Diabetes mellitus and mountain sports

Jordi Admetlla Batlle, Conxita Leal Tort, Antoni Ricart de Mesones

Institut d'Estudis de Medicina de Muntanya, Muntaner 231 08021, Barcelona. Spain..

Correspondence to: Jordi Admetlla Batlle, 25491jab@comb.es

SUMMARY

An unknown and probably increasing number of diabetics frequent mountain areas and practice mountain-related sports. Regulation of type-1 Diabetes Mellitus (DM-1) in the mountains may well be affected by a number of factors such as unpredictable meals and exercise load, the poor conservation and efficacy of insulin or other equipment, extreme temperatures and altitude etc. However, data are scarce. Specifically, there are no conclusive data on the evolution of Diabetes at altitude. To improve our understanding of DM-1 during a mountain expedition, the "Institut d'Estudis de Medicina de Muntanya" (IEMM) monitored the members of the IDEA2000 Expedition, 7 of whose 8 diabetic team members reached the summit of Cerro Aconcagua (6,962m) without any serious medical complications. All the diabetic members of the group had wide experience of mountaineering and proven ability to manage the disease in extreme conditions. Our results, based on the days of intense exercise showed that the insulin dosage per hour is significantly higher above 5,000m (0.06±0.04UI/10g carbohydrate/h) than at lower altitudes (0.04±0.02UI/10g carbohydrate/h). These findings can be explained by the greater activity of counter-regulatory hormones at altitude or by the subjective perception of exercise intensity, which varies between low and high altitude. However, the insulin demand per hour was significantly higher below 5,000m (1.9+0.7 UI/h) than at higher altitude (1.7+0.6 UI/h), indicating that rest and increased food intake at lower camps have a greater effect on the regulation of glycemia than altitude. During this expedition we found no medical impediment to diabetics climbing to altitude and practicing mountain sports. Skilled management of DM-1 and proper acclimatization are essential preconditions of the safety of diabetics at altitude.

INTRODUCTION

A statement by the American Diabetic Association (ADA, 2002) says that "all levels of exercise, including leisure activities, recreational sports and competitive professional performance can be performed by people with type 1 diabetes mellitus (DM-1) who do not have complications and are in good blood glucose control". Since altitude itself probably has little effect on diabetes (Milledge, 1999) and the incidence of AMS is similar among diabetic and non-diabetic climbers (Moore 2001) the ADA recommendations might be extended to diabetic patients at high altitude.

An unknown and probably increasing number of diabetics frequent mountain areas or practice mountain-related sports. In the last few years there have been reports of diabetics climbing in the Himalayas and recently at least two expeditions, most of whose members were diabetic, climbed to high altitude (Moore, 2001; Admetlla, 2001).

Little data about the presence of diabetics at altitude is available: There is no information on the incidence of diabetes in recreational areas at altitude or ski resorts in either Europe or North America. However, statistics on mortality while trekking in Nepal attribute 3 out of 40 deaths to diabetic ketoacidosis in a total population of 275,950 trekkers (Shlim, 1989,1992) which may mean a larger number of diabetics without fatal consequences. Turning to mountaineers; although none of the 900 climbers included in a study carried out on Cerro Aconcagua mentioned being diabetic in the medical records (Pesce, 2002), in another study that was done in the Capanna Margherita (4,559 m), 10 out of 1,220 mountaineers (0.8%) reported diabetic hypoglycemia (Schneider, unpublished data, 1997-2000).

Possible difficulties and problems

1) The effects of altitude on DM-1 are unknown. Some studies on non-diabetic subjects at altitude show an increase in fasting glucose and counter-regulatory hormones (Sutton, 1977; Currie, 1990; Martínez Ferrer, 1990; Brooks, 1991; Sawhney, 1991; Favier, 2000) although other factors like acclimatization or time at altitude modify this rise (Larsen, 1997; Richalet 2001). Consequently, the balance between glycemia and pancreatic function in non-diabetics differs between high and low altitude. Extrapolating from these data to diabetic subjects the dosage of insulin might have to be increased at altitude, as counter-regulatory hormones are increased at altitude. Insulin resistance at high altitude in diabetics has been suggested previously (Basnyat, 1995), but there is a lack of definitive experimental data.

