjects showed a statistically significant decrease in blood glucose concentration after the first training – a 13.2% reduction was observed ($p<0.001$). In the group of girls with type 1 diabetes mellitus, blood glucose concentration was significantly reduced by 31.2% ($p<0.001$). Before and after training 14 the difference in blood glucose concentration between the healthy group and the group of type 1 diabetes mellitus subjects was statistically significant too ($p<0.001$). A 15.7% decrease in blood glucose concentration after training 14 was observed in the healthy group ($p<0.001$). For the subjects with type 1 diabetes mellitus blood glucose concentration was significantly reduced by 30% ($p<0.001$) after training 14 in the water. When comparing the change of glucose concentration between the groups during training 28, a statistically significant difference in mean values before training ($p<0.001$) and after it ($p<0.05$) was noticed too. A 10.2% reduction in blood glucose concentration after training 28 was seen in the healthy group ($p<0.001$). In the group of girls with type 1 diabetes mellitus, blood glucose concentration was significantly reduced by 30.9% ($p<0.001$) after training 28 in the water.

When comparing the blood glucose concentration of type 1 diabetes mellitus subjects before the first training (the beginning of the research) and before training 28 (the end of the research), a significant decrease in blood glucose concentration was observed. Blood glucose concentration decreased by 15.6% from the initial (first training) value during a 14-week period ($p<0.05$). Comparing the blood glucose concentration after trainings 1 and 28, a 15.2% decrease from the initial (first training) value was observed during this period, but it was not statistically significant ($p>0.05$).

When comparing the blood glucose concentration of healthy girls before training 1 (the beginning of the research) and before training 28 (the end of the research), a significant decrease in blood glucose concentration was observed too. Blood glucose concentration decreased by 7.5% during a 14-week physical training program. Comparing the blood glucose concentration after trainings 1 and 28, a 4.3% decrease was seen during this period ($p<0.05$).

The change in healthy girls' blood glucose concentration after trainings 1, 14, and 28 in the swimming pool was not big. However, the swimming has significantly reduced blood glucose concentration for the girls with type 1 diabetes mellitus, and the total change after trainings 1, 14, and 28 is bigger than that of the healthy girls (Fig. 2). On the first training due to physical activity in water the mean blood glucose concentration of the girls with type 1 diabetes mellitus decreased by 3 mmol/l. As a result of adaptation during the training process, on training 14 the change in blood glucose concentration was 2.7 mmol/l, whereas at the end of the training program, the change in mean blood glucose concentration decreased even more, up to 2.5 mmol/l.

Discussion

Insulin type, site of injection, and individual patient's response differences can all affect the onset, peak, and duration of insulin activity. Insulin requirements are usually based on body weight, age, and pubertal status (5). Hormonal changes of puberty dictate higher doses (5). The data obtained during our research show that insulin doses of girls with type 1 diabetes mellitus aged 9–14 years are rather high too. The question is, "Is the dose of insulin depended on the duration of illness?" According to the data of our research, the injected insulin dose of the researched girls with type 1 diabetes mellitus did not correlate with the duration of diabetes. In the literature there are contradictory data regarding this issue. M. Kerouz and his colleagues (1995) reported that insulin dose did not correlate with duration of disease (14). Whereas R. L. Jackson and co-workers (1979) presented contradictory data: according to them there was a positive correlation between the duration of type 1 diabetes mellitus and insulin requirement per kilogram of body weight (15). B. Balkau *et al.* (1998) reported that girls with type 1 diabetes had higher insulin requirements during their maturation period than upon its end, and it increased with disease duration (16).

