Physical activity in type 1 diabetic young and early adults treated with insulin pump therapy. A preliminary report.

Roszkowski A.[1,A-F], Kulesza K.[1,DEF], Cybulski M.[2,EF], Witkowska A.M.[1*,CDEF]

1. Department of Food Biotechnology, Faculty of Health Sciences, Medical University of Białystok, Poland
2. Department of Integrated Medical Care, Faculty of Health Sciences, Medical University of Białystok, Poland

---

A- Conception and study design; **B** - Collection of data; **C** - Data analysis; **D** - Writing the paper;
E- Review article; **F** - Approval of the final version of the article; **G** - Other (please specify)

ABSTRACT

Purpose: To determine the level of physical activity in young and early adults with type 1 diabetes in comparison with their healthy counterparts and to determine whether the use of insulin pump facilitates physical activity.
Materials and methods: This study included 40 type 1 diabetes (T1D) subjects of both sexes treated with a personal insulin pump therapy, and 30 healthy controls. The diagnostic survey included questions about nutrition, knowledge about the disease and whether the patient can control diabetes through physical activity, diet and self-monitoring. The International Physical Activity Questionnaire – long form (IPAQ-L), was used to assess the level of physical activity of both diabetic and control individuals.
Results: 87.5% T1D subjects believe that using an insulin pump facilitates their physical activity. The level of physical activity associated with cycling ($p=0.038$) and vigorous physical activity ($p=0.008$) was higher in T1D than in the control group. Statistically significant differences ($p=0.043$) were found for total physical activity. The total mean activity was higher in participants with T1D (8147.70 MET-min/week) compared to the control group (5857.55 MET-min/week).
Conclusions: Young and early adults with type 1 diabetes may be more physically active than their healthy counterparts, mainly in their leisure time. The use of a personal insulin pump facilitates physical activity, but most diabetics experience episodes of hypoglycemia after physical activity.
Key words: Type 1 diabetes, insulin pump, physical activity, young adults, early adults, IPAQ

DOI:

***Corresponding author**
Anna Witkowska
Department of Food Biotechnology, Medical University of Białystok
ul. Szpitalna 37, 15-295 Białystok, Poland
Tel.: 85 6865090, Fax 85 6865089, e-mail: witam@umb.edu.pl

Received: 16.01.2019
Accepted: 01.03.2019
Progress in Health Sciences
Vol. 9(1) 2019 pp 13-21

INTRODUCTION

Diabetes mellitus (DM) is a metabolic disorder which, if not treated, leads to serious medical complications, including atherosclerosis, nephropathy, retinopathy, neuropathy, cardiovascular disease [1]. Physical activity plays a key role in the prevention of health complications in diabetes [2]. Moderate intensity activity at least once a week reduces the risk of death by about 40% regardless of age, body mass index (BMI), smoking, alcohol consumption, chronic complications, gender, or diet [3].

Until 1986, physical activity was not considered safe during the insulin therapy. It is only LaPorte et al. studies that physical activity is beneficial in type 1 diabetes (T1D) by reducing the risk of chronic complications and preventing the development of microangiopathic complications, osteoporosis and cancer [3]. Regular physical activity helps to maintain proper blood pressure, increases HDL cholesterol, lowers the LDL fraction and increases myocardial function, which contributes to reducing the risk of stroke and myocardial infarction, supports insulin sensitivity, improves well-being and helps to maintain normal body weight [4]. Physical activity in healthy individuals and diabetics increases insulin sensitivity of tissues for several days after the last moderate physical training. In order to maintain elevated insulin sensitivity, it is necessary to train and exercise regularly [4,5]. Glucose monitoring techniques and insulin pump therapy can make a significant contribution to regular physical activity in type 1 diabetes, but numerous guidelines are needed from healthcare providers, especially doctors, nurses and nutritionists [6]. Continuous subcutaneous insulin infusion (CSII) (or insulin pump therapy) is particularly recommended for patients with DM in whom the concentration of glycosylated hemoglobin (HbA1c) cannot be reduced to less than 7.5% without causing disabling hypoglycemia [7]. CSII requires T1D patients to develop skills and competences for its effective application [6]. Carbohydrate counting, insulin therapy and physical activity must be coordinated to achieve proper blood glucose regulation [6].

