Diving methods and decompression sickness incidence of Miskito Indian underwater harvesters

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Dunford RG, Mejia EB, Salbador GW, Gerth WA, Hampson NB, Diving methods and decompression sickness incidence of Miskito Indian underwater harvesters. Undersea Hyper Med 2002, 29(2): 74-85. Diving conditions, dive profiles, and symptoms of decompression sickness (DCS) in a group of Miskito Indian underwater seafood harvesters are described. Dive profiles for 5 divers were recorded with dive computers, and DCS symptoms were assessed by neurological examination and interview. Divers averaged 10 dives a day over a 7-day period with a mean depth of 67 ± 7 FSW (306 ± 123 kPa) and average in-water time of 20.6 ± 6.3 minutes. Limb pain was reported on 10 occasions during 35 man-days of diving. Symptoms were typically managed with analgesic medication rather than recompression. Indices of the decompression stress were estimated from the recorded profiles using a probabilistic model. We conclude that the dives were outside the limits of standard air decompression tables and that DCS symptoms were common. The high frequency of limb pain suggests the potential for dysbaric bone necrosis for these divers.

dive profile, dive computer, harvester, decompression sickness, Miskito, dysbaric bone necrosis

INTRODUCTION

The Miskito Indians inhabit the remote La Mosquitia region of the eastern shore of Honduras and the northeastern shore of Nicaragua. These indigenous people have used breath-hold diving to harvest lobsters as a principal form of income since at least 1960 (1). In about 1980, SCUBA diving techniques were introduced, allowing divers to harvest lobsters in deeper waters (1,2).

A recent survey of 39 Miskito Indian lobster harvesters indicated that they lack formal training in diving techniques, do not understand the causes of decompression sickness (DCS), and dive highly stressful profiles (3). Unpublished reports from a hyperbaric treatment facility in Honduras indicate that joint pain is common among these divers and that they routinely dive with symptoms of neurological decompression sickness (observation G.W.S.).

Popular accounts throughout the Western world have focused attention on the high incidence of morbidity and mortality resulting from DCS among Miskito Indian divers. However, there is little first-hand information on the specific characteristics of Miskito diving practices. In the present study, we monitored 5 Miskito Indian divers to record the dive profiles that they undertake and the associated symptoms of DCS that they experience.

METHODS

Divers and their assistants (cayuceros) were recruited for lobster diving in January 1998 from Wuavina, a Miskito village located on the Patuca River in Honduras. A representative of the 70-foot Honduran registered vessel *Harmac I* advanced divers approximately US$50 to board the vessel while the cayuceros received approximately US$10.

Eight of the 24 divers aboard were selected for inclusion in the study during diving equipment issue, a time when all divers were present. Prior to selection, 3 divers were eliminated because of prior treatment for DCS, while all others denied such prior treatment. Subjects were selected from a list of the remaining 21 divers without regard to the listing order. No diver declined to participate before or after selection. While some divers admitted to excessive alcohol or drug use (principally marijuana and another locally grown product similar to marijuana in use and in intoxicating effect) on the night before boarding the vessel, the observer noted that all appeared to be intoxicated on that occasion. However, none were eliminated from the study on that basis.

The 8 participants were male, with mean age of 31 years (range 24 to 38) and mean dive experience of 12 years (range 4 to 20). Their heights and weights averaged 168 cm (range 164 to 172) and 70 kg (range 64 to 76), respectively. All divers indicated that 24 days had elapsed since their last dive.

A Honduran observer accompanied the trip to assess the presence of DCS prior to diving and to conduct daily examinations for DCS during diving operations. Prior to the first dive, all participants were observed for signs and/or symptoms of DCS by interview and neurological examination and, in addition, information on dive training and knowledge of decompression sickness *per se* was obtained. Divers were not evaluated for the existence of dysbaric osteonecrosis, though previous studies have suggested that the prevalence may be high (4). During diving operations, divers were assessed each day for DCS by interview and by neurological examination. Interviews consisted of questions regarding joint pain, abnormal sensations and the quality of sleep. Each diver was given a neurological examination at the day's end, when the number of air tanks used per diver was also logged.

The neurological exam tested 9 neurological functions at a combined 56 separate sites. These included strength, sensation, Babinski's reflex, gait, Romberg's sign, tandem gait, micturation, vibratory sense, and reflexes. In addition, the observer evaluated the ear canals and tympanic membranes for trauma, ocular range of motion, proprioception of great toe, additional evaluation for sensory level using a pinwheel and skin sensation on the dorsum of the hand (pinch, heavy touch, light touch, sharp/dull, two point discrimination), as well as testing for nystagmus and clonus. Sensory level and hand sensitivity were tested on the initial, pre-dive exam and following any dive in which the diver presented with sensory deficits. The observer, a US Army trained corpsman, had performed this examination approximately 4,000 times in his 8 years on staff at St. Luke Medical Mission, Roatan, Honduras.

Participants signed an informed consent written in Spanish and approved by the St. Luke Medical Mission. For participants who could not read, co-signers verified that the terms of the consent form were understood.

Eight Cochran Commander dive computers, accurate to 1 FSW (3 kPa), logged dive time and deepest depth at 15-second intervals. Prior to boarding, the observer tested all units to 165 FSW in a chamber, checked all batteries for freshness and practiced battery removal and replacement, as data loss can occur if batteries are not replaced within 10 seconds of removal or if the batteries are inserted improperly (i.e. backwards). Further, he carried enough replacement batteries on board for at least one change-out on all computers.

