Plasma glucose responses in recreational divers with insulin-requiring diabetes.

G. DE L. DEAR,[1,3,4] N. W. POLLOCK,[1,3] D. M. UGUCCIONI,[1,4] J. DOVENBARGER,[1,4] M. N. FEINGLOS,[2] R. E. MOON, [1,2,3,4].

Depts. of Anesthesiology[1] and Medicine[2], Center for Hyperbaric Medicine and Environmental Physiology[3], Duke University Medical Center, and Divers Alert Network[4], Durham, NC, 27710

Dear G de L, Pollock NW, Uguccioni DM, Dovenbarger J, Feinglos MN, Moon, RE. Plasma glucose responses in recreational divers with insulin-requiring diabetes. Undersea Hyperb Med 2004; 31(3)291-301. Insulin-requiring diabetes mellitus (IRDM) is commonly described as an absolute contraindication to scuba diving. A 1993 Divers Alert Network survey, however, identified many active IRDM divers. We report on the plasma glucose response to recreational diving in IRDM divers. Plasma glucose values were collected before and after diving in IRDM and healthy control divers. Time/depth profiles of 555 dives in IRDM divers were recorded. IRDM divers had been diving for a mean of almost nine years and had diabetes for a mean of over 15 years. No symptoms or complications related to hypoglycemia were reported (or observed). Post-dive plasma glucose fell below 70 mg·dL^{-1} in 7% (37/555) of the IRDM group dives compared to 1% (6/504) of the controls ($p<0.05$). Moderate levels of hyperglycemia were also noted in 23 divers with IRDM on 84 occasions. While large plasma glucose swings from pre-dive to post-dive were noted, our observations indicate that plasma glucose levels, in moderately-controlled IRDM, can be managed to avoid hypoglycemia during routine recreational dives under ordinary environmental conditions and low risk decompression profiles.

INTRODUCTION

Diabetes, particularly insulin-requiring diabetes mellitus (IRDM), has most commonly been viewed as a condition that should preclude participation in activities during which sudden loss of consciousness may pose a significant risk. Scuba diving is one such activity, as impaired consciousness due to hypoglycemia underwater would impair the ability to help oneself or a partner and could be fatal (1-5). Recent developments in the U.S. have encouraged reevaluation of the blanket proscription against the participation of individuals with IRDM. The Americans with Disabilities Act (Public Law 101-336; 104 Stat. 327; 1990) was designed to remove barriers and promote equal access for all individuals. A secondary effect was that exclusionary policies were more easily challenged, thus requiring clear and compelling evidence to justify such decisions. The legislation has substantial weight in cases where prohibitions are primarily based on theoretical risk and the wisdom of the medical community.

The self-reported incidence of diabetes in the U.S. in 1998 was 5.3% (6). The estimated prevalence of diabetes, using World Health Organization guidelines based on NHANES III 1997 data (7), is much higher at 12.3% and includes many individuals for whom no formal diagnosis has been made. Pressure to reconsider conservative medical standards tends to increase as conditions become more common.

International differences have developed regarding the treatment of divers with diabetes. The medical committee of the British Sub-Aqua Club (BSAC) instituted a prohibition on diving for individuals with IRDM in the mid-1970s. The ban was relaxed in 1991 in response to a growing awareness of individuals successfully diving with IRDM. Individuals with IRDM were then allowed to dive within the BSAC system as long as they did not have cardiovascular or other complications (8). North American medical guidelines have maintained a more consistent prohibition but a recommendation has been made for case-by-case evaluation (5). Furthermore, while some authors have held to the conservative stance and support medical disqualification, they acknowledge that a relaxation in the guidelines may be expected in the future (2).

The Divers Alert Network (DAN) conducted a survey in 1993 of all members (115,300) to determine the number of active divers with diabetes (9). A total of 164 divers with diabetes (129 with IRDM) reported participating in over 27,000 scuba dives with no major complications (9). Some individuals reported experiencing symptoms of hypoglycemia, though none reported loss of consciousness.

