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PHYSICAL EFFORT CAPACITY AND GLYCEMIC CONTROL IN TYPE 1 DIABETES PACIENTS

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ABSTRACT. Introduction. Physical activity may be considered as an efficient and relatively inexpensive non-pharmacological tool for diabetes treatment, added to the usual insulin administration. **Objectives.** The aim of this study was to investigate the possibility to improve physical effort capacity in type 1 diabetes patients, maintaining an adequate glycemic control. **Materials and methods.** The subjects included in this study were three patients (two men and one woman), aged 19-22, diagnosed with type 1 diabetes. The study was conducted at a fitness studio in Cluj-Napoca for a period of 6 weeks with a frequency of 3 sessions per week, 60 minutes each session. Aerobic exercise capacity was assessed before the physical exercises program (CAEi) began and at the end of the program (CAEf). The arithmetic mean of subjects' glycemic counts recorded each day for each of the four moments of glycemic control was calculated: morning, noon, evening and bedtime (the week before the physical exercises program, after 3 weeks, after 6 weeks and the week after the physical exercises program was completed). **Results.** In our study, with regular physical exercise, we managed to increase aerobic exercise capacity by maintaining satisfactory glycemic control in patients with type 1 diabetes. **Conclusions.** The aerobic exercise capacity has increased in patients with type 1 diabetes who have undergone a regular exercise program. Glycemic control can be maintained at an appropriate level during a regular exercise program in patients with type 1 diabetes.

Keywords: *physical activity, physical effort capacity, glycemic control, type 1 diabetes.*

REZUMAT. Capacitatea de efort fizic și controlul glicemic la pacienții cu diabet de tip 1. Introducere. Activitatea fizică poate constitui o metodă non-farmacologică eficientă și necostisitoare pentru tratamentul pacienților cu diabet de tip 1, concomitent cu administrarea de insulină. **Obiective.** In acest studiu

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am investigat dacă putem crește capacitatea de efort fizic la pacienții cu diabet de tip 1, menținând, în același timp, un control glicemic adecvat**. Materiale și metode**. În studiu au fost incluși trei pacienți cu diabet de tip 1, (doi bărbați și o femeie), cu vârste cuprinse între 19-22 de ani. Programul de exerciții fizice s-a desfășurat într-o sală de fitness din Cluj-Napoca, pe parcursul a 6 săptămâni, de 3 ori pe săptămână, 60 de minute fiecare ședință. Capacitatea aerobă de efort fizic a fost evaluată înainte și după cele 6 săptămâni de exerciții fizice. S-au măsurat glicemiile pe tot parcursul studiului, in fiecare zi, dimineața, la amiază, seara și înainte de culcare. S-au calculat mediile glicemiilor pentru fiecare moment al zilei, pentru săptămâna de dinainte de începerea programului de exerciții fizice, după trei săptămâni, după 6 săptămâni și în săptămâna de după terminarea programului de exerciții fizice. **Rezultate**. Rezultatele studiului arată că s-a reușit creșterea capacității de efort fizic aerob la toți pacienții incluși în studiu, menținând, în același timp, un control glicemic adecvat. **Concluzii**. Capacitate de efort fizic aerob a crescut la pacienții cu diabet de tip 1 care au urmat un program regulat de exerciții fizice. Controlul glicemic a fost menținut la un nivel adecvat pe tot parcursul programului de exerciții fizice, la pacienții cu diabet de tip 1.

Cuvinte cheie: *activitate fizică, capacitate de efort fizic, control glicemic, diabet de tip 1.*

Introduction

Type 1 diabetes (T1D) is a chronic disease that requires intensive effort on the part of the person with diabetes and caregivers. Exercise training is known to induce several benefits by reducing inflammation, improving antioxidant defenses (Farinha et al., 2017), improving glycemic control, delay cardiovascular complications and increase overall well-being (Nadella et al., 2017). In this context, exercise training may be considered as an efficient and relatively inexpensive non-pharmacological tool for diabetes treatment, added to the usual insulin administration. Unfortunately, as Yates and Davies (2017) stated, physical activity is an underused therapy and most people with T1D do not reach the recommended levels of physical activity due to concerns regarding hypoglycemic episodes (Moser et al., 2017). Several studies concluded that patients with type 1 diabetes have poorer exercise capacity than their aged-matched nondiabetic individuals (Hagglund et al., 2012; Peltonen et al., 2012; Koponen et al., 2013; Rissanen et al., 2015). On the other hand, there are studies prooving that type 1 diabetes pacients can successfuly compete in ultramarathon races with satisfactory glycemic control (Belli et al., 2017).

