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A new table for prevention of hypoglycaemia during physical activity in type 1 diabetic patients

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► Résumé

Une nouvelle table de prévention des hypoglycémies lors de l'activité physique chez les patients diabétiques de type 1

Objectif

La combinaison de l'ajustement d'un traitement à l'insuline avec une approche diététique adéquate permet une bonne pratique de l'exercice physique chez les patients diabétiques. Cette approche est reconnue comme étant une stratégie importante dans la gestion de la maladie chez ces patients. En particulier, le patient joue un rôle primordial en mesurant ses glycémies lui-même durant l'activité physique et en utilisant ces données dans le but d'améliorer ses performances et de diminuer le risque du nombre d'hypoglycémies. L'objectif principal de cette étude est de comparer, chez ces patients (n = 67), différentes options thérapeutiques avec ou sans compensation en hydrates de carbone et/ou avec ou sans diminution des doses d'insuline pendant l'activité physique afin de prévenir les hypoglycémies pendant et après l'exercice.

Méthodes

Soixante-sept patients diabétiques de type 1 ont été répartis dans quatre catégories de traitement selon quatre stratégies prévenant les épisodes d'hypoglycémie, avec ou sans compensation d'hydrates de carbone et/ou avec ou sans une réduction du dosage de l'insuline. Le protocole comprend 7 disciplines différentes et 9 sous-groupes selon trois différentes durées (\ll 20 min, 20-60 min., > 60 min.) et trois degrés d'intensité (\ll 60 % des pulsations maximales, 60-75 % et > 75 %).

Résultats

Notre étude montre qu'en remplaçant de façon adéquate les hydrates de carbone durant l'activité physique, il est possible de prévenir presque toutes les hypoglycémies indépendamment des ajustements des dosages d'insuline. Par ailleurs, la corrélation entre les compensations d'hydrates de carbone et le nombre d'hypoglycémies est significative alors que la diminution du dosage d'insuline ne l'est pas.

Conclusion

La prise adéquate d'hydrates de carbone pendant et après l'exercice physique semble être la mesure la plus importante pour prévenir les hypoglycémies. Cependant, l'ajustement du dosage de l'insuline ne joue pas un rôle si important. Une diminution de 20 à 30 % semble raisonnable uniquement pour l'exercice de longue durée (> 60 min.). Finalement, un nouveau tableau simple d'utilisation en clinique est proposé pour une activité physique d'intensité et de durée différentes.

► Abstract

A new table for prevention of hypoglycaemia during physical activity in type 1 diabetic patients

JJ Grimm, J Ybarra, C Berné, S Muchnick, A Golay

Objective

The ability to adjust both insulin and nutrition to allow safe participation in physical activity and high performance has recently been recognized as an important management strategy in these patients. In particular, the important role played by the patient in self-monitoring blood glucose during physical activity and then using these data to improve performance and decrease hypoglycaemias is now fully accepted. The primary objective of this study is to compare different therapeutic options in exercising Type 1 diabetic patients (n = 67) with or without CHO compensation and/or with or without insulin dosage reduction in order to prevent hypoglycaemias during and after exercise.

Methods

Sixty-seven type 1 diabetic patients were aggregated into four treatment categories according to four strategies to prevent hypoglycaemia episodes, with or without carbohydrate compensation and/or with or without insulin dosage reduction. The protocol included 7 different disciplines and 9 subgroups according to 3 different durations (\ll 20 min., 20-60 min., $>$ 60 min.) and 3 intensity degrees (\ll 60% of Maximal Heart Rate, 60-75% and $>$ 75%).

Results

Our study shows that by replacing adequately the carbohydrates during the practice of physical exercise it is possible to prevent almost all hypoglycaemia episodes, independently of the insulin dosage adjustments. Furthermore, the amount of extra-carbohydrates correlates well with the number of hypoglycaemia while the decrease in insulin dosage does not.

Conclusion

Adequate carbohydrate replacement during and after exercise seems to be the most important measure to prevent hypoglycaemia. However, the insulin dosage adjustment does not play such an important role. A decrease from 20 to 30% seems reasonable only for a long duration exercise ($>$ 60 min.). Finally, a new user-friendly table for prevention of hypoglycaemia is proposed for physical activity of different intensity and duration.