The American Diabetes Association (ADA) believes that the majority of adults with type 1 diabetes can perform any kind of physical activity, unless contraindicated [8]. Patients with diabetes are recommended to have at least 150 minutes of moderate to intense activity per week [8, 9]. It is also claimed that strength training can increase insulin sensitivity more effectively than aerobic exercises [2]. Physical training in diabetic subjects may cause both hypoglycemia or hyperglycemia, depending on the type of physical activity, patient's knowledge of diet and self-control [10]. The effect of lowering the level of glycemia is much smaller at high intensity up to 90% VO2max. During such exercises, glucogenic hormones are secreted i.e. adrenaline, cortisol, growth hormone and glucagon, which contribute to increased glycaemia [10]. On the other hand, hypoglycemia is caused by aerobic activity of moderate intensity of 60% VO2max. Aerobic training can reduce blood glucose levels up to several hours after exercise [10].

There are no studies focusing on physical activity in type 1 diabetic patients treated with personal insulin pump. The aim of the study was to determine the level of physical activity in young and early adults with type 1 diabetes in comparison with their healthy counterparts and to determine whether the use of insulin pump facilitates physical activity.

MATERIALS AND METHODS

This study included 40 participants with type 1 diabetes mellitus of both sexes treated with a personal insulin pump enabling continuous subcutaneous insulin infusion (CSII) and 30 healthy people as a control, adjusted to age, sex and body mass index (BMI). The study has been approved by the local bioethics committee. Table 1 shows the characteristics of participants by age, BMI, place of residence, level of education and employment.

The diagnostic survey included questions about nutrition, knowledge about the disease and whether the patient can control diabetes through physical activity, diet and self-monitoring. The level of glycosylated hemoglobin, obtained from each diabetic subject, was an indicator of diabetes control. Patients were asked if they knew the influence of physical activity on the course of the disease and glycemic compensation.

The International Physical Activity Questionnaire – long form (IPAQ-L), was used to assess the level of physical activity of both diabetic and control individuals [11,12]. The level of physical activity is presented using the Metabolic Equivalent of Task (MET) calculated on the basis of the conversion factor [13]. MET is the ratio of the metabolic level associated with physical activity to the resting level. The MET ratio is expressed as 1 kcal per kg body weight per hour (1 $kcal \cdot kg^{-1} \cdot h^{-1}$). Each activity is expressed in units of MET-minute/week using a formula: MET-min/week = MET Factor value*number of days per week*number of minutes in one day [14]. IPAQ-L has been validated in several studies. Cronbach alpha for IPAQ is >0.7 [15].

Statistical analysis was based on Mann-Whitney's U-test and descriptive statistics (mean, standard deviation) to determine the significance of differences related to physical activity. Data calculations were carried out using Statistica 13.1, StatSoft, computer software.

Table 1. Characteristics of participants in the survey

	T1D subjects (N=40)	Control (N=30)
Gender	M=20, F=20	M=14, F=16
Age (years) Mean + SD	25.15 ± 6.04	26.37 ± 7.80
BMI (kg/m2) Mean + SD	23.59 ± 2.51	24.30 ± 3.99
Body mass index (%)		
Underweight (BMI<18.5)	0%	3.3%
Normal weight (BMI 18.5-24.9)	72.5%	63.3%
Overweight (BMI 25.0-29.9)	27.5%	26.7%
Obese (BMI >30.0)	0%	6.7%
Location (%)		
Rural area	17.5%	0%
Town (< 20 thousand inhabitants)	7.5%	10%
Mediumsized city (20 thousand-100 thousand inhabitants)	12.5%	16.5%
City (< 100 thousand inhabitants)	62.5%	73.5%
Education (%)		
Primary	12.5%	0%
Secondary	37.5%	43.5%
Vocational	5%	0%
Higher	45%	56.5%
Employment (%)		
Blue-collar work	12.5%	10%
White-collar work	40%	46.5%
Retired	0%	0%
Disability benefit	7.5%	0%
Unemployed	17.5%	0%
Student	22.5%	43.5%
Disease duration		
1-5 years	30%	
6-10 years	27.5%	
11-15 years	32.5%	
16-20 years	7.5%	
20 years and more	2.5%	
Duration of use of the insulin pump		
1-5 years	55%	
6-10 years	32.5%	
11-15 years	12.5%	
Glycosylated hemoglobin:	7.18% ± 0.99	

M/F – male/female

RESULTS

Among the T1D participants, 47.5% calculated the number of carbohydrate exchanges they consume experimentally, 47.5% used weight and nutritional tables, and only 5% used weighting method and online dietary diary (Table 2).