Objectives

The aim of this article is to study the means to improve physical effort capacity while maintaining an adequate glycemic control in patients with T1D.

Materials and methods

The study was conducted at a fitness studio in Cluj-Napoca for a period of 6 weeks with a frequency of 3 sessions per week, 60 minutes each session. The selection criteria were as follows: patients without effort contraindications; patients who meet the number of daily calories required by doctor prescription; patients following an insulin regimen with 4 injections per day (three ultra-fast and one long-acting insulin).

Subjects included in the study

The subjects included in this study were 3 students (two men and one woman), aged 19-22, diagnosed with type 1 diabetes.

Table 1. Subjects included in the study

Subject 1	Subject 2	Subject 3
Patient data: - Age: 20 years old - Sex: F - Weight: 60 kg **History of the disease:** - Starting date: March, 2011; **Symptoms:** - polyuria, polydipsia, increased fatigue; **Lifestyle:** - Diet: 2000 calories / day, divided in 3 main meals and 3 snacks;	**Patient data:** - Age: 19 years old - Sex: M - Weight: 72 kg **History of the disease:** - Starting date: October, 2007; **Symptoms:** - polyuria, polydipsia, increased fatigue; **Lifestyle:** - Diet: 2200 calories / day, divided in 3 main meals and 3 snacks;	**Patient data:** - Age: 22 years old - Sex: M - Weight: 84 kg **History of the disease:** - Starting date: August, 2010; **Symptoms:** - polyuria, polydipsia, increased fatigue; **Lifestyle:** - Diet: 2100 calories / day, divided in 3 main meals and 3 snacks;

The time points studied

Aerobic exercise capacity was assessed before the physical exercises program (CAEi) began and at the end of the program (CAEf).

The week before the physical exercises program started: the arithmetic mean of subjects' blood glucose was calculated each day of the week prior to the beginning of the kinetotherapeutic program (G0), for each of the four moments of the glycemic control: morning, noon, evening and bedtime.

After 3 weeks of physical exercises program: the arithmetic mean of subjects' blood glucose was calculated daily for the first 3 weeks of kinetotherapeutic program (G3) for each of the four moments of glycemic control: morning, noon, evening and bedtime.

After 6 weeks of physical exercises program. The arithmetic mean of subjects' glycemic counts recorded each day during the last 3 weeks of physical exercises program (G6) for each of the four moments of glycemic control was calculated: morning, noon, evening and bedtime.

The week after the physical exercises program was completed: the arithmetic mean of the subjects' glycemic counts was calculated each day of the week after the physical exercises program (Gppk) for each of the four moments of glycemic control: morning, noon, evening and bedtime.

Methods

Assessment of aerobic exercise capacity

The aerobic exercise capacity (AEC%) was evaluated indirectly by the Astrand-Ryhming method by performing a submaximal 6 minute exercise on a cycloergometer at 60 rotations/minute with a load of 2.1 W/kg body, maintained constant throughout the test. Thus, the maximum oxygen consumption in absolute value (VO2 max), expressed in ml/minute, was obtained. The unit value of VO2 max (VO2 max / G) was compared to the ideal unit value of VO2 max, obtained by the following calculation: 110-0.4xG for male subjects and 91.6-0.332xG for female subjects. Depending on the percentage obtained, the aerobic exercise capacity was assessed (Ionescu in Dragan, 2002). Values were expressed as a percentage.

Measuring blood glucose

Blood glucose measurement was performed with the Accu-Chek® Active Accu (Accu-Chek, n.d.) meter using the Accu-Chek® Softclix punch (Accu-Chek, n.d.) and was expressed in ml/dl.

The kinetotherapeutic program

The kinetotherapeutic program was conducted over 6 weeks, 3 sessions/ week, 60 minutes/ session, from 10.00-11.00 a.m. and included stretching exercises, exercises to improve aerobic exercise capacity, isometric and isotonic exercises. To avoid hypo or hyperglycemia, blood glucose values were measured before, at the middle and at the end of the session. If the blood glucose was above 250 mg/dl before the session, it was postponed until the blood glucose was rectified; if the blood glucose was below 100 mg / dl, the subject consumed 10g of fast or slowly absorbable carbohydrates.

