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NITROGEN NARCOSIS DURING NO LIMITS FREEDIVING WORLD RECORD TO 160 M (525 FT)

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Introduction

This is a case report from my 2002 world record dives to 160 m (525 ft) in No Limits and a couple of previous training dives.

Methods

The No Limits dives in which I experienced what I believe to be nitrogen narcosis ranged between 100-160 m (328-525 ft) in depth and utilized a weighted sled for descent and inflated liftbag for the ascent. Approximate travel speeds were 1.5-2 $m \cdot s^{-1}$ round trip and the total times of 3:00-3:32 min:s. Prior to each dive, approximately 40 min of preparation took place, consisting of two shallow dives to between 15-25 m (49-82 ft) for 1:30-2:45 in time, and two short static apneas at the surface. The rest of the time was spent ventilating. During the descent of the final deep sled dives, the brake was used to facilitate easier equalization. I believe that I have also experienced brief narcosis on Constant Weight/Free Immersion dives to between 50-70 m (164-230 ft).

Results

The sensations of my narcosis were essentially the same on each occasion (approximately five instances total) and varied only in severity. On the worst occasion (at 160 m [525 ft] on a No Limits dive) I spent approximately 10 s unable to concentrate enough to operate my liftbag and was confused about what functions I had already performed. Once on the ascent, I felt severe numbness especially in my head and bit my tongue hard on purpose so that I could feel something. I do not remember a large portion of the first part of the ascent, until around 90 m (295 ft) or so.

Conclusion

My conclusion is that these feelings and symptoms were due to nitrogen narcosis.

PRESENTATION

MS. STREETER: Thank you very much. I appreciate very much the efforts that Dr. Lindholm and the organizing committee who have brought us together. It is really an honor for me to speak here, to follow Dr. Lundgren, who I never met, but have heard so much about, and also DAN and UHMS. I really want to thank everybody involved for bringing us all together.

We stand to learn a lot. We stand to be able to improve a lot in our performances. We are athletes first, so that tends to be our objective, and, obviously, to stay safe. So it is greatly appreciated.

I am going to discuss my experiences with narcosis. I thought a lot about how I would do this presentation, as intimidated as I am by the audience and what I can person personally offer other than personal experience. So I decided that it would just be my personal experience that I would offer you. And rather than presenting a Power Point presentation or anything, I had the advantage of a film being made about this particular dive that I am going to discuss today. So I will show you that film which lasts in total about 20 min. There is a gap in the middle, which kind of gives me a good opportunity to say a few things about the first part of the film and what you can expect in the second part of the film.

Other than that, I will point out that it is a film. It was made by a United Kingdom production company in conjunction with the Discovery Channel here. Some of you may have seen it. I apologize if it is a little bit repetitive. However, from my perspective, being the subject of the film and living the training and the diving and everything as I was doing in 2002 when this was made, I thought that the real-life version was plenty dramatic enough, and was clearly irritated by how overdramatized and oversensationalized the film ended up being. But that is what audiences need in our world of channels being changed every three seconds; it has to be exciting the entire time, the attention deficit disorder television generation of which I am as well.

So I did not watch it. I watched it once. I was really irritated. I am irritated to the point where I got very, very upset about it. And I did not watch it again until I started thinking seriously about what I was going to talk to you about today. And when I watched it a few weeks ago, I actually, I was quite impressed. I mean, enough time has passed that I have forgotten a lot of the details of my own experience. So I thought, okay, it is not such a bad film after all.

I do just want to warn you, that, especially for this particular audience, there are things that the narrator says that are completely off the charts wrong. It does give you a good idea of how my experience is building up, how a record like this is put together. For those of you who do not know, it is a no-limits dive to 160 m (525 ft).

I had not discussed my experience with narcosis at depth publicly until about a year afterwards. When I say publicly, I just meant at dinner parties, mainly because I did not want my mom to know. I really did not.

As part of the rules, the iron rules of competition, the videos from the bottom and the top do get reviewed immediately after the record dive. There were a core group of people who saw what happened at the bottom. But what we were mainly focusing on was did I reach the bottom, was I assisted, and did I come back up myself. It was yes, no and yes. Nobody was particularly worried about the length of time I spent at the bottom and what you see on the tape.