Regular food intake is important for diabetes. Of the studied T1D, 90% consumed at least 4 meals a day.

The vast majority of DM type 1, 72.5%, preferred to be active during hyperglycemia and 80% experienced hypoglycemia after physical activity.

Among people with T1D, 42.5% believe that their activity increased after the diagnosis of diabetes (Figure 1).

Different sources of education on diabetes were used by T1D subjects, with an emphasis on self-education via the Internet (82.5%) (Figure 2). Other sources of self-education were literature (35%) and lectures for diabetics (27.5%). The education of health care workers was provided mainly by diabetologists (32.5%) and diabetes educators (27.5%). Thirty percent of T1D subjects benefited from the education of personal trainers.

Table 2. Selected aspects of nutrition and glycaemia in diabetic subjects

	Percentage of type 1 diabetic subjects
Counting method of carbohydrate exchanges	
Experience-based estimation	47.5%
Using food weighting and nutrition tables	47.5%
Using food weighting and online nutrition diary	5%
Number of meals consumed	
3 or less	10%
4 meals	32.5%
5 meals	50%
More than 5 meals	7.5%
Physical activity taken up during hyperglycaemia	
Yes	72.5%
No	27.5%
Episodes of hypoglycaemia experienced after physical activity	
Yes	80%
No	20%

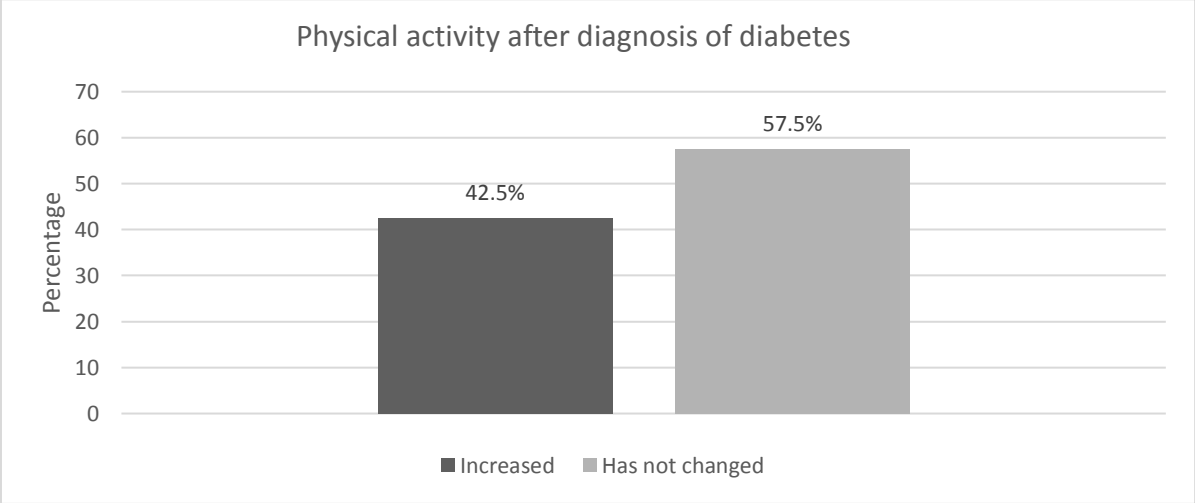

Figure 1. Percentage distribution of T1D subjects according to the influence of diabetes diagnosis on the level of their physical activity

All participants with T1D were physically active (Figure 3). The majority of subjects, 67.5%, preferred walking as a kind of physical activity in their leisure time. Both regular strength training and running were preferred by 42.5%, and 37.5% took up cycling, 32.5% fitness/aerobics, 20% swimming. 27.5% declared physical activity other than mentioned above.

In this study, the vast majority of T1D subjects, 87.5%, believe that the use of an insulin pump facilitates their physical activity (Figure 4).

Table 3 shows the results of the Mann-Whitney test for physical activity in diabetic subjects and control group. There were no statistically significant differences in physical activity related to job, housekeeping and family care. Statistically significant differences were found in the level of physical activity related to cycling as a means of transport (p=0.038).

