

## Appendix 1: Articles with original data on scuba diving and diabetes

Article	Objective	Participants	Suitability for diving	Dive protocol	Findings
<b>Hyperbaric chamber simulation study</b>					
Edge, C. J., (1997) UHM UK [1]	Cross over study of T1D and control. Simulated diving in hyperbaric chamber.	T1D (n=8, 6 male, TDD 0.69 u/kg)  Control (n = 8)	NA	Exercise on bike for 16 mins. Control 101 kPa vs. hyperbaric chamber at 375 kPa  Sessions 1 day apart.  Frequent venous blood samples	<ul style="list-style-type: none"> <li>No difference to BGL levels of T1D participants between 101kPa and 375 kPa</li> <li>BGL only starts to drop after 140 mins (dive is already over)</li> <li>At 375 kPa BGL decrease appears slower than at 101 kPa.</li> </ul>
<b>Questionnaires in diver with diabetes</b>					
Kruger, D. F., (1995) Diabetes Care USA [2]	Case series of 18 T1D divers from a physician who signed medical release forms (Questionnaire)	T1D (n=18, mean age 33yrs, 1 on CSII)		More frequent SMBG. BGL > 8.3 mmol/L to dive. Post meal. If <8.3, mmol/L ingest CHO. Carry glucose underwater. Avoid alcohol for 24hrs	<ul style="list-style-type: none"> <li>No hypoglycaemia related events in this cohort</li> </ul>
Edge, C. J., (2005) UHM UK [3]	Description of data from mandatory annual questionnaire completed by T1D divers in UK.	T1D on database (n = 323 persons, 269 male)	To be fit to dive: <ul style="list-style-type: none"> <li>No severe hypo last 1 yr</li> <li>No hospitalisation for diabetes last 1 yr</li> <li>Sign off from endo "acceptable control"</li> <li>No complication except background retinopathy (even microalb excluded)</li> </ul>		<p>Of n = 323 (persons) n = 8760 dives</p> <ul style="list-style-type: none"> <li>65% (211) still diving</li> <li>11% (55) ceased diving</li> <li>4% (11) refused certification to continue diving</li> <li>1% (2) died while diving (both NIDDM) – one due to AMI other unknown.</li> <li>13% (42) lost to F/U (but not found on diving accident registries)</li> </ul> <p>75% (241) IDDM: mean age 34 yrs 25% (82) NIDDM/ diet: mean age 47 yrs</p> <p>Of IDDM:</p> <ul style="list-style-type: none"> <li>Pre dive: 80% always, 19% sometimes test BGL</li> <li>Carries glucose paste underwater: 98% always, 2% sometimes</li> <li>1 report of hypoglycaemia underwater- treated with glucose paste</li> </ul>