When the film came out a few months later, I was a little bit scared about, you know, what people were going to say within the free diving community, whether my mom was going to pick up on it. She did not really, so that was okay. She was sitting next to me at the time going, and I am going, it is okay, mom, I survived. I am here. It is fine.

Retrospectively, I can say that I had suffered narcosis before this. My first no-limits dive I did suffer, I think, once, maybe twice. Kirk Krack was there. Sorry. I was rude to him afterwards because I did not understand narcosis so I did not know what was going on. My first public apology.

There was probably only two times after that that I suffered narcosis. Neither of them were on the sled. The sled has us upright, and they were dives when I was inverted and not going quite so deep. The temperature of the water was not any different. I have always done a lot of my diving in the

Caribbean, so I am spoiled rotten by the warm water. Perhaps I am not exposed to as many elements that can cause as much narcosis.

(The film was shown.)

MS. STREETER: Basically everything that sort of happened so far in the film happened – it is relatively realistic. The test that took place in the chamber was completed about six weeks before we got out.

MS. STREETER: My mom was very pleased at how much she made it into that film. I was just acutely embarrassed. So that is how it all played out. We did not discuss any of the effects of the nitrogen narcosis that I felt at depth.

Basically, my experience was, as you can see, it was a stressful dive. It was not quite as dramatic in terms of how it played out in terms of how I was progressing. I was a few feet away two days beforehand, but within a week, within a seven-day period, I did progress an awful lot because I was not hitting my target depths in training.

And the record was set on a Saturday at 160 m [525 ft]. On the Thursday, which is the dive I did before I did, 156 m [512 ft]. And on the Tuesday before that I did 152 m [499 ft]. But up until that point I was still – I cannot remember the depth. I just know it was less than the one I was trying to beat, so it must have been 135 or 136 m [443 or 446 ft]. So I made the sort of big leap of 20 m [66 ft] within just seven days of setting the record.

And then on the day itself, as you saw, anyway, I was nervous and stressed because it was record day, but I also had this momentary loss of consciousness right before I dived. And we reviewed the video time and time again, the surface video, and it was about 20 s between when I woke up to when I went again. I was very aware that everyone was in position, and I did not have time to prepare properly again, to relax completely again. Under the rules at that point in the sport, the Judge is only worried about blacking out after the record. There were not any rules about blacking out before the record.

I always say there is a thin line between trying hard and trying too hard. And as a good athlete, I butt up against that line but try not to go over it. I will be the first person to tell you that I certainly went over it that day.

I have a determination that I sometimes do not even understand in terms of what I am capable of doing. And on that day deciding in such a short space of time that I was still going to go for it, I do not know what process was going on in my head, but I did ask the Judge and the Judge said yes. So I took a quick breath, and I would estimate that I probably descended with about 75% of the lung volume that I would normally have done in a dive like that. I just did not have the time to prepare. I did not pack anything as much. I did not take initially as deep a breath as I would have taken.

During part of the descent, my first thought was what am I doing? We have tomorrow. There is no need to do this. Then my second thought, and I have this constant battle with myself on every dive, and I think a lot of free divers would confess to the same thing. I essentially decided that, okay, I will just treat it like a training dive and I will do the best that I can. Because everybody else was already in the water already doing the best that they can.

By the time I got to about 80 m [262 ft], I started to have problems equalizing. On a dive like this that is actually very shallow. I normally am able to equalize comfortably to about 110 m [361 ft].

When I did reach somewhere between 100 and 110 m [328 and 361 ft], and I did know this because my divers are stationed there, that is the point at which I stopped completely because I just could not equalize anymore. I recall being able to equalize just a little bit at that depth and making the decision to go on, and just see how far I can go. Because that is kind of what every training dive is like. I will just do my best and see how far I can go.

Consequently, the descent was a lot slower than normal. And then I did not equalize again between about 110 and 160 m [361 and 525 ft]. So I was in significant discomfort with my eardrums, not that much more than I expect I would have been, but, like I said, I normally have my last equalization around 130 m [427 ft]. So to have not equalized between 110 and 160 m [361 and 525 ft], my eardrums were already significantly bent in and compressed anyway, so there was quite a lot of pain.

