THE SUGAR LEVEL IN DIVERS' BLOOD IN HYPERBARIC CONDITIONS

Augustyn Dolatkowski, A. Szczeblewska, Lucjan Łaba, Bogdan Łokucijewski

Department of Maritime and Tropical Medicine WAM, Gdynia, Poland

ABSTRACT

The authors examined 104 divers performing dives in water, 14 exposed to simulated conditions in decompression chambers and 11 control subjects. The average blood sugar reading before diving amounted to 100 mg% with readings of 101 mg% after diving, whereas in the control group these readings were 107 and 100 mg% respectively and in the group of simulated dives, 102 before and 106 mg% after the exposure. It was found that the diet applied ensured a sufficiently high level blood sugar level in the subjects to protect them against hypoglycaemia. Further research in decompression chambers is required.
Keywords: diving, sugar level.

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INTRODUCTION

The effect of elevated pressure on the human system is multifaceted and often manifests itself in detectable changes in the cardiovascular and respiratory system, peripheral blood [5,8,12,17], and presumably in a number of other changes.

Depending on the flexibility of the adaptive processes of an organism, such disturbances may not only occur whilst exposed to an atmosphere of increased pressure, but may also persist once the exposure ceases. Some of these phenomena are not yet sufficiently known, as evidenced by repeated research on the physiopathology of high pressure.

The behaviour of blood sugar levels in an atmosphere of an increased pressure is one of the issues that has already been investigated due to its great theoretical and practical importance. This particularly applies to the possibility of lowering blood sugar levels. Indeed, despite the existing compensatory systemic mechanisms, hyperbaric conditions may lead to an occurrence of dangerous disorders in the diver in the form of hypoglycaemia, whose clinical symptoms such as a feeling of weakness and dizziness have been occasionally reported by examined dives. This fact prompted us to undertake research in this direction.

The assumption of our work was to investigate whether there are significant fluctuations in blood sugar levels due to the divers' staying and working in hyperbaric environments.

MATERIAL AND METHOD

The study was conducted among military divers aged between 21 and 23 performing training dives with the use of air-fed diving apparatuses. The blood sugar level was studied in 104 divers, with a total of 208 assays. Dives during which the study was carried out were divided into 3 groups depending on the diving depth. These were dives: up to 40 meters, up to 60 meters and over 60 meters [4]. The average duration of stay under water for the group diving up to the depth of 40 meters was 20 minutes, up to 60 meters 35-50 minutes, for those diving at depths exceeding 60 meters up to 90 minutes.

At the same time, a blood sugar test was run on 14 divers who did not dive in water but instead performed simulated dives in pressure chambers, where they were exposed to a pressure of 1 to 6 atm. They were also examined before entering and after leaving the chamber in which they stayed for a varied amount of time depending on the decompression time strictly defined in Haldane's tables.

In parallel to the research with divers, blood sugar levels tests were conducted in a group of 11 people, i.e. the control group. The control group consisted of the same divers, remaining in the same conditions as the main group, who did not perform dives on the defined day. In this group the sugar level was tested three times: at 9.00 am, two hours after breakfast when a group of divers began to descend into the water, at 10.00 am, when the divers were at the bottom, and at 11.00 am, when the divers ascended to the surface, which corresponded to the "post-diving" test in the experimental group.

The examined group encompassed healthy men under constant medical supervision, ensured of the same living conditions and uniformly fed. The daily caloric value of food was 5700 kcal, of which breakfast encompassed 1580 calories (44g protein, 50g fats, 241g carbohydrates).

Breakfast was consumed at 6 am, with the dives commenced at 9.00.

Blood was drawn from the ulnar vein twice immediately before the dive (prior to putting on the suit) and afterwards (5 minutes after the diver left the water). Blood sugar levels were determined by the Hagedorn and Jensen method according to Charłampowicz-Laszczkowa. [2] Blood was drawn from the ulnar vein due to the simultaneously performed work on protein fractions in the serum.

The first phase of the study, namely blood deproteinisation, was performed immediately at the sampling site. Further activities were carried out at the laboratory upon the lapse of 3 to 5 hours after the deproteinisation, which in relation to the above described course of action could lead to a 10mg% decrease in glucose [3]. The error of the method was established on the basis of standard tests on the glucose solution and blood samples from one specimen.