Article	Objective	Participants	Suitability for diving	Dive protocol	Findings
<b>Prospective cohort studies in open water</b>					
Lerch, M., (1996) SPUMS J. Germany/Australia [4]	Cohort study of T1D vs control divers	T1D (n = 7, 3 male) <b>n=77 dives</b>  Controls (n = 7) (n=77 dives)	A1c 5.5 – 9.0% No hypo unawareness Fitness to dive (UHMS or BSAC criteria) Adequate fitness  Excluded: any complications or severe hypoglycaemia < 1yr  Pre-dive: ECG, exercise ECG, RFT, complication screening	11 dives in total (over 6 days) in PNG. (up to 30m, and 45 mins)  BGL test 60, 30 & 0 mins pre-dive  BGL >8.9 mmol/L. Ingest CHO if BGL < 8.9 mmol/L OR falling between 60-30mins.  Adjust insulin each day	<ul style="list-style-type: none"> <li>15 – 20% reduction in insulin required over the 6 days</li> <li>No hypoglycaemia</li> <li>Increase in Hct in T1D: - corrected by hydration 2 L/day</li> </ul>
Uguccioni, D. M., (1998) Med Sci Sports Exer Durham USA [5]	Cohort study of T1D diving with protocol	T1D (n = 16)  <b>n = 131 dives</b> over 1 week		BGL check 60, 30, 10 mins  BGL > 4.4 mmol/L (stable or rising) 42% required CHO prior to dive	No complications of hypoglycaemia occurred during or post dive.
Dear, G De L., (2004) UHM Durham USA [6]	Cohort study of T1D diving according to protocol.	T1D (n=40, 20 male, A1c 7.1-7.8%, 8 on CSII, <b>n=555 dives</b> )  Control (n=43, n=504 dives)  Average: 12-15 dives over 5 days	A1c < 9.0% No hospitalisation for diabetes for 12m Non pregnant No Cx	Depth: 20 +/-6m Duration: 41 +/- 10 mins Temp  BGL check 60, 30, 10 mins  BGL > 4.4 mmol/L (stable or rising) 42% required CHO prior to dive	<ul style="list-style-type: none"> <li>Post-dive hypo &lt;3.9 mmol/L in 7% of all dives</li> <li>Pre dive: BGL : 10.8 +/-3.6 mmol/L male, 12.4 +/- 3.9 mmol/L female</li> <li>Post dive: BGL: 7.8 +/-3.4 mmol/L male, 10.0 +/- 4.2 mmol/L female</li> <li>11 episodes of symptomatic hypoglycaemia (not during diving)</li> </ul>
Lormeau, B., (2005) Diabetes Metabolism France [7]	Cohort study of T1D divers	T1D (n = 15, 12 male, 1 CSII & CGM) Avg Age 40  <b>n=95 dives (of 120 completed)</b>	HbA1c: 7.2% Duration diabetes: 9yrs No complications	8 dives (over 4 days). (up to 20m, and 40 mins)  BGL test 60, 30, & 0 mins pre-dive:  BGL 8.8 – 13.8 mmol/L: dive BGL 6.6 – 8.8 mmol/L: 15g CHO & dive. BGL < 6.6 mmol/L: 30g CHO. Retest at 15min: If > 8.8 mmol/L: dive BGL > 13.8 mmol/L: test ketones. If Neg: dive.	<ul style="list-style-type: none"> <li>95/120 planned dives took place.</li> <li>2 dives cancelled due to low BGL, 1 for ketonemia.</li> <li>Others due to non-diabetes related factors.</li> <li>No hypo during dive.</li> <li>50% of dives required CHO pre-dive.</li> <li>Avg BGL drop 2.2 mmol/L</li> </ul>

Article	Objective	Participants	Suitability for diving	Dive protocol	Findings
Pollock, N.W., (2006) UHMS USA [8]	Cohort study of T1D diving. For close monitoring of BGLs	T1D (n = 7, 3 male, A1c 7.2%) <b>n = 42 dives</b>	A1c < 9.0% No hospitalisation for diabetes for 12m No Cx	Up to 17m, 44 mins  BGL check 60, 30, 10 mins > 6.7 mmol/L and rising to dive. If < 6.7 and/or falling: CHO and retest 15 mins prior to dive	<ul style="list-style-type: none"> <li>• CHO required prior to 76% of dives</li> <li>• BGL drop 4.3 mmol/L</li> <li>• 2 dives with post dive BGL &lt; 4.0, no symptoms</li> </ul>
Adolfsson, P., (2008) J Diab Sci Tech. Sweden [9]	Cohort study CGMS and SMBG	T1D (n =12, male, A1c 7.1%, 3 on CSII), <b>n=58 dives</b>  Controls (n=12) 5 dives over 3 consecutive days. (n=59 dives)	No secondary complications (macrovascular or proliferative DR). No hypo unawareness	Depth: 18-22m Duration: 42-52 mins Dry suit Insulin Mx as per pt BGL check, 90, 60, 10 mins CHO prior to dive	<ul style="list-style-type: none"> <li>• Mild hypo: 3 pre-dive, 6 post-dive</li> <li>• Hypos on CGM in the two weeks pre-dive correlates with hypoglycaemia peri-dive.</li> <li>• Pre-post BGL difference: -1.4 to -3.3 mmol/L in T1D</li> </ul>
Adolfsson, P., (2009) Diab Tech Therap Sweden [10]	Cohort study CGM accuracy and durability in diving	As above		Depth: 18-22m Duration: 42-52 mins Dry suit Insulin Mx as per pt BGL check, 90, 60, 10 mins CHO prior to dive	<ul style="list-style-type: none"> <li>• 85% survival of CGM over 48 hours</li> <li>• CGM relatively accurate</li> </ul>
Bonomo, M., (2009) Diab & Metab. Italy [11]	Cohort study Safety of T1D diving according to protocol via CGM & SMBG	T1D (n=12, 8 male, A1c 7.1%, 1 on CSII, 11 MDI)  <b>90 dives</b>  Medtronic CGM	A1c < 8.5% No hospitalisation for diabetes for 12m Absence of hypo-unawareness (<3.5 mmol/L on 72h CGM) No Cx (> background retinopathy, >20mg/d microalbuminuria, neuropathy, macro CX)	Depth: 21 +/- 3.7 m Duration: 46 +/- 5 mins Temp:  BGL check, 60, 30, 10  Insulin if BGL >16.7 mmol/L at 60min or BGL > 13.9 mmol/L at 30 min  CHO (15-30g) if BGL < 6.6 mmol/L or dropping  If hypo: eat CHO underwater	<ul style="list-style-type: none"> <li>• 4 occasions of symptomatic mild hypoglycaemia</li> <li>• all four occasions: protocol wrongly followed</li> <li>• Pre dive: BGL 11.1 +/-3.4 mmol/L</li> <li>• Post dive: BGL 8.8 +/- 4.4 mmol/L</li> <li>• Poor CGM availability: 56%</li> </ul>