The other thing that I think was probably the leading factor in why I stayed at the bottom so long and the confusion that I suffered was, we have a system. When we arrived at the bottom, I have three steps. My first step is to put my left hand on the lift bag because that way I know I am holding on to my ride back. My second step is to crank open the valve and start releasing air into the lift bag. My third step is to pull the pin.

It is very simple, it is one, two, three. We practice it time and time again on training dives. We practice it after a couple of glasses of wine. I am just kidding about that part. You would not drink during training. We just make sure that this is a habit, that we are going to do it no matter what.

When I arrived at the bottom, I had already decided weeks beforehand that I did want to spend a couple seconds there, maybe three, four or five seconds. I knew that I may never go that deep again. I knew I was always going to get asked the question what is it like. So I wanted to be able to give my best answer. I also wanted to do my little, romantic thing and blow a kiss to the sea.

When I arrived at the bottom, I went one, two, three. And I thought, okay, well, I have done three steps. That is when I knew I was not thinking very clearly. I waited and I thought, okay, well, I am not moving. I did not feel any physical sensations other than just not being able to think clearly.

I was going through the steps in my mind. Yes, I have done three steps. And I remembered back to three or four years previous when I did my first record, I was diving with a sled that used to stick. The top part of the lift bag used to stick on the aluminum pole, and we used to have to jiggle it a little bit, which is quite unnerving.

I thought maybe I am just stuck. That is the point at which you see me shake the bag a little bit. I thought maybe there is not much air in it. I was thinking but just not thinking clearly. I brought my fins up out of the wedge, the fin bin, and decided that I was going to try to push 90 pounds of weight back up to the surface.

The total time that I spent at the bottom was about 17 s. It looks a lot more on the film because that is what sells. But it was about 17 s, which is about 15 s too long, but it was, it was not as agonizing and long as it looks.

Finally, it was sort of like a light bulb went off, "Oh, pull the pin." Because I had opened the tank valve so much, I began to move a lot faster than I ordinarily would move. All of the clips of the ascent that you saw in that film are all from the record ascent. Then generally, it would move a lot slower. I would put enough air into it where it would just start moving, and I would enjoy the ride up and let it go slowly.

I, for one, believe, it is kinder on your body to return to the surface as slowly as possible. I would normally let go of the lift bag at around 150 ft [46 m] and then swim the rest of the way up. We are not out of breath on a dive like this. We are not burning a lot of oxygen. So we believe there is not the danger of blacking out for that reason. We believe it is kinder on your body to let everything return to normal in your body as soon as possible.

Having suffered the little crisis I did at the bottom, when I did leave the surface, as soon as I relaxed in the knowledge that I was on my way back up again I did start to have an overwhelming sensation of numbness in my whole body, so I actually bit down on my tongue very, very hard so that I could feel something in my body because I truly could not feel anything else except this pain that I was inflicting on myself.

And I remember very clearly leaving the bottom, and for probably about 100 ft [30 m]. But there is probably a good 250 ft [76 m] of travel that I do not remember at all. I would normally wave at my divers as I went by. I would normally give them a signal or I sense where the cameras and will do something funny. But I did not do any of that. I just held on for dear life. Retrospectively, I can tell you that I do not remember a significant portion of that.

Then probably around 100 ft [30 m], I noticed the light, and started to become aware of what was going on again. And, obviously, I am still holding onto the lift bag. Where I would ordinarily have reached back and released my safety clip, which is a line attaching me to above the rope on the lift bag, I was trying to reach back and release it. But it needs to be taut. And because I was holding onto the lift bag and not with my arms straight up, I was really gripping onto it because it was so full, I had my arms slightly bent so there was not the tautness on the safety line that I needed to be able to release it. From about 150 ft to 50 ft [46 m to 15 m], I was just trying to release the clip.

I was not feeling any sensation of narcosis anymore, but I could not release the clip, which is why I went whizzing past my husband. And I managed to release that and let go of the slack probably about 30 ft [9 m] from the surface and then swam up.