At the beginning of the first session, the subjects were explained the role of the exercises to be performed on the body.

Insulin administration

Subject 1 - NovoRapid: Breakfast (18u), Lunch (18u), Dinner (18u); Levemir: at bedtime (20u).

Subject 2 - NovoRapid: Breakfast (20u), Lunch (20u), Dinner (20u); Lantus: at bedtime (20u).

Subject 3 - Apidra: breakfast (19u), lunch (20u), dinner (19u); Levemir: at bedtime (19u).

Starting with week 4, insulin doses of 2 units were reduced to all subjects.

Results

Table 2 presents the baseline values of the aerobic exercise capacity of subjects, in percentage, based on body weight and heart rate.

Table 2. Initial rates of effort aerobic capacity, expressed as a percentage

	Weight	Hart rate	CAEi
Subject 1	60 kg	144 bpm	66,26%
Subject 2	72 kg	138 bpm	63,27%
Subject 3	84 kg	168 bpm	46,74%

Table 3 presents final values of the aerobic exercise capacity of the subjects, in percentage, based on body weight and heart rate.

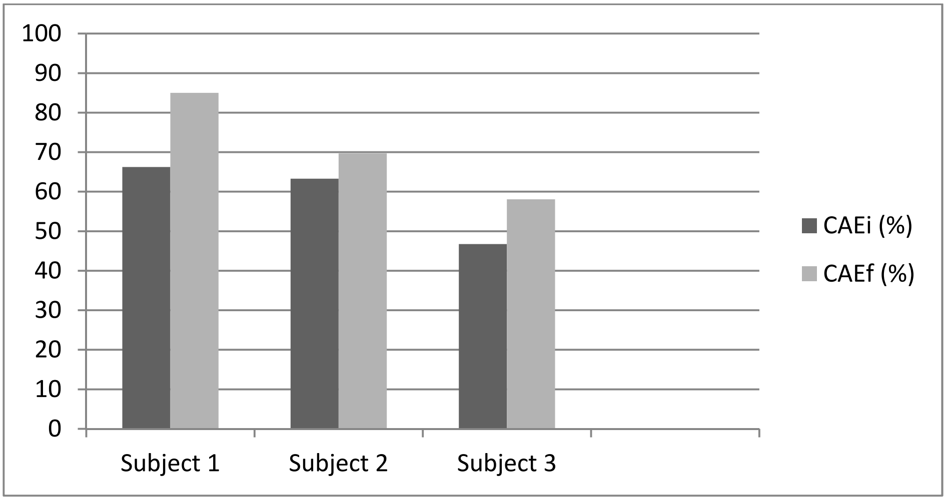
Table 3. Final aerobic exercise capacity, expressed as a percentage

	Weight	Hart rate	CAEf
Subject 1	61 kg	126 bpm	85%
Subject 2	70 kg	132 bpm	69,68%
Subject 3	81 kg	150 bpm	58,06%

Table 4 presents in comparison the initial and final values of the aerobic exercise capacity of the subjects, in percent, based on body weight and heart rate.

Table 4. Initial and final strength of aerobic exercise capacity, expressed as a percentage

	CAEi	CAEf
Subject 1	66,26%	85%
Subject 2	63,27%	69,68%
Subject 3	46,74%	58,06%



Graph 1. Initial and final aerobic exercise capacity, expressed as a percentage

Table 5 shows the mean glycemic values for subject 1 during the study.

Table 5. Median glycemic values for subject 1

	G0	G3	G6	Gppk
Morning	175 mg/dl	168 mg/dl	159 mg/dl	163 mg/dl
Noon	212 mg/dl	189 mg/dl	175 mg/dl	179 mg/dl
Evening	192 mg/dl	184 mg/dl	178 mg/dl	183 mg/dl
Bedtime	181 mg/dl	177 mg/dl	169 mg/dl	175 mg/dl