2) In addition to hypoxia, other aspects of the evolution of DM-1 at altitude should also be considered. DM-1 must be controlled in spite of extreme temperatures, technical difficulties, unpredictable meals and exercise load. Some of the concerns are the preservation of insulin since it may be damaged by light and heat, and the accuracy of glucometers at altitude and with cold temperatures. Studies on the reliability of these devices have been performed at altitudes below 4,000m or with models that are now outdated (Giordano, 1989; Piepmeier, 1995; Gautier, 1996; Fanghanel, 1998; Pecchio, 2000; Williams, 2000). It has also been suggested that hemoconcentration, quite frequent at altitude, may cause an underestimation in the results given by glucometers (Barreau, 1988). Visual strips seem to be less reliable at altitude (Williams, 2000).

3) The evolution and management of mountain-related complications (severe AMS, high-altitude pulmonary or cerebral edema, hypothermia, and infections) are not well established in diabetic patients in remote areas (Shlim, cited by Hackett 2001, Chartier, 1992).

4) Drugs administered to accelerate acclimatization may affect DM-1 management. Dexamethasone increases resistance to insulin and acetazolamide, an inhibitor of carbonic anhydrase, modifies the acid-base imbalance, reduces buffer blood capacity and thus may enhance ketoacidosis.

Reported experiences in the literature

Severe medical complications during high-altitude expeditions have been reported in diabetic climbers: In one case death was attributed to high altitude cerebral edema (Chartier, 1992); and ketoacidosis has been attributed either to poor preservation of insulin, unreliable glucometers or the mismanagement of the disease (Herter, 1999; Williams, 2000; Moore, 2001 a, b). In an expedition to Kilimanjaro (5,985m) including 15 diabetics, four developed ketosis and of these, two evolved into ketoacidosis and severe AMS (Moore, 2001). Like most of the expedition members, those developing ketosis used acetazolamide to prevent AMS, which might be linked to the decompensation. These authors suggest that the glucometers may have lost reliability at altitude and that symptoms of AMS could have been mistaken for hypoglycemia. Nevertheless the diabetic members of this expedition had no previous experience in mountaineering. In a previous investigation (Leal, unpublished data) 19 out of 24 Type 1 diabetic climbers had reached altitudes above 4000 m (15 above 5000 m and 3 above 7000 m with no major medical complications) and did not confound hypoglycemia with symptoms of AMS nor take drugs to prevent AMS.

Some top diabetic climbers have reported their personal experience in sports journals, in meetings and journals of diabetic associations or on the Internet (Bladé, 1996; Giné, 1997; Panofsky, 2001 and chapter in this book). In contrast to the above-mentioned medical publications, they reported positive experiences under extreme conditions at altitude and often describe highly creative and practical ways of managing their diabetes (Fleming, 1997).

To improve our understanding of DM-1 at altitude, in January 2001 the “Institut d’Estudis de Medicina de Muntanya” (IEMM) monitored the members of the IDEA2000 Expedition, during which seven out of eight experienced diabetic climbers reached the summit of Cerro Aconcagua. None of the diabetic members of the summit or base camp groups developed any serious medical complication. The study aimed to determine variations in insulin requirements related to carbohydrate (CH) intake, either at rest or during exercise and at low and high (above 5,000m) altitudes. The expedition doctor, who carried out the study, did not interfere with the way the diabetic climbers managed their disease.

SUBJECTS, MATERIALS AND METHOD

Two groups of diabetic subjects were monitored. The summit group consisted of eight experienced type 1 diabetic climbers, while the base camp group included seven diabetics who stayed at the base camp at 4,200m during the whole exposure. Four non-diabetic climbers accompanied the expedition, three in the summit team and one in the base camp group. The main characteristics of the two groups of diabetics are shown in Table 1.

Only one member of the expedition took acetazolamide to prevent AMS but he stopped taking the medication after the first day at base camp. The members of the expedition self-recorded their capillary blood glucose values, registered CH intake, the insulin doses administered, the duration and intensity of exercise, and heart rate. They also recorded location, altitude and atmospheric pressure and any other events or complications. The diabetic subjects used an intensive insulin treatment either with pump or multi-injection and everyone self-adjusted insulin doses to recorded capillary glucose, next CH intake and expected exercise.

CH intake over 24 h was estimated by each individual on the basis of the information provided by the manufacturers of pre-cooked meals. Exercise intensity was classified in four categories according to subjective perception. A period of intense exercise in a day classified the day as intense exercise. Intense-exercise days and rest days are compared.