My sensations experienced at the surface was no different other than thinking, oh, my goodness, I am just glad that is over. I did not want to go do it again in the next day or two. My ears were painful, but other than that I felt completely fine.

I do not think there is anything else that I can tell you about that dive. The way I thought I would handle this is rather than give you information that you perhaps do not want or are not looking for was just to open it up to questions a little bit earlier than normal. I invite any questions that you might have that I can answer from my completely non-scientific, non-medical background.

WORKSHOP DISCUSSION

DR. BENNETT: You mentioned narcosis. The problem is that you take only one breath and you have only got 80% nitrogen. I do not think there are enough molecules of nitrogen to make you narcotic with nitrogen. I think what you are getting is the effect of hydrostatic pressure on your brain. And that starts to appear between 400 and 600 ft [122 and 183 m]. And it is a difficult one to recover from. You recover when you come up from the pressure, but the pressure itself will cause the problem.

MS. STREETER: Should it not happen on every dive then?

DR. BENNETT: Yes. If you go deep.

MS. STREETER: I have probably done between 15 and 20 dives over 100 m [328 ft].

DR. BENNETT: It is going to be about 500-600 ft [152-183 m], ideally.

MS. STREETER: I have suffered from that sensation between 150 and 200 ft [46 and 61 m] while in an inverted position. But I have not suffered from it every time I have gone over 400 ft [122 m]. Probably only twice, and I have been beyond that depth about 10 times.

DR. BENNETT: Well, I do not know. There may be some other explanation, but the most likely one is divers getting deeper and deeper to the 600 ft [183 m] level is HPNS. The CO_2 level, CO_2 narcosis, all kinds of things.

DR. LUNDGREN: Again, congratulations. This is the first time, certainly in front of a wider audience, that anybody has admitted to narcosis in breath-hold diving, which I think is extremely interesting. Now, these questions are not for you, but maybe we are allowed to also have an interchange between us here. I would like to ask this, since you brought up this interesting question, did this sound to you like a typical HPNS? To me it sounded like nitrogen narcosis. But this requires some rather involved quantitative calculations.

This is a situation where the nitrogen that is available is in the lung, and it is not that little, would potentially be the cause of narcosis. Do you know your total lung capacity?

MS. STREETER: When I did that dive, probably around 7.2 L.

DR. LUNDGREN: At any rate, it is compressed here. It is an amount of nitrogen that is not likely to be evenly distributed to the body tissues in the short period of time that you are talking about here. With a diving response, where the periphery is vasoconstricted the nitrogen would go mostly to the brain. And if you look at that, I bet you will find that there may be a very substantial brain PN_2.

The other aspect, and this is not a question but a comment – that I find pertinent here, is that, if this is nitrogen narcosis it answers a question that has often been raised. Namely, is it at all possible to absorb a significant amount of nitrogen from a lung that is severely compressed. The lung tissue follows the compression of the air, so that the exchange surface area normally about 70 m^2 between the lung blood and the gas space is reduced to an extremely small area. That could support the HPNS theory, of course, but it is most interesting that if you stick with the nitrogen narcosis theory for while, that here we have nitrogen being taken up, certainly on the way down, but very rapidly through a severely shrinking exchange area. I think you have provided some very interesting information. Thank you again.

MS. STREETER: Thank you.

DR. BENNETT: I agree. Just add some other factors. If you were to breathe compressed air from scuba or something like that, and certainly U.S. Navy and the British Navy did studies with breathing oxygen at 400 ft [122 m] plus and taking that away, going back to compressed air. And at 2.5 min they are unconscious.

We studied British Navy submariners experiencing very rapid compressions of the sort of thing you are doing because we want to get individuals out of those submarines very rapidly. We tested 400 ft

and 500 ft [122 and 152 m] compressed air with compression in 11 s. So it is pretty fast. And we had reaction time measurements.

There was no immediate reaction time change at 400 ft [122 m]. There was a decrement at 11 s, and 30 s later there was a decrement, which was significant. There is some narcosis at 500 ft [152 m] with a full compressed air situation, but not one breath. There was only just a small significance. It was not strong. So I still have my suspicions about nitrogen narcosis. I think it may be a combination effect.

