ORIGINAL PAPERS

DIABETES AND DIVING: CAN THE RISK OF HYPOGLYCAEMIA BE BANNED ?

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In November 1995 seven insulin dependent diabetics and an equal number of matched non-diabetics went out to challenge the opinion of several diving related authorities that insulin dependent diabetics, due to their unpredictable changes in blood glucose levels, should not have a place in the sub-aquatic realm.[1-3]

We conducted, in Port Moresby, Papua New Guinea, an international field study, with particular emphasis on safety, to see whether, by adjusting insulin dosage, carbohydrate and water intake, diabetic divers could dive without risk of hypoglycaemia.

Of special interest were the differences in physiological parameters between the diabetics and their non-diabetic counterparts. Due to the possibility of hypoglycaemia under water, a great emphasis was laid on the blood glucose levels, tested following a set regime before and after every dive in addition to the daily routine checks.

In addition to the blood glucose, haematocrit, blood pressure, pulse rate, occurrence of proteinuria, microalbuminuria and ketone bodies were tested frequently before and after the dives.

To compare the underwater activities of both groups within the trial, dive profiles and mean air consumption were recorded with air-integrated dive computers while they underwent a specially designed open water dive course with a IAHD (International Association of Handicapped Divers) diving instructor (Claudia Lutrop, Cairns, Australia). It was a learn-to-dive course because some of the participants were not certified divers. All the participants, including the certified divers, underwent the same training.

This customised dive course could be one of the answers to diving safety for diabetics. Taking E P Joslin's words "Teaching is treatment" literally, a special emphasis was put on educating the non-diabetic "buddy", as well as the diabetic, in basic diabetic knowledge such as blood glucose level testing, symptoms of hypoglycaemia and its proper treatment on land as well as in and under water, administration of glucose gel under water and glucagon injections out of the water.

Apart from that, and the basic theory of diving, the participants were introduced to a "diabetic dive log" (page 63). This extended version of a dive log helps the diabetic diver and his buddy memorise not only the dive related facts but also the diabetes related facts of a particular dive such as insulin intake, blood glucose level before and after the dive and the amount of carbohydrates eaten.

Material and methods

The subjects were seven insulin dependent diabetics (diabetes duration 0.75-10 years, mean 6.1 years), 4 female and 3 male, and seven non-diabetics, 4 female and 3 male. Their ages ranged from 24-41 years, with a mean of 32 years. Knowledge and experience in diving was evenly spread in both groups. Both groups underwent all tests.

Subject inclusion criteria

Insulin dependent diabetes mellitus (IDDM).

Age 18-65.

Diabetes related education and self-managed insulin regime.

At least 9 months on insulin and a minimum of 4 blood glucose measurements a day.

A current HbA1c-level of 5.5-9.0%. HbA1c = the percentage of glycated haemoglobin, which gives an idea of the stability of glucose haemostasis within the last three months.

No history of hypoglycaemic unawareness.

Fitness to dive (using Undersea and Hyperbaric Medical Society (UHMS) or British Sub-Aqua Club (BS-AC) or Gesellschaft für Tauch- und Überdruckmedizin (GTÜM) criteria.

Adequate physical fitness, a normal PWC 150. (PWC = physical working capacity in Watt/kg body weight at a heart rate of 150/minute.)

Subject exclusion criteria

A diabetes unrelated illness which prohibits diving.

A severe hypoglycaemia (loss of consciousness) within the last year.

Evidence of alcohol or drug abuse.

History of a cardiovascular, neurological or psychiatric illness.

Signs of diabetic retinopathy, nephropathy or polyneuropathy.

Pregnancy.

History of decompression sickness.

Inability to equalise the ears.