Diabetes treatment focuses on intensive daily ma-

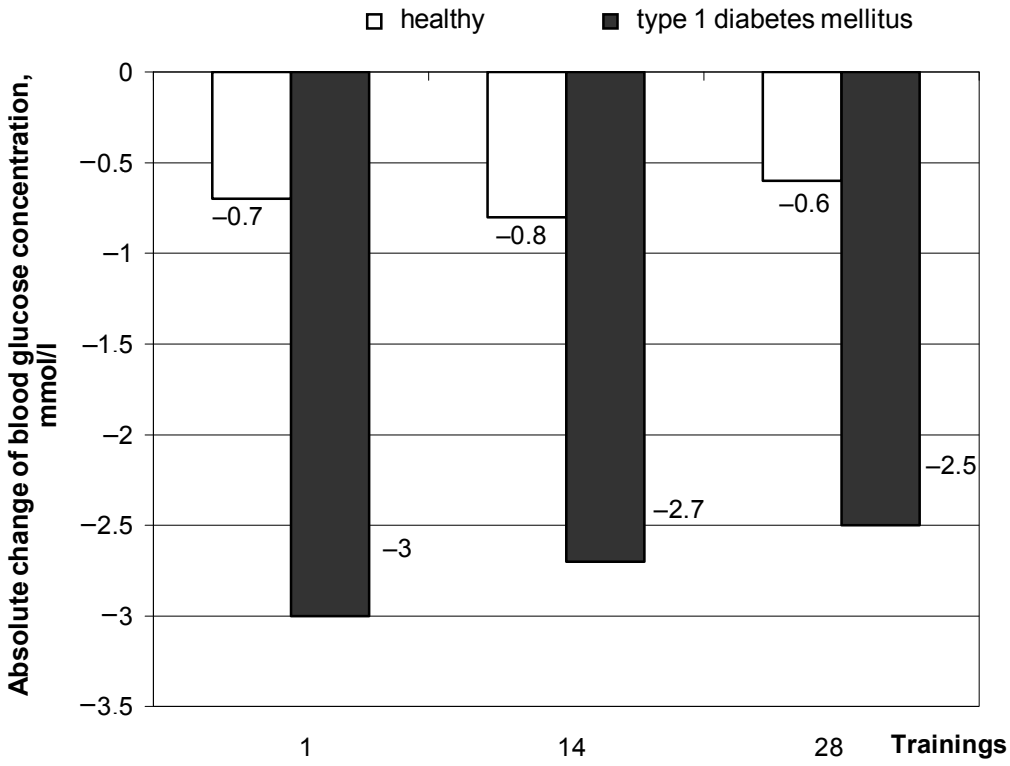

Fig. 2. **Absolute change of blood glucose concentration (mmol/l) of the healthy girls and type 1 diabetes mellitus subjects after the 1st, 14th and the 28th trainings in the water**

nagement of blood glucose by balancing insulin, food intake, and physical activity (17). Data of our research confirmed this statement: 52.6% of respondents with type 1 diabetes mellitus control their diabetes with diet, physical activity, and insulin.

The glycemia control of the girls participating in our research was satisfactory according to the value of HbA1C (13). Before our research the girls with type 1 diabetes mellitus had HbA1C levels above the recommended norm. After the long-term physical training program the mean HbA1C value was significantly reduced ($p<0.01$), however, it remained above the recommended norm (13). In accordance with the results of changes in blood glucose concentration, which were registered during our study, the following conclusion can be made: long-term physical activity effectively decreases blood glucose (18). In our study, long-term physical activity in the water significantly decreased blood glucose concentration ($p<0.001$). Specific biochemical changes of organism take place in water. Water environment limits sweating; therefore, upon the presence of similar water and air temperature, in water human organism releases four times more of heat. In water oxidation processes get much more intensive due to the increased heat conduction; energy input is larger (19). Due to the above-mentioned facts, one of the mechanisms to decrease blood glucose concentration might be the above-described process during which blood glucose is utilized.

Conclusions

Due to the aforementioned physical activity program, there was a decrease in blood glucose concentration, but the higher decrease was observed in the group of girls with type 1 diabetes mellitus. Under the effect of long-term physical activity, glycosylated hemoglobin concentration decreased for type 1 diabetes mellitus subjects.

Ilgalaikio fizinio krūvio vandenyje poveikis 14–19 metų sveikų ir sergančių I tipo cukriniu diabetu merginų glikemijos reakcijai į fizinį krūvį

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Raktažodžiai: I tipo cukrinis diabetas, ilgalaikis fizinis krūvis, glikozilintas hemoglobinas, glikemija.

Santrauka. *Tikslas.* Įvertinti 14–19 metų sveikų ir sergančių I tipo cukriniu diabetu merginų ilgalaikio fizinio krūvio vandenyje poveikį kraujo gliukozės koncentracijai.

Tirtųjų kontingentas ir tyrimo metodai. Tyrime dalyvavo 19 sergančiųjų I tipo cukriniu diabetu, sirgimo trukmė – 8,1±0,9 metų ir 28 sveikos merginos. Prieš ir po ilgalaikio fizinio krūvio programos vandenyje atliktas sergančiųjų I tipo cukriniu diabetu glikozilinto hemoglobino tyrimas, po to – anketinė apklausa. Kraujo gliukozės koncentracija buvo matuojama visoms tiriamosioms prieš ir iškart po kiekvieno užsiėmimo vandenyje. Aerobinio pobūdžio užsiėmimai vandenyje vyko 14 savaičių, dukart per savaitę, trukmė – 45 min. Įvyko 28 užsiėmimai. Krūvio intensyvumas koreguojamas matuojant pulsą (144–156 k/min.).

Rezultatai. Po ilgalaikės 14 savaičių trukmės fizinės programos vandenyje glikozilinto hemoglobino koncentracija kraujyje reikšmingai sumažėjo ($p<0,01$) sergančiosioms I tipo cukriniu diabetu. Kraujo gliukozės koncentracija reikšmingai sumažėjo visoms tiriamosioms, tačiau sergančiųjų I tipo cukriniu diabetu merginų glikemijos reakcija į fizinį krūvį vandenyje buvo didesnė ($p<0,001$).

Išvada. Ilgalaikis fizinis krūvis vandenyje sumažino hiperglikemiją visoms tiriamosioms.

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