DR. FEINER: I am not going to do the math to try to prove whether or not it is possible, because it is very complicated. Nitrogen is soluble, so that the pressures could build up pretty substantially. It is also likely that there is some hypoxia. At that depth with that loss of lung volume you are probably going to mix venous oxygen levels. Having experienced both nitrogen narcosis and oxygen saturations at 50%, the feeling is not that dissimilar. I think the higher CO_2 levels may lead you to be more susceptible to it. And I think from comparative physiology there is certainly a lot of belief that part of the reason elephant seals exhale is bulk susceptibility to the bends, susceptibility to shallow water blackout and nitrogen narcosis as well.

It is also very strange having experienced nitrogen narcosis with someone as a diving partner who has been diving for many years at 200 ft [61 m] in Fiji who does not even get it anymore, it is a very strange phenomenon. One of my colleagues Dr. Eager already proved, there is nitrogen narcosis at sea level, so we are already starting from nitrogen narcosis.

DR. DUEKER: I am an anesthesiologist. I am thrilled by your dive. It is really exciting. I think the only thing that is going to work is if you make several more to the same depth.

MS. STREETER: You are going to have to talk to my mom about that. She is not going to go for it.

DR. DUEKER: Aristotle was known for a lot of wisdom. One of the things he said was that one swallow does not a spring make. That is one dive like this, one experience like this, it is fascinating, very provocative, but I do not think we can say that it is narcosis. There are a lot of different things going on.

It is very difficult to imagine that nitrogen would become that much of a problem with that little bit that you had, really. So I think it needs to be studied a lot more. Very provocative, and I hope you do it a lot more.

DR. SMITH: I am a surgeon from Key Biscayne, Florida. I am just interested in diving. How long was the total amount of time down and up? How much actual squeeze do you feel in your chest and airway being that deep on a single breath of air? And when do you start exhaling on the way up, because there is more and more data showing that exhalation on the way up might be beneficial.

MS. STREETER: The total dive time was 3:32 min:s. I did not begin my ascent until about two minutes into it. That includes the 17 s or so I spent at the bottom. I was fairly quick to 100 m [328 ft], but I took slightly over one minute to go from 100 to 160 m [328 to 525 ft]. That part was really quite slow. And then the ride back up is about 90 s.

DR. SMITH: Did you feel a tremendous squeeze in your airway or your lungs?

MS. STREETER: You feel it. I do not know how to quantify that, but it is significant. I feel it, particularly around 80 m [262 ft] or so, and I do not think it gets much worse between 80 and 160 m [525 ft]. A little bit, but it is nothing like the change from 0 to 80 m [262 ft].

DR. SMITH: Do you have a protocol when you start exhaling?

MS. STREETER: About two meters [six feet] from the surface. At the point you feel like you are going to explode if you do not because we have this tremendous inhalation and then packing on top of it. As soon as we leave the surface, the pressure is relieved. On the way back up again, you build back up and can feel quite significant intrathoracic pressure.

DR. SMITH: The only reason I ask is there is a recent article in Science about penguins or seals or whales that really do a lot of exhaling very early up in their dive. If you figure your lungs are compressed down to a nub and as they start expanding, you are coming up quicker, you might wonder if it might be beneficial to exhale earlier.

MS. STREETER: Freediving, on the way up, we use every ounce of buoyancy that we can to help us. Not in this dive because we are using the lift bag. But in the other disciplines of diving where we are self-propelled, if not on the way down and on the way up, then certainly just on the way up again, it helps.

A year later I did a world record to 400 ft [122 m], riding a sled down and coming up self-propelled. In that particular instance, having kicked all the way up, I did not want to lose any buoyancy in the last few meters, so I did not exhale.

MR. KRACK: I am with Performance Freediving. I can attest to Tanya's first narcosis incident. I want to back Tanya up by saying that both Martin Stepanek and Mandy-Rae Cruickshank have also experienced narcotic episodes. We have lots of evidence of divers both in constant ballast disciplines, other than self- or sled-propelled, where the descent rates are approximately one meter per second. And we have seen that in cold water or darker environments that sometimes this can be enhanced, which would support a narcotic type effect, whether it is CO_2-enhanced or whatever. So there are a lot of other instances of narcosis with freediving.