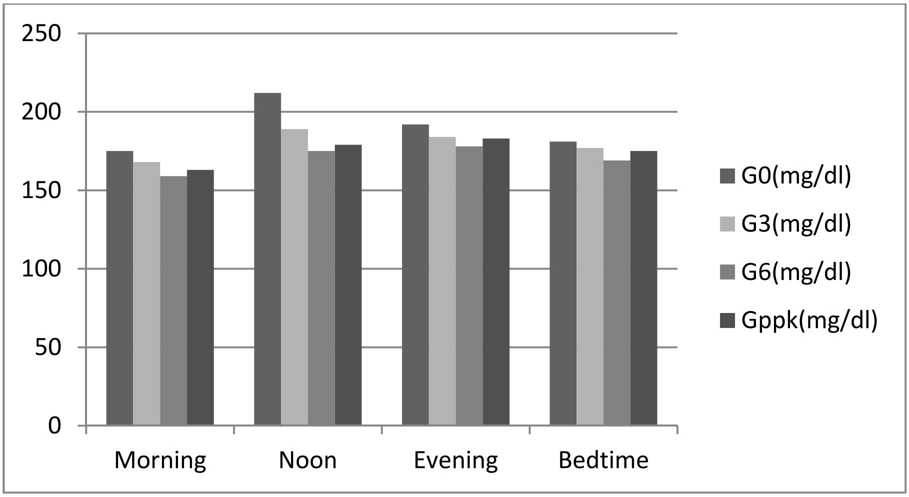


Figure 2. Comparison of mean glycemic values for subject 1

Table 6 shows the mean glycemic values for subject 1 during the study.

Table 6. Median glycemic values for subject 2

	G0	G3	G6	Gppk
Morning	159 mg/dl	150 mg/dl	138 mg/dl	143 mg/dl
Noon	185 mg/dl	166 mg/dl	154 mg/dl	158 mg/dl
Evening	180 mg/dl	175 mg/dl	167 mg/dl	171 mg/dl
Bedtime	178 mg/dl	171 mg/dl	164 mg/dl	168 mg/dl

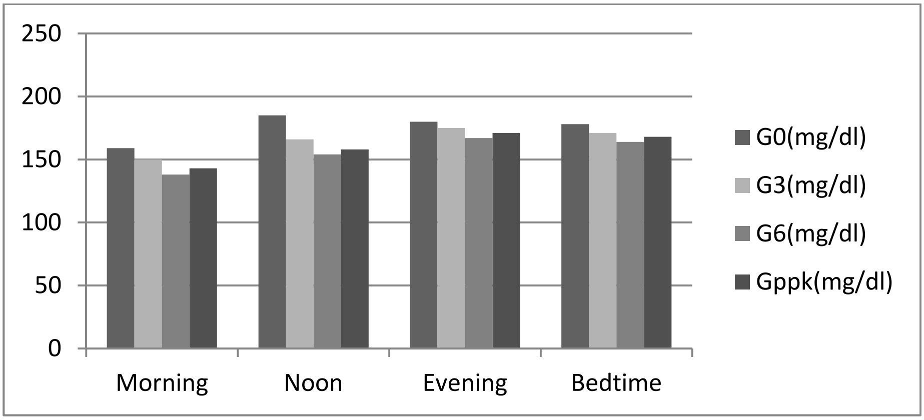


Figure 3. Comparison of mean glycemic values for subject 2

Table 7 shows the mean glycemic values for subject 1 during the study.

Table 7. Median glycemic values for subject 3

	G0	G3	G6	Gppk
Morning	208 mg/dl	195 mg/dl	181 mg/dl	185 mg/dl
Noon	193 mg/dl	170 mg/dl	162 mg/dl	166 mg/dl
Evening	199 mg/dl	186 mg/dl	168 mg/dl	175 mg/dl
Bedtime	224 mg/dl	201 mg/dl	189 mg/dl	190 mg/dl