In T1D, statistically significant differences (p=0.008) in the level of vigorous physical activity during recreation, sport and leisure time were found. The mean activity related to vigorous physical activity was almost 3 times higher in diabetics compared to the control group.

Statistically significant differences (p=0.043) were found for total physical activity. The total mean activity was higher in participants with T1D (8147.70 MET-min/week) compared to the control group (5857.55 MET-min/week).

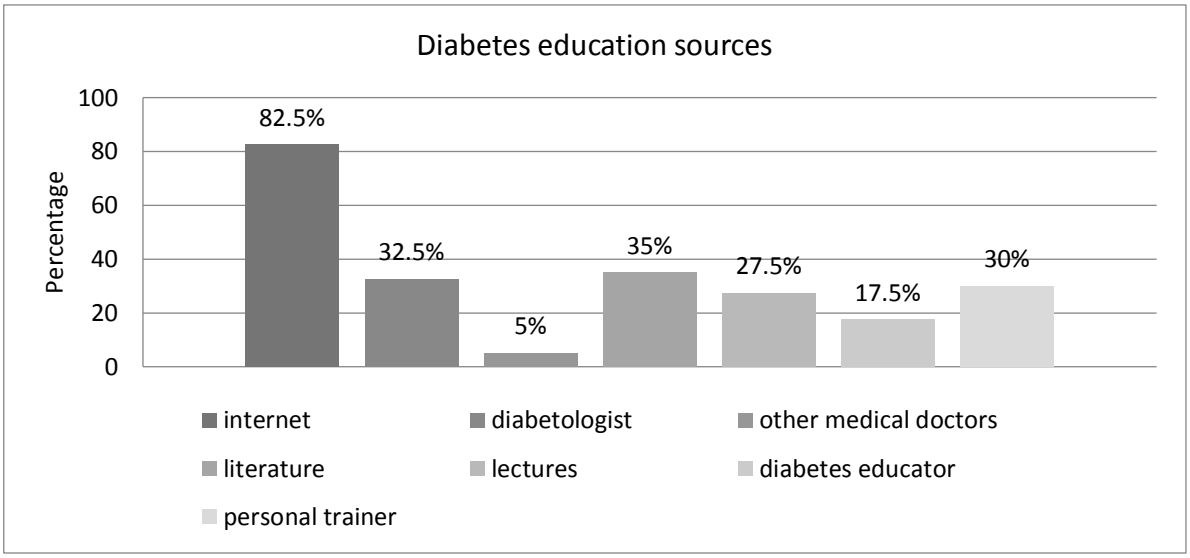

Figure 2. Diabetes education sources used by T1D subjects

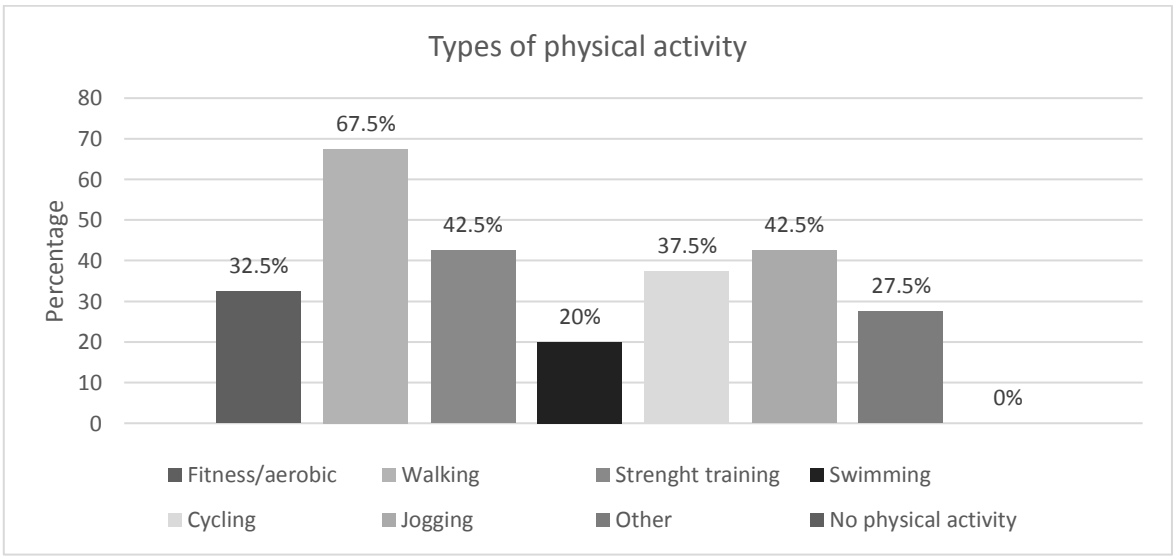

Figure 3. Percentage distribution of T1D subjects according to preferred types of physical activity