Several preliminary reports have suggested that individuals with IRDM diving under closely controlled conditions may dive safely (8,10,11). George Burghen of the University of Tennessee developed guidelines for use at a special camp for people with diabetes in the U.S. Virgin Islands (Camp DAVI [Diabetes Association of the Virgin Islands], St. John USVI). His standards require plasma glucose to be measured four times: one hour pre-dive, 30 minutes pre-dive, immediately pre-dive and post-dive. Lerch et al. used these guidelines to monitor seven divers with IRDM (four female, three male) participating in a special training course in Papua New Guinea (mean age 32 years [range 21-41] and HbA1c values between 5.5 and 9%) (11). Applying a fairly strict series of controls and monitoring protocols, six sequential days of diving with a total of 11 dives for each diver in tropical waters were completed without difficulty. There were no cases of hypoglycemia reported during their study period.

Edge et al. (12) evaluated the hematological and plasma glucose response to a simulated 20 minute dive in a hyperbaric chamber. Eight IRDM subjects were taken to 27 m (89 fsw) where they completed 16 minutes of exercise on a cycle ergometer. The authors reported no incidents of hypoglycemia and the plasma glucose response of subjects with IRDM did not differ significantly between hyperbaric and sea level trials. In an 11 year longitudinal survey of 323 scuba divers with diabetes from the UK's Diving Diseases Research Centre, Edge et al. (13) found that the majority was still diving and there was no evidence that these divers were over represented in the accident statistics.

The effect of more typical, relatively uncontrolled, and repetitive recreational diving on plasma glucose levels are not well known. DAN started the current study in 1997 to investigate plasma glucose response to recreational scuba diving in certified divers with IRDM. This report presents data to assist in developing recreational diving guidelines for divers with IRDM.

METHODS

Entry criteria

The Institutional Review Board of Duke University Medical Center approved this research project and all subjects provided written informed consent prior to participation. The plasma glucose was monitored at specific intervals around the start and finish of each dive with no attempt to influence dive depth, duration or frequency of diving. Subjects were adult, previously-certified, active divers with a history of at least moderately controlled diabetes. Moderate control during the previous three months was confirmed by glycosylated hemoglobin measures (HbA1c) of ≤9% and a detailed medical history. The HbA1c results were required within a two-week period before the study trip (and within one month after the trip). Qualifying participants with IRDM had to be free of secondary complications of diabetes (including neuropathy, cardiovascular disease, and retinopathy), could not have been hospitalized within the previous 12 months for severe hypoglycemia or ketoacidosis and must have had a good understanding of the relationship between plasma glucose and exercise. Female participants were required to state that they were not pregnant or trying to become pregnant during the study period.

Subjects, recruitment and diving

Recruitment was by national advertisement of partially underwritten DAN-sponsored trips. All trips were attended by a physician familiar with diving medicine and a staff researcher. Control divers were healthy, certified divers with no history of diabetes who participated in the same trips. They were not formally evaluated medically. Demographic and anthropometric data recorded for all subjects included age, height and weight. Waist-to-hip ratios and estimates of body composition from seven-site skinfold thickness were recorded for most subjects.

The majority of dives took place from commercial live-aboard dive boats (60%) or from day charter boats (40%) operating out of warm-water coastal resorts in the Caribbean, Mexico, the Bahamas, Honduras, the Cayman Islands and Belize. Shore-based dives were monitored in the Bahamas and Cozumel.

Participants regulated their own diving but also agreed to adhere to the protocol approved for the study. Plasma glucose had to be maintained >80 $mg \cdot dL^{-1}$, with stable or rising values during a series of three measurements prior to each dive (see monitoring plan). There was no upper limit to the acceptable plasma glucose. The exact strategies used to regulate plasma glucose level were chosen by each individual. The study was observational in design, but information was exchanged between researchers and subjects and self-initiated adjustments in both diet and insulin dosages were made during the study that might not have happened if diving activity was unmonitored. The fact that participants agreed to have a plasma glucose level >80 $mg \cdot dL^{-1}$ before every dive may have changed their behavior, such as altering the frequency of pre-dive ingestion of supplementary glucose. Hyperglycemic and hypoglycemic episodes occurred throughout the trips as the divers were adjusting their diet/exercise/dosage balance. Some hyperglycemia may have been caused by divers attempting to prevent hypoglycemia.