## APPENDIX 2: SUITABILITY FOR DIVING (Comparison of guidelines)

Country/Region	USA	UK	France	Italy	Canada	Sweden	South Pacific
Source	NW Pollock (UHMS, DAN consensus guidelines) [12]	UKSMDC, BSAC & UK diving (Guidelines) [13, 14]	B Lormeau (Cohort study) [7]	M Bonomo (Cohort study) [11]	Harrison (Guidelines) [15]	Jendle (Recommendations) [16]	SPUMS (Guidelines) [17]
Year	2005	2005	2005	2009	2005	2012	2010
Age	> 18 yrs (>16 yrs if specialised training program)		> 18 years		Adult		> 18 yrs
Glycaemic Control	HbA1c: ≤ 9.0% (<1mth + annual review)	Physician in charge considers "satisfactory control"	HbA1c: < 8.5%	HbA1c ≤ 8.5% (<2mths)	Well-controlled	HbA1c: 5.0 - 8.8%	HbA1c: ≤ 9.0% (<1mth + annual review)
Diabetes regimen changes	More than 3 months since significant alteration in glucose lowering medications. More than 1 year since initiation of insulin (or 6 months since initiation of insulin in T2D on medication therapy)						More than 3 months since significant alteration in glucose lowering medications. More than 1 year since initiation of insulin (or 6 months since initiation of insulin in T2D on medication therapy)
Diabetes self management	Good knowledge of insulin, carb adjustment					Good knowledge of insulin, carb adjustment. Regular BGL testing 4-6x/day in the week lead up to dive. Annual CGM.	Good knowledge of insulin, carb adjustment
History of Hypoglycaemia	No hypo/ hyper requiring 3rd party assistance for 1 yr.	No severe hypo for 1 yr	No severe hypo for 1 yr			No severe hypo for 1 yr	No severe hypo for 1 yr
Hypoglycaemia awareness	No history of hypo unawareness		Good perception of hypo	No hypo unawareness (asymptomatic when BGL <3.3 mmol/L for >10mins on 72h CGM)		No hypo unawareness	No hypo unawareness
Hospitalisation		No diabetes-related hospitalisation for 1 yr		No diabetes-related hospitalisation for 1 yr		No repeated episodes of admission	
Diabetes Complications	No significant complication		No significant complication		No complications		
- No microalbuminuria	Yes	Yes	Yes			Yes	Yes
- No neuropathy	Yes	Yes	Yes			Yes	Yes
- No more than background retinopathy	Yes	Yes	Yes			Yes	Yes
Cardiac Screening	Stress testing if > 40yr + surveillance as per local guidelines	Stress ECG if >50yrs					Stress ECG if > 40yr
Physician Assessment & certification	Diabetes physician & Diving doctor certification	Physician statement: "diver is mentally and physically fit to dive"	Medical certificate from diabetologist & Federal French diving federation physician				Diabetes physician & Diving doctor certification
Physician Review	Annual	Annual					Annual