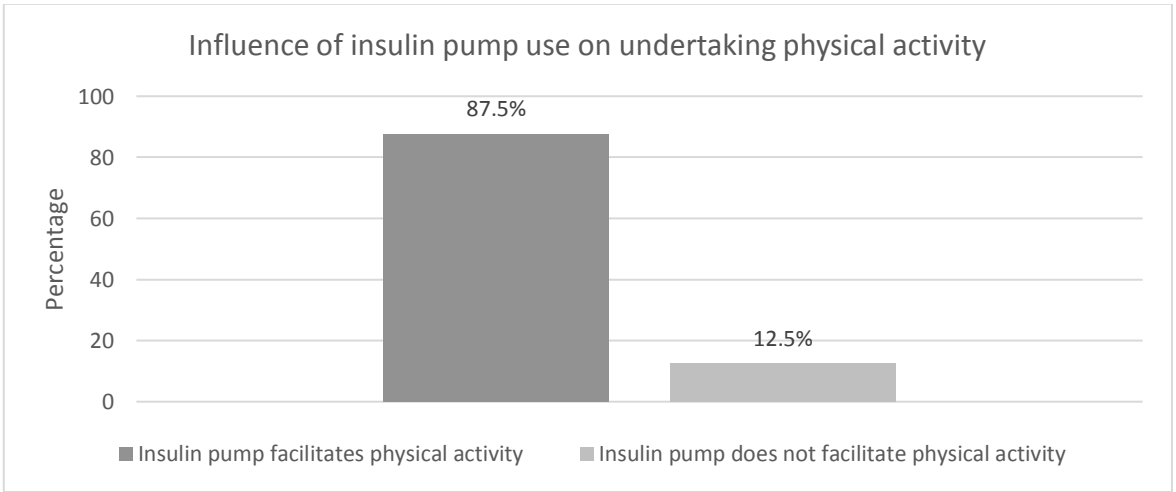

Figure 4. The T1D subjects' opinion associated with insulin pump use and their physical activity

Table 3. Physical activity assessment in type 1 diabetic subjects and controls

Types of physical activity	T1D subjects	Control	P-value*
	Mean ± SD (MET-min/week)	Mean ± SD (MET-min/week)	
Job-related physical activity			
Vigorous	1143.00 ± 3210	1154.67 ± 1508	NS
Moderate	355.00 ± 792	1060.00 ± 2258	NS
Walk	646.80 ± 1149	520.85 ± 1140	NS
Transportation physical activity			
Walking	1262.66 ± 1385	784.41 ± 837	NS
Bicycling	182.25 ± 429	18.00 ± 99	0.038
Housework, house maintenance, and caring for family			
Vigorous (in the garden or yard)	496.38 ± 1189	162.80 ± 403	NS
Moderate (in the garden or yard)	498.00 ± 690	271.33 ± 417	NS
Moderate (inside home)	431.63 ± 500	485.00 ± 657	NS
Recreation, sport and leisure-time physical activity			
Walking	829.04 ± 1067	425.15 ± 740	NS
Moderate	371.50 ± 665	252.67 ± 566	NS
Vigorous	1933.00 ± 1939	722.67 ± 1059	0.008
Total physical activity			
Total physical activity	8147.70 ± 3580	5857.55 ± 2080	0.043

NS – Non-significant.
*calculated with Mann-Whitney's U test.

DISCUSSION

Physical activity has a positive effect on the functioning of the human body, both in healthy people and diabetic subjects. This positive effect on diabetes was found in many studies and meta-analyses [16,17]. Physical activity increases cardiopulmonary function and vigor, allows for control of glucose concentration, reduces insulin resistance, improves lipid profile, lowers blood pressure, helps maintain proper body weight, improves glycosylate hemoglobin [8]. Regular physical activity helps to maintain glycemic control and prevents the complications of diabetes [18]. It decreases the level of HbA1c glycosylated hemoglobin [19] and tissue advanced glycation end products [20].