Table 1: Number, age, sex, history of mountaineering, duration of diabetes and way of insulin administration

	Total	**Summit Group**	**Base Camp Group**
Number	15	8	7
Average age ± SD (range)	30.3 ± 5.3 (25 – 45)	31.6 ± 6.1 (25 – 45)	29 ± 4.2 (26 – 38)
Sex F/M	4/11	2/6	2/5
Years of mountaineering ± SD	11.3 ± 6.5	13.4 ± 6.8	6.8 ± 4.9
Exposures > 5,000 m		1.5 ± 1.6	0
At least one exposure > 5,000 m		6	0
Years duration DM-1 ± SD (range)	13.3 ± 7 (6 – 26)	11.4 ± 4.5 (6 – 17)	15.5 ± 8.9 (6 – 26)
Pump users	10	4	6
Multi-injection users	5	4	1

The Student's t test was used for data analysis.

RESULTS

Results refer exclusively to the summit group. The daily average of glycemia self-measurements was 7 ± 2.2. The CH intake (g/day) was 383.9 ± 120.8 below 5,000 m and 315.8 ± 126.6 above 5,000 m ($p<0.05$).

Observations on blood glucose levels

One case of mild post-prandial hypoglycemia was observed at 5,000m. Several subjects, including this one, observed a tendency to lower post-prandial glycemia levels, followed by hyperglycemia between 2 and 3 hours later. This was attributed to a delay in the absorption of CH caused by altitude (Heath, 1981; Richalet, 1984). Administration of insulin after food intake avoided this situation.

The increase in fasting glycemia in some of the climbers was thought to be caused by early dinner the previous night, a common practice in expeditions.

Table 2: Insulin administration related to exercise (UI Insulin /h).

	Altitude<5,000m	**Altitude>5,000m**	**Significance**
Overall	1.94 ± 0.7	1.74 ± 0.6	P< 0.05
Overall (days of rest excluded)	1.83 ± 0.6	1.76 ± 0.6	NS
Rest days	2.08 ± 0.7	1.79 ± 0.6	NS
Intense exercise days	1.56 ± 0.4	1.71 ± 0.5	NS

Table 3: Insulin administration related to CH intake and exercise (UI Insulin/ 10g CH/h).

	Altitude<5,000m	**Altitude>5,000m**	**Significance**
Rest	0.064 ± 0.02	0.083 ± 0.02	NS
Intense exercise	0.042 ± 0.02	0.064 ± 0.04	P< 0.05

DISCUSSION

Although the increased activity of counter-regulatory hormones at altitude suggests that more insulin is needed at altitude above 5000 m, results show that higher insulin doses are taken at low camps. This finding is as expected and can be explained by the fact that on expeditions mountaineers rest more and eat more at lower altitudes as evidenced in the results. This finding suggests that diet and exercise affect glycemia regulation in diabetics more than altitude does.

If, however, we relate the insulin dosage to carbohydrate intake, we find that the insulin dosages at altitude are higher, although these results are statistically significant only in cases of intense exercise. Two major factors influencing sensitivity to insulin may be considered as explanations: Hypoxia could increase insulin resistance (Sutton, 1977; Martínez Ferrer, 1990; Sawhney, 1991; Favier, 2000). This has been shown to occur in the first days at 4559 m by hyperinsulinemic, euglucemic clamps (Larsen, 1997) and may at least partly be attributed to increased plasma levels of counter-regulatory hormones.

Furthermore, decreased exercise intensity at very high altitudes might also contribute to increased insulin needs since maximum aerobic capacity decreases considerably, by about 1% for every 100 m above 1500 m (Ward, 2000). Because the subjective sensation of effort depends on the relative work load, levels of absolute work load are significantly decreased at high altitude compared to low altitude at a comparable degree of subjective rating of exercise intensity.

Although exercise intensity and food intake are based on subjective judgment and our data recording may have been affected by factors related to the extreme conditions at altitude, they were used consistently throughout the study and should give a reliable estimation. They allow, however, only comparison of days with intense or no exercise. The differences found in insulin requirements between low and high altitude might increase when exercise/rest and CH intake are measured precisely in periods of a few hours. Clearly, to clarify the role of hypoxia and exercise in insulin resistance observed at very high altitudes, studies with controlled work loads and possibly clamp technique at different levels of acclimatization will have to be undertaken.