1. Method error based on 10 samples of standard solution (200 mg in 100 ml.): glucose level 198 ± 6.3 mg%, mean error (S): 1.9,
2. Method error based on 10 blood samples from one specimen: glucose level 100 ± 6.6 mg%, mean error (S): 2.1.

RESULTS

The obtained results are presented in table 1.

Tab. 1

Blood sugar levels in particular groups.

Up to 40 m (44 persons))	Mean A	stand. deviation	stand. Error S	max	min
Before diving	101	±13,7	2,0	134	77
After diving	95	±13,2	2,0	123	70
$3S_1 + 3S_2 < A_2 - A_1$ 2>6					
Up to 60 m (27 persons)	Mean A	stand. deviation	stand. Error S	max	min
Before diving	97	±15,2	2,9	128	74
After diving	103	±15,9	3,1	134	64
$3S_1 + 3S_2 < A_2 - A_1$	18>6				
Above 60 m (33 persons)	Mean A	stand. deviation	stand. Error S	max	min
Before diving	102	±13,5	2,3	132	75
After diving	108	±16,6	2,9	143	77
$3S_1 + 3S_2 < A_2 - A_1$ 15>6					

The table shows that the observed "before" and "after" differences are small and are statistically insignificant; calculations were made according to the formula: $3S_1 + 3S_2 < A_2 - A_1$, i.e. the difference is significant when the sum of the tripled standard error (S) is smaller than the remainder of the arithmetical means (A) of the two groups being compared. As it can be seen, the sum of the tripled error is greater than the remainder of mean values, which proves the statistical insignificance of these differences [17,22].

The following results were obtained for the dives simulated in the chambers: before exposure: 120 ± 10.8 mg %; after exposure: 106 ± 10.7 mg%. The results of the examination of divers and the control group are presented in Table 2.

Tab. 2

Comparison of blood sugar levels in divers from the control group.

Groups	Time	9.00	10.00	11.00
Diving (104 people)	Average A	100	-	101
	Stand. deviation	±14,3	-	±16,1
	Stand. error S	1,4	-	1,5
	Max	134	-	143
	Min	74	-	64
Control (11 people)	Average A	107	93	100
	Stand. deviation	±10,6	±10,3	±14,8
	Stand. error S	3,2	3,2	4,8
	Max	126	114	136
	Min	90	79	87

The table shows that the blood sugar level in divers before and after diving is basically the same (a difference of 1mg%); in the control group, the 9.00 and 11.00 o'clock examinations also showed a small difference of 7mg%.

The comparison of the two groups at the same time (9.00 and 11.00 am) also reveals small differences (at 9.00 am – 7mg%, at 11.00 am – 1mg%).

The juxtaposition of the statistical significance of these differences is presented in Tables 3 and 4.

Tab. 3

Groups	9.00 am	11.00 am
Diving	100 ± 14,3	101 ± 16,1
Control	107 ± 10,6	100 ± 14,8
$3S_1 + 3S_2 < A_2 - A_1$	13,8>7	18,9>1

Tab. 4

Groups	9.00 am	10.00 am	$3S_1 + 3S_2 < A_2 - A_1$
Control	107 ± 14,3	93 ± 10,3	19,2>14

As before, all differences appear to be statistically insignificant. Only one interesting result is found in the control group in the examinations performed at 9.00 and 10.00 am, where the difference is closer to statistical significance and is equal to 14 mg%.

The 10 o'clock test, where the sugar level amounted to 93 mg%, corresponds to the time when the diver is at the greatest depth. Compared to the other average results, this value is the lowest.

Tab. 5

The comparison of results of total standard deviation values A ± before the exposure; A=100, stand. dev. = ± 14.3.

Porównanie wyników wartości A ± odchyl. stand. całości przed ekspozycją; A=100, odchyl. stand. = ± 14,3.

Group	A+stand. dev.=114	A-stand. dev.=86
up to 40 m	7	7
up to 60 m.	3	8
above 60 m	4	4
	14/13%/	19/18%/

Tab. 6

The comparison of results of total standard deviation values A ± after the exposure; A=101, stand. dev. = ±16.1.

Group	A+stand. dev.=117	A-stand. dev.=85
up to 40 m	2	11
up to 60 m.	4	2
above 60 m	10	3
	16/15%/	16/15%/

Tables 5 and 6 present the cases with values exceeding stand. dev. A ±. We have assumed that this range covers most of the average cases with values beyond that range deserving further attention. Before diving 13% of results are above and 18% below the stand. dev. value A±.