On the other hand, the risk of mortality is much higher in people who avoid physical activity and spend a lot of time sitting [21]. The life expectancy in diabetics can be increased by physical activity and reduced sitting time. Physical activity can improve health parameters and reduce mortality among T1D individuals [16].

In this study 82.5% of diabetic subjects declared that they were aware of the importance of physical activity in the treatment of T1D, and the vast majority of participants (82.5%) gained this knowledge via the Internet. Only 32.5% were educated by a diabetologist and 17.5% by a diabetic educator. These findings point to the need of T1D subjects for better lifestyle education acquired from health service providers.

For 87.5% of patients with diabetes in this study, the use of an insulin pump facilitated physical activity. Insulin dosing must be coordinated with carbohydrate intake, and this study investigated the methods of carbohydrate exchange (CE) counting in meals consumed by T1D participants. The results show that 47.5% of diabetic patients estimate the number of CEs in a meal using a method based on experience, while the remaining 52.5% used kitchen scales and online nutrition diaries or energy tables. The ability to correctly estimate the number of CEs in a meal preprandially is important for adjusting the dose of insulin and affects postprandial glycaemia [22]. The high percentage of T1D individuals who evaluate CE number using an experience-based method shows that they estimate the amount of CE without analyzing their composition and inject insulin without calculating the correct dose. The estimation of carbohydrate intake is associated with a small margin of calculation error, which may increase the episodes of hypo- and hyperglycemia and consequently lead to a higher HbA1c score. Alternatively, the assessment of carbohydrate intake based on experience-based estimates may be related to the perception of lifestyle flexibility in T1D subjects.

Hypoglycemia is the most common complication in diabetes. This may cause anxiety related to the possibility of its occurrence, which may lead to a possible non-compliance with the treatment regimen [23]. Hypoglycemia has a significant impact on the performance of type 1 diabetic patients; severe episodes of hypoglycemia

may lead to unconsciousness [24]. Cornelis et al. [25] found that diabetes patients often deliberately caused hypoglycemia in an attempt o improve their HbA1c levels. Emral et al. [26] found that 97.4% of patients with 1 type diabetes reported episodes of hypoglycemia on average 7 times a month. Physical activity can be an additional factor that can lead to hypoglycemia. Our research shows that most (80%) T1D subjects experience hypoglycemia after training.

In this study, the level of physical activity was assessed using the International Physical Activity Questionnaire – long form (IPAQ-L). IPAQ is recommended in several international projects, including the European Physical Activity Surveillance System (EUPASS) and the European Health Interview Survey (EHIS), as a unified method of measuring physical activity in different countries with different habits [27]. IPAQ-L is used to assess the physical activity of men and women aged 15-69 within 7 days. The questionnaire consists of 5 units: physical activity related to job, physical activity related to transportation, physical activity related to domestic work and family care, physical activity during leisure time and time spent sitting. Each part of the questionnaire has been described in detail in order to facilitate understanding of the concept.

Earlier evidence suggests that people with T1D are more sedentary than the healthy population, and fear of hypoglycemia would be a barrier to regular physical activity [28]. The present study was the first in which the level of physical activity in young and early adult T1D subjects was evaluated. In general, diabetic subjects were characterized by a higher physical activity compared to the control group. According to IPAQ categories of physical activity levels [17], T1D individuals as well as control group met criteria of vigorous physical activity ($\geq$ 3000 MET-minutes/week), but T1D individuals were much more active than the control group. Interestingly, earlier studies have shown that physical activity in older age groups of adults did not differ between T1D and healthy control [29] and decreased with age [26].

According to our study, job-related and house-related physical activity in T1D did not differ significantly from control. These results show that T1D individuals are economically active and do not avoid daily physical activity related to employment and housework. The increased level of activity in T1D was related to cycling for transport purposes. The level of cycling activity was ten times higher than in the case of controls. This statement may probably result from increased awareness of the beneficial effects of physical activity on health among people with T1D [30].

This study has its limitations related to different levels of education among diabetics and controls. Unlike the control group, among diabetics there were participants with primary and vocational education. Another constraint is the low number of participants. Therefore, the results are given in the form of a preliminary study.