Pre-study examinations

DIABETES DIVE LOG

Date:___/___/___

Time	BS blood sugar	Bolus short insulin	long insulin Basal rate	CHO	units/CHO	COMMENTS

Dive-Planning:

	-60	-30	0	After
BZ				
CHO				
Lactat				
Haematokrit				
Fluid				

TIME OF ENTRY:	:
= Time after injection:	
of short insulin	min
of long insulin	min
TIME OF EXIT :	:

DIVE:

No.___ Location:_______________________ **shore/boat/wreck/drift/night/cavern/other:**______________

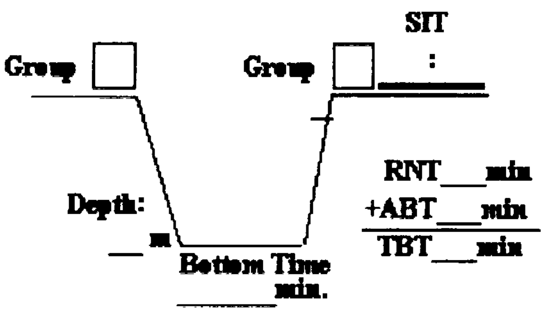
_______________________________________ **Visibility:**_____**m** **Water temp.**_____

Weather:__________ **Sea Condition:**_________ **Suit:**_____________ **Weights:** ______**kg**

BUDDY:________________________________**informed about:**

glucagon ☐ **hypo symptoms** ☐ **glocose-gel** ☐ **emergency** ☐

DIVE PROFILE:



COMMENTS:

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____

____

Accum. Dive Time:____**h**_____**min**

Dive Supervisor:____

Diving medical examination.
Electrocardiogram (ECG).
Exercise ECG (minimum PWC 150).
Chest X-ray.
Lung function tests using a body plethysmograph or resistance testing (Oscillation method).
ENT, dental, neurological and ophthalmological examinations.
Urine testing was done for proteinuria with test strips and sulfosalicylic acid and for ketone bodies with test strips. Microscopy was used to identify urinary sediment and the number of erythrocytes, leucocytes etc.
Full blood count.
Documentation of diabetes history and blood glucose diary.

Methods and test procedures

Blood glucose was measured by the One-Touch II, electro-refractometric method using capillary blood from the fingertip.

Haematocrit was measured using a Mini Centrifuge (Bayer Diagnostics), using 9 microlitres of blood in a glass tube spun at 11,500 /minute for 3.20 minutes.

Blood pressure Riva Rocci method. (The diastolic blood pressure was taken at the point when the Korotkow sounds cease).

Pulse rate ascertained by palpation of the radial pulse.

Daily fluid intake was measured in units of 0.4 l.

Proteinuria, microalbuminuria and ketone bodies were measured with Combur 9 test strip (Boehringer Mannheim).

Dive profiles and air consumption were recorded using MARES Genius (ZH-8 Adaptive algorithm) and SUUNTO Eon (U.S. Navy Diving Tables) air integrated diving computers.

Blood glucose testing when diving

On the day of a dive blood glucose levels were determined one hour, thirty minutes and immediately before the dive. Testing continued after the dive. The first test was immediately after removing diving equipment then at least six further tests were done that day. Late night testing (12-15 hours after the dive) was done to assess the effects of muscle storage repletion.

The diving course

11 dives were carried out by each participant. On the first and second days there was one dive, on the third, fourth and fifth days there were two dives and on the sixth day three dives. Maximum depth/time on the first two days was 12 m/45 minutes. The following days maximum depth/time was 30 m/40 minutes. A three minute safety stop at 3-5 m was carried out after all dives.

Before the first dive the participants were instructed to aim for a minimum blood glucose level of 160 mg/dl (8.96 mmol/l) before entering the water. Although there was no fixed maximum level, a blood glucose level of 220 mg/dl (12.32 mmol/l) was targeted to avoid excessive osmotic diuresis with rising blood sugar levels. To achieve this goal the dose of short acting insulin was reduced by approximately 33%. The adaptation of the insulin dose (short and long acting insulin) for the following day was done on a individual basis considering the development of the blood glucose levels during the previous day of diving. The diabetic dive log was used to plan insulin doses, when similar dives to those in the log were proposed for another day. We could make predictions for the adaptation of insulin and carbohydrate intake from the written experiences in the dive log.