These data still leave many questions unresolved: do insulin requirements vary with acclimatization? Are there any individual or sex-related variations in the response to hypobaric hypoxia and do these affect insulin requirements? Is DM-2 affected by altitude? Does altitude affect long-term evolution of diabetes-related disorders? Are diabetic retinopathy, vasculopathy, and neuropathy enhanced by retinal hemorrhages, frostbite or altitude neuritis?

CONCLUSIONS

Our data indicate that 1) There are no medical restrictions for diabetic mountaineers climbing to high altitude if the individual has good knowledge and experience in self-management of DM-1. 2) The need for insulin is greater at lower camps where food is more abundant and rest more plentiful. 3) During days with intense exercise at high altitude, the insulin needs are increased.

PRACTICAL RECOMMENDATIONS:

Based on our clinical experience with diabetic climbers and on the mentioned enquiry to diabetic climbers, strongly supported by the results of the IDEA2000 Expedition, we propose the following practical recommendations.

Regarding the climber
-Frequent self-monitoring under all conditions (consider post-prandial monitoring at altitude). -Skills to calculate insulin and CH intake. -Skills to handle early hyper and hypoglycemia.
Regarding equipment and insulin
-Extra supplies (insulin, emergency food, glucometers, glucagon) also in separate rucksacks. -Alternative methods for self-monitoring (visual strips) and for administering insulin (syringes). -Easily accessible glucagon.
Regarding team members
-They need guidelines to follow in emergency situations, like hypoglycemia. -Glucagon. All team members should know where the glucagon is stored and should be trained to manage hypoglycemia.
Regarding acclimatization
-Slow acclimatization to avoid AMS. Preventive drugs are not recommended. -Awareness that HAPE and HACE may complicate and/or be complicated by severe diabetic decompensation.

ACKNOWLEDGEMENTS:

This survey was possible thanks to the enthusiastic collaboration of the members of the IDEA2000 Expedition: Chris, David D., David P., Doug, Elise, Emilio, Jay, Jeremy, Katherine, Lisa, Marco, Petr, Terra, Todd, Vito, Bob, Mark and Greg.

We are also grateful to many other generous collaborators: Ernest Bladé, Mª Elena Cepparo, Susana Guàrdia, Sylvia Brunoldi, Berta Nofre, Alberto de Leyva, Mercedes Rigla, Carlos Pesce and Anna Serra.

REFERENCES

1. American Diabetes Association (2002). Diab Care 2002 Jan; 25 (Sup1): S64-8
2. Admetlla J., Leal C., Ricart A. (2001). Management of diabetes at high altitude. Br J Sp Med; 35:282
3. Barreau, P.B., Buttery J.E. (1988). Effect of hematocrit concentration on blood glucose value determined on Glucometer II. Diab Care. 11(2) pp 116-118.
4. Basnyat, B. (1995). Himalaya Rescue Association. Diabetic Ketoacidosis in Mountain Trekkers. ISMM Newsletter 5(3), pp 4-5.
5. Bladé i Castellet E. (1996). Expedició UPC-Everest 95. Esport i Vida. n 13. AIED. pp 12-13
6. Brooks G.A., Butterfield G.E., Wolfe R.R., Groves B.M.,Mazzeo R.S. Sutton J.R., Wolfel E.E., Reeves J.T. (1991). Increased Dependence on Blood Glucose After Acclimatization to 4,300 m. Journal of Applied Physiology. 70:919-927.
7. Currie C.J., Lacey L., Peters J.R. (1999). Changes in glucose tolerance at high altitude. Diabetes; 48 (Suppl): A399-400
8. Chartier P. (1992). Oedème cérébral de haute altitude Hinku (Nepal). Bulletin de l'Arpe. pp 3-4
9. Fanghanel G., Sanchez-Reyes L., Morales M., Torres E., Chavira J., Sotres D., Valles V. (1998). Comparative accuracy of glucose monitors. Arch Med Res; 29: 325-329
10. Favier Roland J.M. (2000). The effects of altitude on the hormonal responses to exercise. In Warren, MP. Sports Endocrinology Chap 21. Humana press inc, Totowa, NJ. pp 371-389
11. Fleming D.R., Jacober S.J., Vandenberg M.A., Fitzgerald J. and Grunberger G. (1997). The safety of injecting insulin through clothing. Diabetes Care. 20 (3): 244-247.
12. Gautier J. F., Bigard A., Douce P., Duvallet M., Cathelineau G. (1996). Influence of simulated Altitude on the Performance of Five Blood Glucose Meters. Diab Care 19 (12), pp 1430-33
13. Giné i Vinaixa, R. (1997). La conquesta de l'Everest. Esport i Vida. 16 pp 26-30 AIED.
14. Giné i Vinaixa, R. (1997). La conquesta de l'Everest. Esport i Vida. 17 pp 18-22 AIED.
15. Giordano, BP, Thrash W, Hollenbaugh L, Dube WP, Hodges C, Swain A, Banion CR, Klingensmith GJ. (1989). Performance of seven blood glucose testing systems at high altitude. Diabetes Educ. 15 (5): pp 444-448.
16. Hackett PH. (2001). High altitude and common medical conditions. In High Altitude. An Exploration of Human Adaptation. Ed. T.F. Hornbein and R. B. Schoene. Chap. 25. Marcel Dekker Inc publishers. New York – Basel. pp 866
17. Heath, D, Williams, D. (1981). Man at High Altitude. 2nd Edition. Chap:25. pp 254-255.
18. Herter C D. (1999). DKA on Mont Rainier: a case report. Diabetes Spectrum. 12 (4): 198-200.
19. Larsen JJ, Hansen JM, Olsen NV, Galbo H, Dela F. (1997). The effect of altitude on glucose homeostasis in men. J Physiol 504.1,pp 241-249
20. Martínez Ferrer (1990). Glicemia y altitud extrema. In Adaptación humana a la altura. Expedición Médica Cho Oyu. Ed. Instituto Municipal del Deporte Vitoria Gasteiz España. Pp 129-130
21. Milledge, JS. (1999). People with pre-existing conditions going to the mountains. Official Guidelines Vol 7. Medical Commission of UIAA.
22. Moore, K. C., Thompson C., Hayes R. (2001). Diabetes and extreme altitude mountaineering. Br J Sports Med; 35:83