CONCLUSIONS

This study shows that young and early adults with type 1 diabetes may be more physically active than their healthy counterparts, mainly in their leisure time. The use of a personal insulin pump facilitates physical activity, but most diabetics experience episodes of hypoglycemia after physical activity.

Funding

None.

Conflicts of interest

The authors declare that they have no conflicts of interest.

REFERENCES

1. World Health Organization [Internet]. Global report on diabetes: World Health report; 2016 [cited: 2018 Aug 22]. Available from: http://apps.who.int/iris/bitstream/handle/10665/204871/9789241565257_eng.pdf?sequence=1.
2. American Diabetes Association. Standards of Medical Care in Diabetes – 2018 Abridged for Primary Care Providers. Clin Diabetes 2018 Jan;36(1):14-37.
3. Tielemans SM, Soedamah-Muthu SS, De Neve M, Toeller M, Chaurvedi N, Fuller JH, et al. Association of physical activity with all-cause mortality and incident and prevalent cardiovascular disease among patients with type 1 diabetes: the EURODIAB Prospective Complications Study. Diabetologia 2013 Jan;56 (1):82-91.
4. LaPorte RE, Dorman JS, Tajima N, Cruickshanks KJ, Orchard TJ, Cavender DE, et al. Pittsburgh Insulin Dependent Diabetes Mellitus morbidity and mortality study: physical activity and diabetic complications. Pedriatrics 1986 Dec;78(6):1027-33.
5. Chimen M, Kennedy A, Nirantharakumar K, Pang TT, Andrews R, Narendran P. What are the health benefits of physical activity in type 1 diabetes mellitus? A literature review. Diabetologia 2012 Mar;55(3):542-51.
6. Scheiner G, Sobel RJ, Smithe DE, Pick AJ, Kruger D, King J, Green K. Insulin pump therapy: guidelines for successful outcomes. Diabetes Educ 2009 Mar-Apr;35(Suppl 2):29-41.