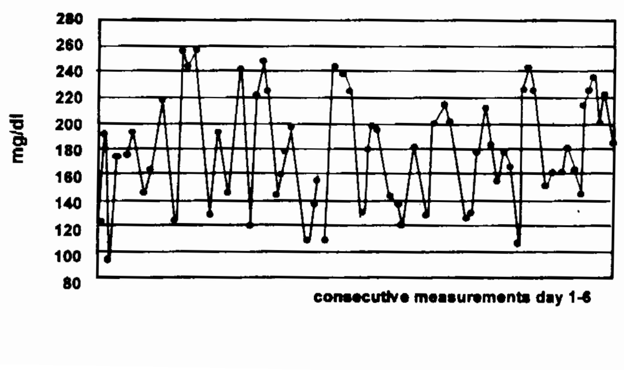
If blood glucose levels dropped during the three measurements before immersion (minus 60 min, minus 30 min. prior to the dive) the subjects were told to eat at least one unit of carbohydrate (1 unit=12 g carbohydrate), even when the set minimum limit of 160 mg/dl (8.96 mmol/l) had been exceeded.

The blood glucose levels before and after the dives in the non-diabetic control group were all within the physiological margins of 60-120 mg/dl (3.36-6.72 mmol/l).

Figure 1 shows the mean values of the blood glucose levels of all diabetics at the same times during the study (before, during and after the dives). It shows that on one hand the overall goal of no severe hypoglycaemia and on the other hand a sufficient blood glucose level before

FIGURE 1

MEAN BLOOD GLUCOSE LEVELS OF 7 DIABETIC DIVERS MEASURED AT THE SAME TIMES ON DAYS 1 (AT LEFT) TO 6



the dives was achieved.

Figures 2 and 3 show the daily doses of insulin (short and long acting) had to be reduced due to the higher energy consumption during the dives as well as the need for higher blood glucose levels before diving and for the prevention of post-exercise hypoglycaemia.

Figure 4 shows that, in addition to the reduction in insulin intake, the daily carbohydrate intake rose significantly during the course. The rise in carbohydrate intake was mostly due to a rise in the daily amount of exercise while diving. Because of the exercise induced higher levels of insulin receptors, especially in the muscle tissues, the amount of insulin in the body was more efficient (falling insulin intake) therefore a higher carbohydrate levels before and after exercise was needed. The carbohydrates were needed after the dive to counter the risk of hypoglycaemia in the phase of muscle glycogen storage repletion which can take up to 12-15 hours.

Due to the higher blood glucose, before and during the dives, with levels above the kidney threshold causing a additional diuresis, the haematocrit levels were significantly higher in the diabetic divers than in the non-diabetic group. When the diabetics drank approximately 1.5-2.0 l, at not more than 1 l an hour, before the first dive of every day this difference did not occur.

The increased mean air consumption of the diabetic subjects (19.7 l/minute) compared with the non-diabetic group (15.8 l/minute) is probably due to there being more experienced divers in the non-diabetic group.

During the whole trial there was no incidence of micro- or macroalbuminuria or ketonuria among the diabetic participants.

During the whole trial no emergency glucose was needed. The emergency glucose dummy was only used in training exercises.