Monitoring plan

Plasma glucose was monitored with a Bayer Elite glucometer (Tarrytown, New York, USA). This device calibrated before and after each trip, assays the hexokinase reaction to measure glucose levels in whole blood. Values were recorded at 60, 30 and 10 minutes pre-dive, and immediately post-dive in the IRDM group and at 10 minutes pre-dive, and immediately post-dive in the control group. The IRDM group maintained records of their insulin dosages, diet and exercise throughout the research trip; this was in the form of a detailed daily diary. The time/depth profiles of all dives were recorded with downloadable dive computers (Suunto Solution Alpha, Vantaa, Finland) for later analysis. Some of the dives approached the decompression limits described by the Suunto computer we used for data logging; individuals used personal dive computers or other planners to control the dives. Symptoms of hypo- or hyperglycemia before, during, or after completion of diving activities were recorded. Subcutaneous insulin pump use was also recorded. Hypoglycemia was defined as plasma glucose of less than 70 $mg \cdot dL^{-1}$.

Statistical analysis

Data are reported as means ± standard deviation with ranges where appropriate. Comparisons of hypoglycemia frequency were made with nonparametric Chi square tests. Comparisons of the change from pre- to post-dive plasma glucose (Delta PG) were made with one way ANOVA. Statistical significance was as accepted at $p<0.05$. We calculated the exact probability from the binomial distribution (14).

RESULTS

A total of 83 divers participated in the study: 40 with IRDM and 43 as controls. A total of 1059 dives were monitored: 555 by IRDM and 504 by control divers. Diving patterns were similar for both groups (Table 1). Dive trips included an average of five days of diving with 15 dives per trip for male IRDM divers and 12 for female IRDM divers. The IRDM divers completed a mean of 2.7 dives per day, averaging a maximum depth of 64 FSW and a 41 minute underwater time. Data for the control divers are also presented in Table 1. No episodes of decompression illness were reported. The average IRDM diver was 45 years of age, had been a diver for almost nine years and had diabetes for over 15 years. Diabetes had been diagnosed in 77% (31/40) of the IRDM divers at the time at the time they obtained scuba certification.

Table 1: Descriptive Measures[1]

Category	IRDM Male	Control Male	IRDM Female	Control Female
Number of Divers	20	27	20	16
Number of Dives	309	293	246	211
Age (y)	44±8 (30-59)	39±10 (18-57)	46±7 (31-62)	34±9 (20-51)
Height (m)	1.78±0.07 (1.55-1.88)	1.77±0.05 (1.68-1.88)	1.65±0.08 (1.52-1.80)	1.67±0.05 (1.57-1.75)
Weight (kg)	85.3±13.4 (65.9-113.6)	78.3±11.2 (68.2-118.2)	67.5±13.8 (49.1-94.1)	67.2±8.3 (54.5-77.3)
BMI ($kg.m^{-2}$)	26.9±4.5 (22.1-39.8)	25.1±3.3 (20.8-36.3)	24.8±4.3 (18.4-36.7)	24.2±3.1 (19.6-27.5)
Body Fat (%) see footnotes	15.2±4.2[2] (8.9-22.1)	11.8±3.8 (7.1-20.3)	21.6±6.1[3] (13.0-35.1)	18.8±4.6 (11.4-27.4)
Waist-to-Hip Ratio	0.90±0.09[1] (0.74-1.04)	0.96±0.06 (0.81-1.03)	0.86±0.10[2] (0.74-1.16)	0.94±0.11 (0.79-1.15)
Years Certified	10±11 (1-37)	12±8 (1-30)	8±6 (1-24)	7±6 (1-20)
Years Since Diabetes Diagnosis	15±9 (3-29)	---	16±7 (1-29)	---
Pre-Trip HbA1c (%)	7.1±0.8 (6.0-8.7)	---	7.8±0.9 (5.8-9.0)	---
Post-Trip HbA1c (%)	7.0±0.7 (6.0-8.6)	---	7.6±0.8 (6.2-9.4)	---
Number of Days of Diving	5.6±1.3 (3-7)	4.4±1.8 (1-7)	4.5±1.6 (2-7)	5.5±1.5 (1-8)
Number of Dives per Trip	15±5.2 (8-23)	11±7 (1-27)	12±7 (2-25)	13±8 (1-23)
Mean # of Dives per Day	2.8±0.7 (1.3-3.8)	2.3±0.8 (1.0-4.5)	2.6±0.9 (1.0-4.2)	2.3±1.2 (0.2-3.8)
Maximum Depth (fsw)	64±21 (11-128)	68±24 (12-150)	63±20 (10-156)	67±21 (12-130)
Underwater Time (min)	41±10 (2-81)	45±10 (10-75)	41±9 (6-71)	45±10 (12-83)