Mots clés : *Activité physique , Hypoglycémies , Hydrates de carbone , Traitement insulinique , Diabète*

Keywords: *Physical activity , Hypoglycaemia , Carbohydrate , Insulin treatment , Diabetes*

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All levels of physical activity, including leisure activities, recreational sports, and competitive professional performance, can be performed by people with type 1 diabetes who do not have complications and are in good blood glucose control. The ability to adjust both insulin and medical nutrition therapy to allow safe participation and high performance has recently been recognized as an important management strategy in these individuals [1]. In particular, the important role played by the patient in collecting self-monitored blood glucose data of the response to physical activity and then using these data to improve performance and enhance safety is now fully accepted [2 et 3].

Hypoglycaemia, which can occur during, immediately after, or many hours after physical activity, can be avoided. This requires that the patient have both an adequate knowledge of the metabolic and hormonal responses to physical activity and well-tuned self-management skills. The increasing use of intensive insulin therapy has provided patients with the flexibility to make appropriate insulin dose adjustments for various activities [4 et 5].

Despite the well known hypoglycaemic effect of acute exercise [6], the consequences of chronic exercise on glycaemia control in Type 1 diabetes mellitus are not so unanimously beneficial as they prove to be in Type 2 Diabetes mellitus [7, 8, 9, 10, 11, 12, 13, 14 et 15]. While some studies report long term benefits in T1DM patients who exercise regularly [3, 4, 5, 6, 7, 8, 9, 10, 11, 12, 13, 14, 15 et 16] others fail to do so [17, 18, 19 et 20]. Moreover, in these patients, long-term glycaemia control is regularly challenged by the succession of hypoglycaemia and counter regulatory hyperglycemias during and after exercise. Therefore, maintaining a good metabolic control, all over exercise periods, is still a challenge for many diabetic patients practising sport.

The strategies proposed in the specialized literature are often difficult to interpret and properly implement in a precise practical situation. It is not unusual to find excellent advice about carbohydrate replacement given by the nutritionist and insulin dosage adjustments counselling given by the diabetologist in a separate chapter without any reference to the link between the two. Several publications describe precisely the carbohydrate needs and insulin adjustments in well defined exercise sessions performed in a laboratory environment [1, 21, 22 et 23]. Indeed these examples provide limited help to the random exercising diabetic person. Such persons exercise at different times in the day, with their own varying intensity and in the sport of their choice. More recently a group [24] with an important practical experience stressed the importance of good extra-carbohydrate compensation during exercise. Most of the total amount of carbohydrate is consumed during the first 40 minutes of exercise [25]. It seems clear that inadequate CHO replacement is the major determinant of hypoglycaemia appearing during and after exercise. Furthermore, it could be dangerous to try to adjust only the insulin dosage and not replacing the CHO during exercise. Many patients trying to avoid weight gain adopt

the latter strategy and are at high risk of hypoglycaemia.

Would it be wise to advise generally to compensate for carbohydrate and to decrease the insulin dosage in some selected situations only?

The goal of the study is to compare different therapeutic options in exercising Type 1 diabetic patients with or without CHO compensation and with or without insulin dosage reduction in order to prevent hypoglycaemias during and after exercise.

Finally, a user-friendly algorithm (easily applicable in clinic) is proposed for physical activity of different intensity and duration.

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► **Methods and subjects**

Patients (N = 67) were selected among those Type 1 Diabetes mellitus (T1DM) patients followed on regular basis at the Service of Therapeutic Education for Chronic Diseases and being admitted once a year (HUG) for regular diabetes check-up (Protocol #1) or attending the diabetic sports summer camps (Protocol 2). Most patients underwent both protocols.

Inclusion criteria were: a) men and women aged 18-35 years old, b) presence of T1DM for more than five and less than ten years, c) absence of any detectable micro-angiopathic complications, d) absence of any detectable macro-angiopathic complications-all patients underwent a stress test prior to being eligible for the study-, e) acceptable degree of metabolic control (HbA1c \leq 7.5%), f) absence of any acute hypo/hyperglycaemic episode motivating hospital admission during the year prior to entering the study, g) absence of any medical and/or psychiatric condition contraindicating the regular practice of moderate-intensity aerobic exercise. A written informed consent was obtained from every single subject participating in the study and the Institution's ethical committee approved both protocols.