### APPENDIX 3: SCOPE OF DIVING (Comparison of guidelines)

Country/Region	USA	UK	France	Italy	Canada	Sweden	South Pacific
Source	NW Pollock (UHMS, DAN consensus guidelines) [12]	UKSMDC, BSAC & UK diving (Guidelines) [13, 14]	B Lormeau (Cohort study) [7]	M Bonomo (Cohort study) [11]	Harrison (Guidelines) [15]	Jendle (Recommendations) [16]	SPUMS (Guidelines) [17]
Year	2005	2005	2005	2009	2005	2012	2010
Number of dives		≤ 2 dives per day ≤ 3 consecutive days	2 dives per day 4 consecutive days	2 dives per day 5 consecutive days			≤ 2 dives per day > 2 hour surface interval
Depth	≤ 30 meters	≤ 30 meters (until considerable experience gained of how diabetic control affected by diving)	15 – 20 metres			≤ 25 meters	≤ 30 meters
Length of dive	≤ 1 hour		30-40 minutes				≤ 1 hour
Dives requiring decompression stops	Not recommended						Not recommended
Dives requiring overhead environments	Not recommended						Not recommended
Requirements for a diving partner/buddy	Buddy should be informed of condition & aware of appropriate response if hypoglycemia. Buddy should not have diabetes	A regular diving buddy and who is familiar with the diver with diabetes or trained medic, nurse, or paramedic who is familiar with the problems of diabetes. Diver must not dive with a buddy who has diabetes	Each diver was assigned instructor from diving crew			Buddy without diabetes	Buddy should be informed of condition & aware of appropriate response if hypoglycemia. Buddy should not have diabetes

#### APPENDIX 4: BGL MANAGEMENT ON THE DAY OF DIVING (Comparison of guidelines)

Country/Region	USA	UK	France	Italy	Canada	Sweden	South Pacific
Source	NW Pollock (UHMS, DAN consensus guidelines) [12]	UKSMDC, BSAC & UK diving (Guidelines) [13, 14]	B Lormeau (Cohort study) [7]	M Bonomo (Cohort study) [11]	Harrison (Guidelines) [15]	Jendle (Recommendations) [16]	SPUMS (Guidelines) [17]
Year	2005	2005	2005	2009	2005	2012	2010
<b>General advice on lead-up to dive day</b>	No diving if unwell, unduly anxious or BGL unstable. Adequate hydration.	Fit & mentally prepared. Adequate hydration. Aim BGL slightly high by consuming glucose.	Fit & mentally prepared.	BGL monitoring intensified to at least 8x daily	Self adjust insulin and meds in consultation with physician	Monitor BGL at least 4-6x daily. Meal 2 hrs prior to dive.	No diving if unwell, unduly anxious or BGL unstable. Adequate hydration.
<b>Pre dive</b>							
<b>BGL testing prior to dive</b>	60, 30 mins & immediately pre dive		60, 30 mins & immediately pre dive	60, 30 mins & immediately pre dive	Frequent testing 30-45 mins pre dive	60, 30 mins & immediately pre dive	60, 30 mins & immediately pre dive
<b>BGL threshold to allow commencement of dive</b>	8.3 mmol/L & stable		8.8 -13.8 mmol/L	13.9-16.7 mmol/L & no ketones; 8.3-13.9 mmol/L & stable; 6.7-8.3 mmol/L & rising		7.0-12.0 mmol/L & stable	9.0 mmol/L & stable or rising
<b>BGL &amp; Carbohydrate management protocol</b>			<ul style="list-style-type: none"> <li>If BGL &lt; 6.6 mmol/L, consume 30g CHO &amp; retest in 15-30min, if BGL increase to &gt; 8.3 mmol/L – OK to dive</li> <li>If BGL 6.6-8.8 mmol/L, consume 15g CHO &amp; OK to dive;</li> <li>BGL &gt;13.8 mmol/L &amp; no ketones - dive.</li> </ul>	<ul style="list-style-type: none"> <li>If &lt; 6.7 mmol/L or dropping, consume 15-30g CHO &amp; retest.</li> <li>If BGL 6.7-16.7 mmol/L – OK to dive.</li> <li>If BGL &gt; 16.7 mmol/L (or &gt; 13.8 mmol/L with ketones) - insulin bolus as calculated by insulin sensitivity factor</li> </ul>		<ul style="list-style-type: none"> <li>Meals 1.5 to 2 hours prior to dive.</li> <li>Additional CHO 15-20g per 70 Kg immediately pre-dive</li> </ul>	
<b>Postpone dive if</b>	BGL < 8.3 mmol/L or falls between any 2 measurements			If BGL < 6.7 mmol/L If BGL > 13.8 mmol/L with ketones; If BGL > 16.7 mmol/L and rising.			BGL < 9 mmol/L or falls between any 2 measurements.
<b>Cancel dive if</b>			Ketonaemia				BGL > 16 mmol/L at any stage
<b>Post dive</b>							
<b>BGL management at end of dive</b>	BGL check end of every dive with response determined by individual mindful of plans for rest of day	BGL check on arrival on boat. Any symptoms immediately reported to buddy or manager	BGL checks 0, 15 and 30 mins after boarding boat	Check BGL immediately post dive	Frequent BGL monitoring 30-45 min after dive	BGL check immediately post dive	BGL check immediately post every dive
<b>Diabetes management following dive</b>	Frequent BGL checks for 12-15 hrs after diving		Insulin adjusted every evening by diver & medical staff				Frequent BGL checks for 12-15 hrs after diving
<b>Documentation</b>	Log all dives, BGL management & refine for future dives.					Logbook of dives and BGL	Log all dives, BGL management & refine for future dives.