[1]the values are presented as mean ± SD and (range); [2]data available for 16 of 20 participants; [3]data available for 18 of 20 participants.

The variability in plasma glucose levels measured prior to and following recreational scuba dives was modest as expected in the control group but dramatic in the IRDM group (Table 2). There were no symptoms or complications related to hypoglycemia reported (or observed) during or immediately post-dive in either group. This was despite some low levels of plasma glucose. IRDM divers took extra glucose before 42% of dives to raise their plasma glucose to greater than 80 $mg{\cdot}dL^{-1}$. Post-dive plasma glucose fell below 70 $mg{\cdot}dL^{-1}$ in 7% (37/555) of the IRDM group dives (minimum 41 $mg{\cdot}dL^{-1}$) and 1% (6/504) of the control group dives (Chi square[1]=20.33, p<0.05) (minimum 56 mg·dL^{-1}). Values as low as 50 mg·dL^{-1}, or even lower, may be found in normal individuals, especially women (15,16).

Table 2: Plasma Glucose Responses to All Dives[1]

Category	IRDM Male	Control Male	IRDM Female	Control Female
60 min before	178±69 (49-402)	---	191±80 (48-493)	---
30 min before	191±67 (58-400)	---	216±77 (52-480)	---
10 min before	194±65 (59-419)	104±18 (61-189)	223±71 (33-482)	104±17 (70-168)
Post-Dive	140±61 (41-365)	95±12 (59-152)	179±76 (54-453)	94±12 (56-133)
Delta PG[2] (All Dives)	-54±63 (-243-+283)	-9±20 (-100-+101)	-44±75 (-370-+206)	-10±22 (-128-+100)

[1]values are presented as mean ± SD (range) in mg·dL^{-1}. [2]Delta PG is the difference between plasma glucose 10 min before water entry and immediately post-dive, negative values indicate a fall in plasma glucose.

Although hypoglycemia did not occur immediately before, during or immediately after diving, other instances were recorded. Eleven individuals in the IRDM group reported 16 events with hypoglycemic symptoms at times unrelated to diving. These occurred when their plasma glucose was <20-64 mg·dL^{-1}. Hypoglycemia was more common in male compared to female divers in the IRDM group (10% [32/309] vs. 2% [5/246] of dives) (Chi square[1]=15.25, p<0.05). The daily diary kept by each diver with IRDM indicated the reasons for and comments about any episodes of hypoglycemia (plasma glucose <70 mg·dL^{-1}) or hyperglycemia (plasma glucose >300 mg·dL^{-1}). Summaries of symptoms relating to episodes of hypoglycemia are shown in Table 3. Symptoms included nausea, anxiety, shaking, feeling cold and headache. On several occasions, these symptoms were enough to wake the diver in the middle of the night. Upon testing the plasma glucose was noted along with the corrective action taken. One diver on a live-aboard dive boat experienced a hypoglycemic seizure six hours post-dive due to an error in programming a personal insulin infusion pump. She recovered after intravenous administration of 50% dextrose.

Eight divers used subcutaneous insulin pumps (removing them prior to entering the water to avoid dislodgment and any pressure effects). Drugs other than insulin that were taken by the IRDM group included antihypertensives [6], antiemetics [6], L-thyroxine [6] and antimalarials [4].