After diving, the proportion is similar; 15% above and 15% below the mentioned value. It is worth emphasising that in the group of the deepest dives 10 results are over the deviate. Stand value A+. (after diving), whereas before diving in the same group there are only 4 such results. Similarly, attention is drawn to 11 results of stand. dev. value A in the group performing the shallowest dives, obtained after their completion.

DISCUSSION

In our work we wish to emphasise two aspects of the discussed issue. The first is the effect of an increased atmospheric pressure on an organism and the second is about having the right choice of diet for diving personnel.

The effect of hyperbaric conditions on the human organism is diverse and, inter alia, manifests itself in changes in the circulatory and respiratory system [5]. The effect of blood pressure on blood sugar has been studied on numerous occasions.

In the cited work [23], the authors report that divergent results were obtained in studies of the effects of hypobaria on blood sugar levels; from hypo- to hyperglycaemia. The same is true of hyperbaria. Based on our research, we cannot comment on the significant impact of an increased pressure on sugar levels which before and after diving was the same. The downside of our work is the inability to perform a glycemic curve that, in a far more specific way, indicates any possible carbohydrate metabolism disturbances as compared with one or two sugar level tests.

In the case of deep dives it is difficult to perform, and in many cases practically infeasible. The average blood sugar level in our study reached 100 mg% before and after dives, with the lowest levels noted upon dive completion in the group diving at relatively shallow depths, whereas in the group performing dives at the greatest depths the results contained the majority of the highest deviations observed upon dive completion.

From the numerous influences that have an effect on blood sugar levels, apart from hyperbaria, we can exclude the time of work, as our research focused on training dives where the divers did not perform any work at the bottom. The slight hyperglycaemia observed in the group executing the deepest dives should not be associated with emotional factors.

They are common in young, under-trained and inexperienced divers, unaccustomed to such working conditions.

The effects of both hyperbaria and emotional stimuli can occur via the hormonal path due to an increased activity of the sympathetic nervous system, and secretion of adrenaline [12, 25] or via other routes.

In order to compare the levels of sugar in humans selected from the same group, but whom however were not executing the dives, we have examined the control group and performed a regular glyceamic curve.

We will quote only three values from the curve – analogously to the researched period. While extreme values are similar, the sugar level at 10 am is slightly lower according to the physiological sugar curve. We can assume that the situation is similar in relation to divers, however the observed slight drop in sugar level in the control group does not entail any complications unlike actual hypoglyceamic states which are dangerous for divers.

The group of divers examined in chambers were not considered in our calculations due to the small number of cases, and moreover because such a study deserves to be the subject of a separate work. The mechanism of hyperbaria used here has a different effect on the organism from an actual dive, as such additional factors as stress, work, dense environment, reduced temperature, or weightlessness which visibly affect the diver's body do not occur, thus it is difficult to evaluate the time when the effect of hyperbaria occurs.

The comparison of blood sugar levels in both discussed groups assumes their similar levels when the same diet is used. The effect of the quality and quantity of food on blood sugar is well known and extensively studied [14,19]. According to the available literature, under normal conditions the blood sugar level at around 10.00 am is lower and reaches 90-100mg%, thus it is similar to the results obtained in our research. The type of diet has a very important effect on blood sugar level. The quoted works show that higher levels of sugar are observed in the case of mixed carbohydrate-fat meals [19].

With such a diet, the sugar level 2-3 hours after breakfast is high enough for the diver to not be in danger of hypoglyceamia, and hunger occurs much later as compared with meals rich in carbohydrates. In light of the above, the qualitative composition of breakfasts received by the surveyed divers seems appropriate.

It is difficult to answer the question of whether blood sugar levels are significantly reduced during extended underwater stays at greater depths. This requires additional research into the isolated hyperbaric effects that can be conducted in decompression chambers.

CONCLUSIONS

1. Based on the blood sugar tests conducted in the divers before and after dives, no statistically significant deviations were found.

2. In the researched control group the examination conducted 2 hours after breakfast showed physiologically lower blood sugar values.
3. Further studies on the effect of hyperbaria in hyperbaric chambers are needed.

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Bogdan Łokucijewski
Katedra Medycyny Morskiej i Tropikalnej
Wojskowa Akademia Medyczna