## APPENDIX 5: MANAGEMENT OF HYPOGLYCAEMIA DURING DIVING (Comparison of guidelines)

Country/Region	USA	UK	France	Italy	Canada	Sweden	South Pacific
Source	NW Pollock (UHMS, DAN consensus guidelines) [12]	UKSMDC, BSAC & UK diving (Guidelines) [13, 14]	B Lormeau (Cohort study) [7]	M Bonomo (Cohort study) [11]	Harrison (Guidelines) [15]	Jendle (Recommendations) [16]	SPUMS (Guidelines) [17]
Year	2005	2005	2005	2009	2005	2012	2010
Education & Preparation			Procedure for hypo, rehearsed pre-dive	Divers learnt to ingest carbohydrate gel underwater		Diver should practice ingesting gels underwater in controlled conditions	
Suspected hypoglycaemia signal	"L" signal with thumb and index finger		Specific hand signal	Specific hand signal		"L" signal with thumb and index finger	"L" signal with thumb and index finger
Access to oral glucose	Carried in readily accessible and ingestible form at surface and during all dives	Oral glucose tablets or tube of glucose paste in dive kit. Person in dive party knowledgeable re use (not necessary if T2DM on diet control or metformin)	Divers & instructors had sachets of glucose and condensed sweet milk in their jackets	Divers carried 2x 30-mL tubes of mixed carbohydrate gel in jacket		Carbohydrate gel or glucose/fructose solution carried by diver and buddy	Should be carried in readily accessible and ingestible form at surface and during all dives
Parenteral glucose/ glucagon	Available at surface (strongly recommended). Person at surface should be knowledgeable in use	In dive kit. Person in dive party knowledgeable re use. (not necessary if T2DM on diet control or metformin)				Available at surface	Available at surface (strongly recommended)
Procedure upon symptoms suggestive of hypoglycaemia underwater	Diver should surface, establish positive buoyancy, ingest glucose and leave the water. Assistance should be available via informed buddy		Ascend to the surface at the appropriate speed (15 m/min) with or without the help of an instructor, intake of sugar after surfacing and before boarding boat	Hand signal alerted buddy and pair started safe ascent		Signal buddy then pair start ascent to surface.  Carbohydrate gel can be ingested whilst underwater prior to ascent.  Test BGL once diving completed.  If hypoglycemia confirmed take 20g CHO if fully awake or 1g glucagon IM if unconscious. Dive aborted following normal decompression routines.	Diver should surface, establish positive buoyancy, ingest glucose and leave the water. Assistance should be available via informed buddy

## Appendix citations

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