23. Moore K., Vizzard N., Coleman C., McMahon J., Hayes R., Thompson C.J. (2001). Extreme altitude mountaineering and Type I Diabetes; the diabetes federation of Ireland Kilimanjaro Expedition. Diab Med; 18 (9): 749-55.
24. Panofsky D. (2001). IDEA 2000. Expedition Summary. http//www.idea2000.org
25. Pecchio, O., Maule S., Migliardi M., Trento M., Veglio M. (2000). Effects of exposure at an altitude of 3000m on performance of glucometers. Diab Care. 23 (1): 129-131.
26. Pesce C., Pinto H., González G., Chiocconi R., Mohr Y., Leal C., Maggiorini M., Schneider M., Bärtsch P. (2002). Characteristics of mountaineers ascending Aconcagua (6,962M). High Alt. Med. Biol. 3(1): 103 (Abstract).
27. Piepmeier, E.H., Hammett-Stabler C., Price M.E., Kemper G.B. and Davis M.G. (1995). Atmospheric pressure effects on glucose monitoring devices (letter). Diab. Care 18:423-424.
28. Richalet, J.P. (1984). Alimentation et altitude. In Médecine de l'alpinisme. pp 50-51.
29. Richalet, J.P. (2001). High altitude and common medical conditions. In High Altitude. An Exploration of Human Adaptation. Ed. T.F. Hornbein and R. B. Schoene. Chap. 25. Marcel Dekker Inc publishers. New York – Basel. pp 623-624
30. Sawhney R.C., Malhotra A.S., Singh T. (1991). Glucoregulatory Hormones in Man at High Altitude. Eur Jour App Physiol and Occup Physiol; 62:286-291.
31. Shlim DR. MD, Houston R. (1989). Helicopter Rescues and Deaths among trekkers in Nepal. JAMA; 261: 1017-1019
32. Shlim D.R., Gallie J. (1992). The causes of death among trekkers in Nepal. Int J Sp Med; 13:74-6
33. Sutton J.R., Viol G.W., Gray G.W., McFadden M.D., Keane P.M. (1977). Renin, aldosterone, electrolyte and cortisol responses to hypoxic decompression. Jour Appl Physiol; 43: 421-424
34. Ward M., Milledge J. and West J. (2000). Exercise. In: High Altitude Medicine and Physiology; 3rd edition. Oxford University Press. pp 139.
35. Williams, R.A., Petoskey, Mich. (2000). Blood Glucose Monitoring at High Altitudes (letter). Diabetes Spectrum, 13 (2), pp 79.