Moderate levels of hyperglycemia (>300 mg·dL^{-1}) were noted in eight divers on 67 occasions pre-dive. Hyperglycemia at that level (or greater) was observed post-dive in 15 divers on 17 occasions, but no episodes of symptomatic hyperglycemia were recorded.

Table 3: Hypoglycemic Episodes That Occurred Outside Dive Times

Subject: Gender/ Age[1]	Trip Day	Time	PG[2]	Comments from Diet Diary
1: F/48	4	0400	40	Awoke due to low PG; ate two apples and ¼ cup mixed nuts
2: F/45	5	2359	47	Awoke feeling sick; drank soda
3: M/52	2	0500	46	Changed diet the night before to allow diving
4: M/36	2	0700	50	Vial of Lente insulin broke, tried to work out equivalent dose of regular insulin
4	3	0500	40	Due to being too conservative with regular insulin as Lente vial broken (carried on waking up with low PG for five days more)

5: F/37	2	0700	57	Took some gel
6: M/49	3	0317	62	Had some cookies
6	4	0124	64	Had two sodas and two cookies in the next hour
6	5	0406	52	Had soda and two cookies
7: M/46	6	0200	46	Took glucose gel
8: F/41	1	0300	39	Took four glucose tablets and stopped pump for three hours
9: F/53	4	0430	43	Awoke; ate two oranges; PG level blamed on small dinner and insulin taken late in the evening
10: F/42	2	0703	50	Ate extra food
10	4	0029	56	Took two glucose tablets
10	7	0630	37	Ate extra food
11: F/48	5	2255	<20	Error in programming pump led to hypoglycemic seizure; required glucagon and IV 50% Dextrose. PG was > 80 $mg \cdot dL^{-1}$ 12 minutes later

[1]M=male, F=female; [2]PG = plasma glucose; there were significant differences in Delta PG between IRDM and control groups (-50±69 vs. -10±21 $mg \cdot dL^{-1}$, respectively; $F=155$, $p<0.05$). Differences in Delta PG within the IRDM group were not significant when comparing single and repetitive dives (-52±64 vs. -48±72 $mg \cdot dL^{-1}$, respectively; $F=0.360$, $p=0.549$). Gender differences in Delta PG within the IRDM group approached significance ($F=3.70$, $p=0.055$).

DISCUSSION

Recent developments in monitoring technology have made analysis of plasma glucose easy and reliable. Our observational study was designed to use commercially-available portable monitors to compare plasma glucose measurements in divers with IRDM with similar measurements in control divers without diabetes. There was considerable variability in the observed plasma glucose levels, but low pre-dive values were easily corrected with oral glucose supplementation using glucose gel (Insta-glucose gel; ICN Pharmaceuticals, Costa Mesa, California, USA) and other strategies. No episodes of symptomatic hypoglycemia were reported during diving.

Limitations

There are a number of important limitations to our study that must be considered. Participation was limited to well-motivated, experienced individuals with at least moderately controlled IRDM. Divers were generally mature and had good experience with both diving and diabetes management. Even so, there was considerable variability in plasma glucose levels in various individuals at differing times, ranging from a rise of 283 $mg \cdot dL^{-1}$ to a fall of 370 $mg \cdot dL^{-1}$. Our study may have influenced the individual level of awareness and exaggerated attempts within the IRDM group to control plasma glucose by adjusting dosage of insulin and food/glucose intake. The magnitude of the plasma glucose changes was frequently noted with surprise by the participants in this study. Conceivably, individuals with less stable IRDM or tighter control (lower HbA1c) may have an increased risk of symptomatic hypoglycemia.

Episodes of symptomatic hypoglycemia may occur once or twice a week in individuals with IRDM who are not diving (17). Severe hypoglycemia (requiring emergency treatment) in individuals with diabetes has also been shown to be fairly common. Over seven percent of patients with IRDM in one study had episodes of severe hypoglycemia requiring external help (18). Furthermore, there is a correlation between intensity of management and the incidence of hypoglycemic episodes. The Diabetes Control and Complications Trial (DCCT) Research Group defined two groups of patients for a 10 year study - intensively treated (those with specific glucose targets, multiple daily injections of insulin or pump use and hospitalization to start therapy) and conventionally treated (no specific glucose targets, one or two insulin injections per day) (19). They found 65 percent of patients had at least one episode of hypoglycemia during the study period with an incidence of 62 per 100 patient years in the intensively treated group. Thirty-five percent of the conventionally treated group had such an episode with a rate of 19 per 100 patient years. Intensive and more aggressive treatment was clearly associated with an increased incidence of hypoglycemia. Of great concern, 27 percent of any of these hypoglycemic episodes were associated with coma and/or seizure (19).