► **Protocol 1**

Sixty-seven T1DM patients performed a long-lasting (> 4 hours) mild-intensity exercise (\ll 60% of maximal heart rate) starting 1 hour after breakfast. The aim of this protocol is to compare different therapeutic options in exercising T1DM patients. Patients were aggregated into four treatment categories — according to their own adopted therapeutic strategy to prevent hypoglycaemic episodes.

Group A: included 18 patients who compensated with 10-20 g of carbohydrate for each hour of exercise without modifying the regular insulin doses.

Group B: included 17 patients who compensated with 10-20 g of carbohydrate for each hour of exercise while reducing their daily insulin dose by more than 10%.

Group C: included 17 patients who did not compensate for exercise with extra-carbohydrates but reduced their daily insulin dose more than 10%.

Group D: included 15 patients, which neither compensated for exercise with extra-carbohydrates nor reduced their daily insulin dose.

Hypoglycaemia was defined as the development of classic adrenergic and neuroglycopenic symptoms together with capillary blood glucose lower than 2.8 mmol/l (50 mg/dl).

The extra CHO given before and during exercise were designed after the available data from the literature [26 et 27] and implemented by the medical team. Insulin dosage changes in groups B and C were as well implemented by the medical team according to a simple -10% algorithm. The insulin dose decrements concerned both the rapid acting and the intermediate acting (NPH) insulin injections.

The insulin regimen of the patients was two NPH injections in addition to 3 pre-prandial rapid acting insulin doses.

► Protocol 2

The identical study population underwent this protocol. The aim of this second protocol is to compare different therapeutic options according to exercise intensity and duration. The protocol included 7 different disciplines (walking, jogging, bicycling, tennis, football, basketball and volleyball) of different duration and intensity degrees. Every single patient was instructed to compensate with supplementary carbohydrates and/or eventually reducing their daily insulin doses whenever engaging in prolonged physical exercises (> 60 minutes).

Exercise intensity was classified according to their effect on patient's heart rate. Assuming that the theoretical maximal heart rate (MHR) was 220 bpm – patient's age [28], the percentage of MHR obtained could be further assessed for each single patient. Hence, three categories of exercise intensity were defined: << 60% of MHR, between 60-75% of MHR and > 75% of MHR.

Exercises were also classified in three categories depending on duration as follows: << 20 minutes, 20-60 minutes et > 60 minutes. Additionally, glycaemia prior to engaging into exercise had to be below 15 mmol/l with negative ketonuria.

The extra CHO given before and during exercise were designed after the available data from the literature [26 et 27] and implemented by the medical team who also advised on the insulin dosage changes according to a simple -10% algorithm.

► Statistical analyses

Data are expressed as means ± SEM (95% confidence interval) and were analysed with the StatView version 5.0 software package (SAS Institute Inc. San Francisco, CA) $p < 0.05$ was considered statistically significant. Statistical analysis was performed using ANOVA for repeated measurements.

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► Results

► Protocol 1

The main anthropometrics and biochemical characteristics of the study population are depicted in **Table I**.

Age, body weight, body mass index, insulin dosage (units/kg), HbA_{1c} and diabetes duration were comparable for each group. Additionally, capillary blood glucose levels were similar both prior to and 2 hours after ending the exercise sessions despite the four different treatment strategies.

Interestingly, Group A and B, where patients ingested the recommended extra CHO before, during and after exercise show significantly ($p \ll 0.01$) less hypoglycaemias than group C and D where the patients exercised without substantial extra CHO replacement during exercise (Fig 1).

Daily insulin dose reduction for groups B and C was $20 \pm 2\%$ and $25 \pm 3\%$, respectively. Extra-carbohydrate consumption averaged 18 ± 1 g/patient and 19 ± 2 g/patient in groups A and B, respectively.