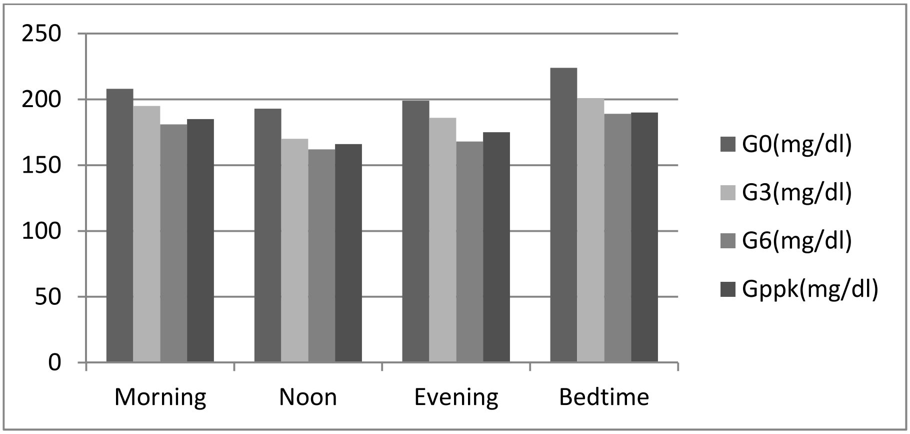


Figure 4. Comparison of mean glycemic values for subject 3

Discussion

Several studies concluded that many patients with type 1 diabetes experience exercise-induced late-onset hypoglycemia (Basu et al., 2014). This might be harmful, especially because of being unaware: patients may unconsciously experience hypoglycemia during sleep. Physical activity during the daytime accelerate the risk of nocturnal hypoglycemia to about 30–40% (Taplin et al., 2010; Iscoe, Corcoran & Riddell, 2008; Maran et al., 2010). Therefore, in order to avoid any episodes of night hypoglycemia, exercise sessions took place between 10.00-11.00 a.m.

During weeks 2 and 3, subjects 1 and 2 had few episodes of mild hypoglycaemia (60-80 mg/dl) treated immediately by ingesting 10g of rapidly absorbing carbohydrates. Moderate post-exercise hypoglycaemia is very common in patients with type 1 diabetes, as concluded by Shetty et al. (2016).

Tsalikian et al. (2015) reported that during 60 min of moderate intensity exercise, 82% of participants experienced at least a 25% decrease in glucose compared to pre-exercise.

Starting with week 4, insulin doses were reduced with 2 units to all subjects and the evolution of glycemic values continued for 3 weeks further. The need to adjust the insulin dose in type 1 diabetic patients performing physical exercise is demonstrated by numerous studies (Rabasa-Lhoret, Bourque, Ducros & Chiasson, 2001; Yardle, et al., Cryer, 2008; Cryer, 2010) There was a continuous improvement in blood glucose levels, a sign that the body responded well to lower doses of insulin administered.

After completing the kinetotherapeutic program, the evolution of glycemic values was monitored in the absence of physical exercise, knowing that regular physical activity is needed in order maintain insulin sensitivity. A slight increase in glycemic levels was observed in all subjects, a sign that the body's sensitivity to insulin began to decline, a fact found in many other studies that concluded that moderate and high intensity physical exercises have the potential to improve short-term glycemic control (Cockcroft et al., 2017).

In our study, with regular physical exercise, we managed to increase aerobic exercise capacity by maintaining satisfactory glycemic control in patients with type 1 diabetes, but further studies are necessary because it is still uncertain whether reduced work capacity in young subjects with T1D results from poor oxygenation (Levy et al., 2008), low muscular capillarization (Kivelä et al., 2006), or poor metabolic control, depending on low regular physical activity (Krause, Riddell & Hawke, 2011).

Conclusions

The aerobic exercise capacity has increased in patients with type 1 diabetes who have undergone a regular exercise program.

Glycemic control can be maintained at an appropriate level during a regular exercise program in patients with type 1 diabetes.

REFERENCES

Basu, R. et al. (2014). Exercise, hypoglycemia and type 1 diabetes. *Diabetes Technol Ther*, *16, 331-7*.

Belli, T. et al. (2017). Glycemic Control and Muscle Damage in 3 Athletes With Type 1 Diabetes During a Successful Performance in a Relay Ultramarathon: A Case Report. *Wilderness Environ Med, 28(3), 239-245.*

Cockcroft, E.J. et al. (2017). High-intensity interval exercise and glycemic control in adolescents with type one diabetes mellitus: a case study. *Physiol Rep, 5(13).*

Cryer, P.E. (2008). The barrier of hypoglycemia in diabetes. *Diabetes, 57, 3169– 3176.*

Cryer, P.E. (2010). Hypoglycemia in type 1 diabetes mellitus. *Endocrinol Metab Clin North Am, 39, 641–654.*

Farinha, J.B., Krause, M., Rodrigues-Krause, J., Reischak-Oliveira, A. (2017). Exercise for type 1 diabetes mellitus management: General considerations and new directions. *Med Hypotheses, 104, 147-153.*

Hagglund, H. et al. (2012). Cardiovascular autonomic nervous system function and aerobic capacity in type 1 diabetes. *Front Physiol, **3**, 356.*

Ionescu, A. (2002). Capacitatea de efort. În Drăgan, I. Medicina Sportivă. (157-170). București, Ed. Medicală.