Good plasma glucose control is demonstrated, according to the American Diabetic Association (ADA), by HbA1c values of less than seven percent (20). Good control is recommended to reduce the risk of long-term complications (20,21). These include neuropathy (22), coronary artery disease (23,24), renal disease, and proliferative retinopathy or peripheral vascular disease that are likely to develop in time despite excellent control. A HbA1c value in the good or better range is one of the best predictors of hypoglycemic complications (19).

The potential risks of elevated plasma glucose in divers are not fully known. It is unclear if elevated plasma glucose may increase susceptibility to decompression sickness, perhaps by inducing an osmotic diuresis. Moreover, if neurological decompression illness were to occur, hyperglycemia could worsen the outcome (25,26). Thus, simply elevating glucose levels to reduce the risk of hypoglycemia developing during a dive may not be a completely benign strategy.

The ADA position statement on diabetes and exercise recommends caution in moderate or severe planned or unplanned exercise programs with any level of abnormal plasma glucose (>300 mg·dL^{-1} or <100 mg·dL^{-1}) (27). The fact that no reports of symptoms associated with hypoglycemia were recorded in our study despite occasional instances of plasma glucose concentration in the range 40-50 mg·dL^{-1} suggests that a failure to recognize or report symptoms may occur in some cases. The inability of individuals to recognize symptoms of hypoglycemia has been to shown to underestimate the true incidence by up to 15% in a cohort of 230 IRDM patients (28). Only 555 dives were monitored with no hypoglycemia observed. Based on these trials, we can estimate that the true probability of hypoglycemia is less than 0.5% ($p=0.048$).

The distractions associated with diving may reduce awareness of impending hypoglycemia to a greater degree than seen with other activities, particularly if the rate of plasma glucose fall is moderate and thus less helpful in aiding symptom recognition. It is noteworthy that the hypoglycemia measured immediately after diving was unrecognized by the divers, whereas similar plasma glucose levels later in the day/night after diving were noted and treated.

The ADA position statement on diabetes and exercise points out that hypo- or hyperglycemia may occur many hours after exercise, too (27). Our IRDM group had a seven percent incidence of asymptomatic hypoglycemia immediately after diving. Another 16 episodes of hypoglycemia were reported well after the dive.

Another risk associated with hypo-/hyperglycemia is the possibility of confusion with other medical conditions. Hypothermia and nausea from seasickness are the two most common in the diving environment. Confusion regarding symptoms compatible with decompression illness is also possible.

Two final limitations of our study are the nature of the dives monitored and restriction to adult subjects. All of the dives monitored were of an uncomplicated recreational nature conducted under minimal or modestly stressful conditions in tropical or subtropical waters. The additional stress associated with increased equipment burden, thermal challenge, more extreme dive profiles or emergency situations may produce more dramatic fluctuations in plasma glucose.

Lastly, our study enrolled only adult subjects free of secondary complications of IRDM. Children may be at greater risk due to increased distractibility, less experience in regulating plasma glucose and are prone to greater variability in plasma glucose levels during exercise (29-30).