DR. SOUTHERLAND: Two comments. Nitrogen narcosis, at least anecdotally, after long saturation dives in the Navy when the guys are coming out of the chamber, so they have been in a healing oxygen environment for a month, month and a half or so, and they come out and take their first breath of fresh air, a lot of times people will get slightly dizzy for just a few seconds. The thing that was thought was always, gee, you just have not been around the nitrogen. So just take a couple of breaths of nitrogen. I do not know that it is something that has been reported.

The other thing is in throwing in with everything else, could the effects that you have also be due to maybe a transient hypovolemia, from the fact that you have had all this blood, so now you are just not perfusing as well at least for a few seconds or so during the time. We see that in our hypovolemic losses from warm-water diving, the guys are coming out of the water. You do have shunting over a few seconds. So that is something to consider.

MS. STREETER: Thank you. That is a lot for me to take in.

MR. LANG: I am interested, and I may have missed your workup dives. On compressed air scuba deep science diving operations, we usually have a series of workup dives, especially to be able to gather quality data and deal with the narcosis. And we find that over a period of two weeks or so, we are getting fairly accurate between 160 and 190 ft [49 and 58 m]. This is on compressed air and scuba. I missed your workup dives. Are these in 10 or 20 m increments?

MS. STREETER: That is a really good question. It takes place over about four or five weeks. I dive every other day. We take a day off in between. Typically six months before the record I will decide on the depth that I am going to go to. And typically that is based on the competitor before me, what they have done. And I will have to go a minimum of two meters [six feet] more to beat them. So we work back from there. I think I was going to do 138 m [453 ft].

What was your record?

MS. CRUICKSHANK: 136 m [446 ft].

MS. STREETER: So I was going to go for 138 m [453 ft]. It was my husband's idea that I go for the men's record. I told him, if you want the men's record, you do it. He did not go for that.

But my point is, we set that target of 160 m [525 ft]. Well, he did on paper, and we worked back from that and we increased. Deeper we go in smaller increments. In the beginning, I think my first dive, we did two dives that day. My first dive would have been to about 50 m [164 ft] and the second one would have been to about 70 m [230 ft]. That would have been it until the following day. Then I think we increased in 10 m [33 ft] increments to 130 m [427 ft] or so, and then in 5 m [16 ft] increments. Overall, I think I did 17 training dives.

On the morning of the dive my preparation involves a little bit of stretching, not yoga. Whoever it was that said that we all did yoga was not correct. And that would take place on the shore. When I get in the water, I will breathe without the mask on just through the snorkel for five minutes. It is very relaxing and it helps me to refocus. I will do a breath-hold, breathe for about three minutes, then hold my breath for two or so, just to relax. Then I will do static apnea for 2:00-2:30 min:s. Then I will do a pull down to about 60 ft [18 m] and stay there for 1:30-2:00 min:s and then pull back up again, so very slow and relaxed. Then a couple of minutes rest. Probably another apnea. Breathe up for another three or four minutes. Hold my breath for around three minutes. Then relax for a few minutes. Breathe up for about four, pull down to 75 ft [23 m] or so, and stay there for between a minute to a minute and a half and then pull back up slowly. And then relax for a couple of minutes. Then we start the 10 min countdown and I go. And the 10 min countdown is very relaxed breathing at the surface, abdominal and chest breathing, just very, very relaxed.

MR. LANG: Do you feel measurable increases in your ability by doing the workup dives like that?

MS. STREETER: I do not know.

MR. LANG: Obviously, it is not an expenditure of energy because you are not actually swimming down.

MS. STREETER: When pursuing record dives in disciplines where you swim down, I do not increase in 10 m [33 ft] increments. I tend to increase in two or three meter increments. But my preparation on each dive day stays the same.

My preparation occurs before I even get to the water, I do a lot of cardiovascular work. I do very little conditioning, sort of breath-holding stuff. I do not like swimming pools, so I do not like to train in swimming pools. I do a lot of cardio, and then I go pretty much straight to my dive training.

Thank you very much for listening.