7. National Institute for Health and Clinical Excellence [Internet]. Continuous subcutaneous insulin infusion for the treatment of diabetes mellitus. London: NICE; 2008 [cited 2018 Aug 22]. Available from: https://www.nice.org.uk/Guidance/TA151
8. Colberg SR, Sigal RJ, Yardley JE, Ridell MC, Dunstan DW, Dempsey PC, Horton ES, Castorino K, Tate DF. Physical activity/exercise and diabetes: a position statement of the American Diabetes Association. Diabetes Care 2016 Nov;39(11):2065-79.
9. Diabetes Poland (Polish Diabetes Association). 2018 Guidelines on the management of diabetic patients. A position of Diabetes Poland 2018. Clin Diabetol 2018 Jan;7(1):1-97.
10. Davey RJ, Paramalingam N, Retterath AJ, Lim EM, Davis EA, Jones TW, et al. Antecedent hypoglycaemia does not diminish the glycemia-increasing effect and glucoregulatory responses of a 10 s sprint in people with type 1 diabetes. Diabetologia 2014 Jun;57(6):1111-8.
11. Hagströmer M, Oja P, Sjöström M. The International Physical Activity Questionnaire (IPAQ): a study of concurrent and construct validity. Public Health Nutr 2006 Sep;9(6):755-62.
12. IPAQ, Polish [Internet]. [cited: 2018 Aug 23]. Available from: https://docs.google.com/viewer?a=v&pid=sites&srcid=ZGVmYXVsdGRvbWFpbnx0aGVpcGFxfGd4OjFlNWMyNjUxM2UwZjI1MmY.
13. Maddison R, Ni Mhurchu C, Jiang Y, Vander Hoorn S, Rodgers A, Lawes CM, et al. International Physical Activity Questionnaire (IPAQ) and New Zealand Physical Activity Questionnaire (NZPAQ): A doubly labelled water validation. Int J Behav Nutr Phys Act 2007 Dec;3;4:62.
14. Sjostrom M, Ainsworth B, Bauman A, Bull F, Hamilton-Craig C, Sallis J. Guidelines for the data processing and analysis of the International Physical Activity Questionnaire - short and long forms. [Internet]. IPAQ; 2005. [cited 2018 Aug 23]. Available: http://www.ipaq.ki.se/ scoring. pdf.
15. Mannocci A, Di Thiene1 D, Del Cimmuto A, Masala D, Boccia A, De Vito E, La Torre G. International Physical Activity Questionnaire: validation and assessment in an Italian sample. It J Publ Health 2010;7(4):369-76.
16. Macmillan F, Kirk A, Mutrie N, Matthews L, Robertson K, Saunders DH. A systematic review of physical activity and sedentary behavior intervention studies in youth with type 1 diabetes: study characteristics, intervention design, and efficacy. Pediatr Diabetes 2014;15 (3):175-89.
17. Kennedy A, Nirantharakumar K, Chimen M, Pang TT, Hemming K, Andrews EC, Narendran P. Does exercise improve glycaemic control in type 1 diabetes? A systematic review and meta-analysis. PLoS One 2013;8(3):e58861.
18. Bohn B, Herbst A, Pfeifer M, Krakow D, Zimny S, Kopp F, Melmer A, Steinacker JM, Holl RW; DPV Initiative. Impact of physical activity on glycemic control and prevalence of cardiovascular risk factors in adults with type 1 diabetes: cross-sectional multicenter study of 18,028 patients. Diabetes Care 2015 Aug;38(8): 1536-43.
19. Beraki Å, Magnuson A, Särnblad S, Åman J, Samuelsson U. Increase in physical activity is associated with lower HbA1c levels in children and adolescents with type 1 diabetes: Results from a cross-sectional study based on the Swedish pediatric diabetes quality registry (SWEDIABKIDS). Diabetes Res Clin Pract 2014 Jul;105(1):119-25.
20. Duda-Sobczak A, Falkowski B, Araszkiewicz A, Zozulinska-Ziolkiewicz D. Association between self-reported physical activity and skin autofluorescence, a marker of tissue accumulation of advanced glycation end products in adults with type 1 diabetes: a cross-sectional study. Clin Ther 2018 Jun;40(6):872-80.
21. Glenn KR, Slaughter JC, Fowke JH, Buchowski MS, Matthews CE, Signorello LB, et al. Physical activity, sedentary behavior and all-cause mortality among blacks and whites diabetes. Ann Epidemiol 2015 Sep;25(9):649-55.
22. Smart CE, Ross K, Edge JA, King BR, McElduff P, Collins CE. Can children with Type 1 diabetes and their caregivers estimate the carbohydrate content of meals and snacks? Diabet Med. 2010 Mar;27(3):348-53.
23. Leroux C, Brazeau AS, Gingras V, Desjardins K, Strychar I, Rabasa-Lhoret R. Lifestyle and cardiometabolic risk in adults with type 1 diabetes: a review. Can J Diabetes 2014 Feb;38(1):62-9.
24. Ortiz MR: Hypoglycemia in Diabetes. Nurs Clin North Am. 2017 Dec;52(4):4565-74.
25. Cornelis AJ, Caris MG, DeVries H, Serne EH: The relations between HbA1c and hypoglycemia revisited; a secondary analysis from an intervention trial in patients with type 1 diabetes and impaired awareness of hypoglycemia. J Diabetes Complications 2018 Jan;32(1):1100-3.
26. Emral R, Pathan F, Cortés CAY, El-Hefnawy MH, Goh S, Gómez AM, et al. Self-reported hypoglycemia in insulin-treated patients with diabetes: Results from an international survey on 7289 patients from nine countries. Diabetes Res Clin Pract 2017 Dec;134:17-28.
27. Elmadfa I. European Nutrition and Health Report. Switzerland: Karger; 2009. Chapter 8,

Health and lifestyle indicators in the European Union; p. 157-201.
28. Brazeau AS, Rabasa-Lhoret R, Strychar I, Strychar I, Mrcescu H. Barriers to physical activity among patients with type 1 diabetes. Diabetes Care. 2008 Nov;31(11):2108-9.
29. Falkowski B, Chudziński M, Jakubowska E, Duda-Sobczak A. Association of olfactory function with the intensity of self-reported physical activity in adults with type 1 diabetes. Pol Arch Intern Med. 2017 Aug;127(7-8):476-80.
30. Ryninks K, Sutton E, Thomas E, Jago R, Shield JP, Burren CP. Attitudes to exercise and diabetes in young people with type 1 diabetes mellitus: a qualitative analysis. PLoS One. 2015 Oct;14;10(10):e0137562.