Diving Standards Issues

There are some concerns regarding current diving standards that need to be taken into account when considering whether to liberalize these standards:

1) Symptoms of severe hypoglycemia, which include seizure and loss of consciousness, are likely to be fatal underwater. We cannot predict absolute risk or threshold values for an individual or an individual dive.
2) There is no reliable means to take a rest from diving as there may be when exercising on land. Conditions may change rapidly and what had been a relaxed dive in benign conditions may turn into a very physically demanding situation. For this reason, individuals with diabetes requiring hypoglycemic medication who are contemplating diving should receive training in adjustment of insulin dosing and caloric intake from a certified diabetes educator and nutritionist. Changes in insulin sensitivity, particularly in patients with type 2 diabetes (insulin resistance type (7)), in whom insulin resistance may be partially reversed with exercise, may require a significant temporary change in insulin dose. In addition, the amount of energy expended rapidly during a dive may require substantially more calories than usual, and the food ingested should energy forms that are both rapidly (carbohydrate) and more slowly (protein) available (31). These dangers faced by IRDM divers have been cogently argued by Edmonds, Gorman et al. (32).
3) Additional training would be required to ensure that all divers, dive leaders and support personnel can recognize and treat the signs and symptoms of hypoglycemia. It is ideal that the buddy diver be aware of the issues related to diabetes. Training would also be required to differentiate diabetes-related problems and decompression illness.
4) Diving certifications are most commonly issued on a 'for life' basis in the United States (unlike many other countries) while diabetes can lead to progressively more severe complications. Therefore, certification of divers with IRDM might appropriately become time-limited and require ongoing documentation of acceptable health status in a manner similar to the medical waiver policy for private pilots with IRDM (33 with website).
5) The consequences of persons with diabetes engaging in recreational diving go beyond the simple issue of whether hypoglycemia is more likely underwater. In a remote location (e.g., an offshore dive boat) the staff and other divers could have to contend with a range of complicated emergencies:
   - Those associated with the complications of diabetes, such as ischemic heart disease (IHD). IHD is involved in over 25 percent of the scuba fatalities in those over 35 years of age (34), 13 percent of all incidents reported to DAN in 2001 (35). Basic first aid and life support (CPR, cardiopulmonary resuscitation) training should be undertaken by the proposed dive buddy and/or support staff.
   - Errors in medical management of the diabetes itself. This is illustrated in our study by the severe hypoglycemia experienced due to an infusion pump programming error. Such a

complication could easily have been fatal had there not been a physician immediately available with the necessary glucose and equipment required for its administration.

- If decompression illness should develop, there are also the issues of over- or under-treatment arising from confusion between symptoms of hypo- or hyperglycemia and those of decompression illness.

6) Problems of providing insulin in a remote area include: appropriate refrigeration, access to an acceptable quality source, and administration issues. Regarding administration issues, for example, a chilled diver may experience a slower than normal absorption of subcutaneous insulin. Similarly, a diver suffering from seasickness may have difficulty with oral administration of glucose.
7) The dive buddy standard is based on the assumption that both individuals are able to provide adequate and rapid support for a partner in time of need. This may not reflect reality if one of the pair is impaired by a pre-existing medical condition.
8) Care must be taken by those who use an insulin pump system to deliver insulin subcutaneously. Catheter tract infections are more likely when dives are made in contaminated water; even seawater has many floating organisms. While these devices are not currently made for use underwater, issues of contamination, dose metering in a pressurized environment and possible dislodgment during vigorous activity will have to be considered if this changes.

Our observations support the contention that, when adhering to an easy to follow regimen, plasma glucose levels in well-motivated individuals with at least moderately controlled IRDM can be managed to avoid hypoglycemia during uncomplicated dives conducted under controlled recreational diving conditions with minimal environmental stresses (e.g., extremes of temperature, current or wave action) and low decompression risk dive profiles. There are risks associated with scuba diving with IRDM. The authors do not recommend opening diving activities to all individuals with IRDM but recognize that many current divers have diabetes. Until generalized guidelines are formulated by the appropriate regulatory and advisory bodies, the authors recommend that IRDM divers who choose to dive follow the general guidelines for this study. Care should also be taken to avoid significant hyperglycemia pre- and post-dive. Reduction in insulin dosage tailored to the individual's response to exercise and resulting hypoglycemia may be necessary and must be evaluated under controlled conditions. Guidelines applicable to the broad range of recreational divers with IRDM need to be delineated for the United States and other countries. Suggestions for professional bodies, instructor training or working divers should be conservative and include procedures to gather data for continued evaluation of both activity and outcomes. While such strategies will be onerous, the information is essential to understand the risks and to facilitate the evolution of appropriate standards.

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