No statistically significant correlation was found between the daily insulin dose decrements and the severity and frequency of hypoglycaemic episodes. Moreover, no correlation was either detected between the capillary blood glucose level prior to exercise and the severity and frequency of hypoglycaemic episodes. On the contrary a statistically significant correlation was detected between the amount of extra-carbohydrates consumed during exercise and the glycaemia 2 hours after exercise ($p \ll 0.01$).

► Protocol 2

On a total of 265 exercises, 6 hypoglycaemias were found. Four of them appeared in the exercise of high intensity and of long duration in spite of a compensation of carbohydrates and a decrease of the dosage of insulin. Two other hypoglycaemias arose in the group of average but also long-term intensity.

All six hypoglycaemias arose after more than 4 hours after the physical exercise. No correlation was found between the decrease of the dosage of insulin and the number of hypoglycaemias or the gravity. On the other hand, there is a correlation between the glycaemia 2 hours after the physical exercise and the compensations of extra CHO during the physical exercise ($p \ll 0.01$). There is no correlation between the glycaemia before the physical exercise and the degree and the number of hypoglycaemias.

Table II represents the results for the 9 types of physical exercises according to 3 intensities and 3 durations. Only the 259 physical exercises without hypoglycaemias were retained. For every category, the number of physical exercise, average \pm SEM and ranges him(it) extras CHO are represented. For the exercises of more than 60 minutes, the results are expressed in grams per hour (g/h) and for the medium and long intensities exercises, a reduction of $22 \pm 3\%$ and $33 \pm 2\%$ was respectively made.

Table III represents a proposition simplified by extra CHO for each of the categories. For the exercises of weak intensity and of short duration, we do not propose compensation of supplementary CHO. On the other hand, for intense exercises of average and long duration, as well as for exercises of long-term average intensity, we suggest decreasing the doses of total insulin from 20 to 30% and compensating in more with 75-100 g/h. These propositions are only indicative and should remain individual.

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► Discussion

Our results show that by replacing adequately the CHO during the practice of physical exercise it is possible to prevent almost all hypoglycaemia episodes (Fig 1), more or less independently of the insulin dosage adjustments. Furthermore, the amount of extra CHO correlates well with the risk of hypoglycaemia while the decrease in insulin dosage does not. The latter does not mean that insulin adjustments are senseless [1].

If a patient does not decrease the insulin dosage for efforts of long duration he/she will necessarily be obliged to compensate for CHO in the upper range of **Table II**. On the long term this would probably lead to a weight gain.

The extra CHO table has been designed for patients who do not commit overt mistakes in insulin dosage. The table supposes also stable and fairly good metabolic control during the hours before exercise. For efforts of long duration, not decreasing the insulin dosage would mean to exercise in a state of over-insulinisation compared to non diabetic subjects and therefore induce a abnormal high need for extra CHO, beyond the amounts proposed by the table. We and other authors [22, 23, 24, 25, 26 et 27] propose to decrease the insulin dosage acting during and after exercise session of a certain duration and intensity. This can result in a 10 to 80% reduction of the short acting insulins and 20 to 60% of the intermediate acting insulins depending of the timing and duration of the effort.

According to our results, a decrease from 20 to 30% of the insulin dosage seems reasonable for the long-term exercises. To simplify, it also seems that the glycaemia before the physical exercise do not influence the number of hypoglycaemias and hence, we do not propose different tables to compensate for the glycaemia of departure.

However, high blood glucose (> 14.0 mmol/l) and positive urine ketones is a contraindication to exercise because of the metabolic misbalance [1, 22 et 23].

We do not advise the practice of physical exercise —particularly intense exercises — if positive ketonuria is present.

Some patients feel sometimes protected by high starting blood glucose. A simple calculation shows that a blood glucose twice as high as normal corresponds to a store of about 5 g of glucose in the circulation. If we consider that the needs during exercise can be as high as 50 g per hour it is easy to understand that high blood glucose does not assure protection against subsequent hypoglycaemias. Our results confirm that high starting blood glucose (without ketones), do not influence the extra CHO needs and the recommendations. A high starting blood glucose can all the most allow a slightly longer delay between the start of the exercise and the first CHO snack.

We conclude that adequate CHO replacement during and after exercise seems to be the most important measure to prevent hypoglycaemia.

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