Iscoe, K.E., Corcoran, M. & Riddell, M.C. (2008). High rates of nocturnal hypoglycemia in a unique sports camp for athletes with type 1 diabetes: lessons learned from continuous glucose monitoring systems*. Can J Diabetes, 3,:182–189.*

Kivelä, R. et al. (2006). Effects of experimental type 1 diabetes and exercise training on angiogenic gene expression and capillarization in skeletal muscle*. FASEB J, 20, 1570-1572.* Koponen, A. et al. (2013). Low total hemoglobin mass, blood volume and aerobic capacity in men with type 1 diabetes*. Eur J Appl Physiol, 113, 1181–1188.*

Krause, M.P., Riddell, M.C. & Hawke, T.J. (2011). Effects of type 1 diabetes mellitus on skeletal muscle: clinical observations and physiological mechanisms. *Pediatr Diabetes, 12, 345–364.*

Levy, B.I. et al. (2008). Impaired Tissue Perfusion. *Circulation, 118, 968.*

Maran, A. et al. (2010). Continuous glucose monitoring reveals delayed nocturnal hypoglycemia after intermittent high-intensity exercise in nontrained patients with type 1 diabetes. *Diabetes Technol Ther, 12, 763–768.*

Moser, O. et al. (2017). Atypical blood glucose response to continuous and interval exercise in a person with type 1 diabetes: a case report*. J Med Case Rep, 11(1), 176.*

Nadella, S., Indyk, J.A., Kamboj, M.K. (2017). Management of diabetes mellitus in children and adolescents: engaging in physical activity. Transl Pediatr, 6(3), 215-224.

Peltonen, J. et al. (2012). Alveolar gas exchange and tissue deoxygenation during exercise in type 1 diabetes patients and healthy controls. *Respir Physiol Neurobiol, 181, 267–276.*

Rabasa-Lhoret, R., Bourque, J., Ducros, F. & Chiasson, J.L. (2001). Guidelines for premeal insulin dose reduction for postprandial exercise of different intensities and durations in type 1 diabetic subjects treated intensively with a basal-bolus insulin regimen (ultralente-lispro). *Diabetes Care, 24, 625–630.*

Rissanen, A.P., Tikkanen, H.O., Koponen, A.S., Aho, J.M. & Peltonen, J. E. (2015). Central and Peripheral Cardiovascular Impairments Limit VO2 peak in Type 1 Diabetes. *Med Sci Sports Exerc, 47, 223–230.*

Shetty, V.B. et al.(2016). Effect of exercise intensity on glucose requirements to maintain euglycemia during exercise in type 1 diabetes*. J Clin Endocrinol Metab, 101, 972–80.*

Taplin, C.E. et al. (2010). Preventing post-exercise nocturnal hypoglycemia in children with type 1 diabetes. *J Pediatr, 157, 784–78.*

Tsalikian, E.N. et al. (2005). Impact of exercise on overnight glycemic control in children with type 1 diabetes mellitus*. J. Pediatr, 147, 528–534.*

Yardley, J.E. et al. (2013). Insulin pump therapy is associated with less post-exercise hyperglycemia than multiple daily injections: an observational study of physically active type 1 diabetes patients*. Diabetes Technol Ther.*

Yates, T. & Davies, M.J. (2017). Physical activity and Type 1 diabetes: an underused therapy. *Diabet Med.*

Accu-Chek.(n.d.). *Dispozitiv de înţepare Accu-Chek Softclix* [Image]. Retrieved from *http://www.accu-chek.ro/produs/7-Accu-Chek-Softclix.html*

Accu-Chek.(n.d.). *Glucometrul Accu-Chek Active* [Image].Retrieved from *http://www.accu-chek.ro/produs/5-Accu-Chek-Active.html*