FIGURE 2

MEAN LONG-ACTING INSULIN DOSES FOR 7 DIABETIC DIVERS ON DAYS 1 TO 6

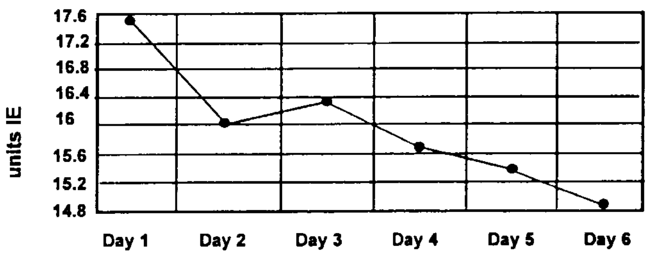


FIGURE 3

MEAN SHORT-ACTING INSULIN DOSES FOR 7 DIABETIC DIVERS ON DAYS 1 TO 6

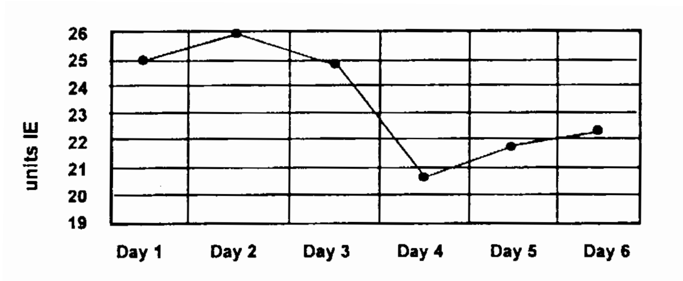
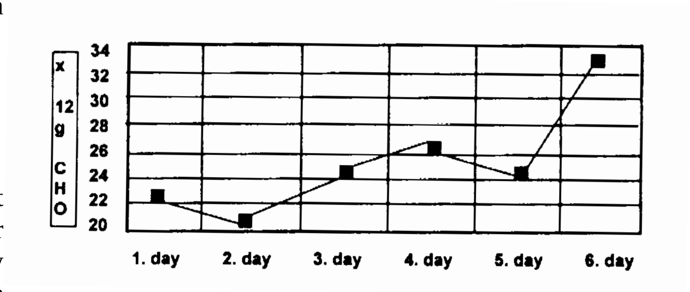


FIGURE 4

MEAN CARBOHYDRATE INTAKE, IN PORTIONS OF 12 g, FOR 7 DIABETIC DIVERS ON DAYS 1 TO 6



Conclusions

The results of this field study verified the fact that the danger of hypoglycaemia for a diver with IDDM in or under water while scuba diving can be minimised by training, experience and following a number of simple rules.[4] These are detailed below.

No scuba diving with manifestations of the complications of diabetes (retinopathies, polyneuropathies, nephropathies etc.).

Limited diving certification (one year), with renewal based on a diving medical and study of the diabetic dive log.

At least one non-diabetic buddy with sufficient knowledge of emergency procedures (blood glucose measurement and glucose administration).

Emergency glucose rations and glucagon in watertight container in the buoyancy compensating device (BCD).

At least three blood glucose tests before the dive (60 minutes before, 30 minutes before and just before the dive) and another immediately after the dive.

A blood glucose level over 160 mg/dl (8.96 mmol/l) before every dive.

Depth limited to 30 m.

Use the diabetic dive log to accumulate "reference" data for similar dives.

Sufficient hydration (a minimum of 2 l before the first dive but not more than 1 l/hour).

Late testing (12-15 hours) after the dive to detect and prevent hypoglycaemia due to muscle-storage repletion.

Oxygen and emergency equipment at the dive site.

We have demonstrated that diving in tropical waters, while on insulin, can be safe for a healthy diabetic with a stable blood glucose situation when training and experience under non-diabetic "buddy-control " is given.

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Key Words

Buddy, diabetes, drugs, environment, fitness to dive, research, safety, training.

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HYPERBARIC RETRIEVALS IN TOWNSVILLE: IS A PORTABLE CHAMBER USEFUL?

Christopher Butler

Abstract

A review of the retrievals of divers with decompression illness (DCI) to the recompression chamber at the Townsville General Hospital (TGH) was conducted for a 2 year period. For the second half of the study a portable recompression chamber was not available for retrievals.

Assuming that portable recompression chamber retrievals were justified in divers with unstable moderate and severe disease, only 1 diver in 108 cases of DCI treated at TGH may have potentially had a better outcome had the facility been available over the second year of the study.

Using patient outcome at discharge as the end point, we cannot demonstrate any superiority of the portable chamber over expeditious sea-level air transport to the hospital based chamber.

Introduction

Recreational diving, by its very nature, tends to be conducted in remote locations. The Great Barrier Reef stretches for some 2, 000 km along the Queensland coast and is one of the world's premier dive locations. Currently (November 1995) there is only one hospital based hyperbaric unit in Queensland, situated at the Townsville General Hospital (TGH).

All cases of decompression illness (DCI) treated at the TGH over a 2 year period have been reviewed. During the second year of this study, divers were transported without the availability of a portable recompression chamber (PRCC). This has provided an opportunity to assess the usefulness of such a unit in support of a hospital based multiplace chamber.

Methods

A retrospective review of patient records from 25/4/93 to 30/6/95 was conducted. Due to the loss of the chamber life support technician employed by the Queensland Emergency Services, the PRCC (a Dräger DuoCom) became unavailable for diver retrievals on the 30th June 1994. Subsequently divers who would have previously been retrieved and treated during transport were transferred by air at sea-level cabin pressure and then definitively treated in the TGH multiplace chamber.