Each dive computer was assigned to a specific diver and affixed to his regulator hose near the first stage using plastic tie-wraps. Divers could not easily reach the computers underwater nor remove them without detection. Dive computers were issued each morning, collected at the end of the day and checked for tampering during surface intervals when aboard the mother vessel. Resulting profiles were up-loaded using software supplied by the Divers Alert Network (Duke University, Durham, North Carolina).

A probabilistic model (5,6) was used to estimate the probabilities of decompression sickness occurrence (**P_{DCS}**) in the recorded profiles. Here, **P_{DCS}** is used as independent indices of the risk of decompression sickness *per se* and does not take into account risks of other decompression-related injuries such as arterial gas embolism. The estimates included both the overall or cumulative probability of decompression sickness for each profile, as well as the probabilities of decompression sickness during specific periods within the profile. The latter were obtained in the form of conditional probabilities (7,8), which gives the probability of decompression sickness occurrence in the period of choice subject to the assumption that decompression sickness has not yet occurred at the start of the period. Individual dives in recorded profiles occurred in "sets", separated by surface intervals of >= 48 minutes (*c.f.*, Results). Each period for the conditional probability analyzed was consequently chosen to begin at first descent in a dive set and end at first descent in the subsequent set or 24 hours after last surfacing in a profile. Thus, while the cumulative probability of decompression sickness increases or remains unchanged as one progresses through a profile, culminating in a final value representing the total or accumulated risk of decompression sickness for the entire profile, the conditional probability (**cP_{DCS}**) increases from zero at the start of the first dive in each dive set and culminates immediately before start of the subsequent set in a maximal value that is the probability of decompression sickness in the dive set itself.

RESULTS

Following heavy drug and alcohol use the night before departure, 6 of 30 contracted divers were unable to board the vessel. Immediately upon departure, all divers began smoking marijuana. Some were reluctant to be observed but others openly used marijuana frequently, including before and after diving and late into the night.

On route to the fishing grounds, divers were issued masks, fins, regulators, lobster snares, and hammers to break conch shells. Buoyancy compensators and weight belts were not issued and only a few regulators were equipped with tank pressure gauges. All subjects were found to have tympanic membrane scarring on physical examination.

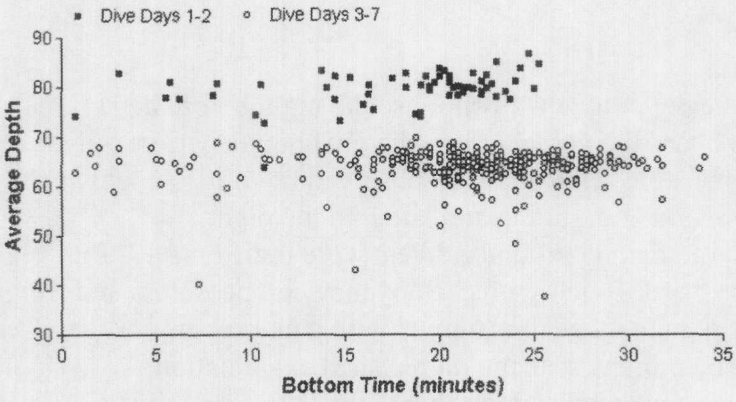
Using local knowledge and the ship's charts to select dive sites of less than 90 FSW, the captain stated he intentionally minimized diving depths to limit liability for DCS treatment and because of the presence of an on board observer in a time when the plight of the Miskito diver is under scrutiny. Despite an understood obligation by divers to produce a large catch to benefit all under scrutiny. Despite an understood obligation by divers to produce a large catch to benefit all the crew, divers are not directed by the captain how to dive or where (personal observation EBM). The observer did not direct or influence diver actions in this regard. All diving was done from a two-man, hand carved, wooden craft (cayuco) with the cayucero following the diver by observing his bubble trail. Dive sites changed by as much as 5 kilometers per day as dictated by available product. The initial two days of diving occurred on the Gorda Banks, northeast of the Honduran-Nicaragua boarder, with the remainder undertaken on the Rosalind Banks, one day further northeast.

Dive Profiles:

Subjects dove for lobster every day of the 11-day trip. However, after 7 days, diver computer malfunction after battery replacement caused loss of all data in three of eight computers. All computers were then removed from service. This analysis consequently centers on the first 7 days of data retained from the 5 divers whose computers did not malfunction (complete data), although tank use and symptom data obtained for all 8 divers over the 11 day monitoring period (symptoms only data) was also examined.

Nine dives that did not exceed 21 FSW (mean depth and dive time of 12 FSW and 0.5 minutes respectively) were excluded from the analysis because these were likely activities related to surface preparation (i.e. returning because of a forgotten item), and did not represent productive harvesting. These data were retained, however, for inclusion in $\mathbf{P_{DCS}}$ calculations. The remaining 368 dives all had maximum depths $\geq$ 46 FSW. All mean depths and times at bottom were retrieved from the dive computer output and calculated after dropping ascent and descent data. Decent time to bottom was calculated from the end of the last 15 second interval at surface through the last interval in which the depth increased by at least 1 FSW from that in the preceding interval. Ascents were calculated similarly, working backward from the interval in which surfacing occurred. Any depth <5 FSW was assumed to be at surface. Mean descent took 1.5 $\pm$ 0.4 minutes to reach an average depth of 66 $\pm$ 8 FSW. Mean ascent took 1.8 $\pm$ 0.5 minutes leaving from a mean depth of 65 $\pm$ 9 FSW.

Figure 1. Mean bottom depth and time at depth per dive that were derived from 368 computer monitored dives to depths >21 FSW. Black squares represent dives carried out on dive days 1-2 while open circles represent dive days 3-7.

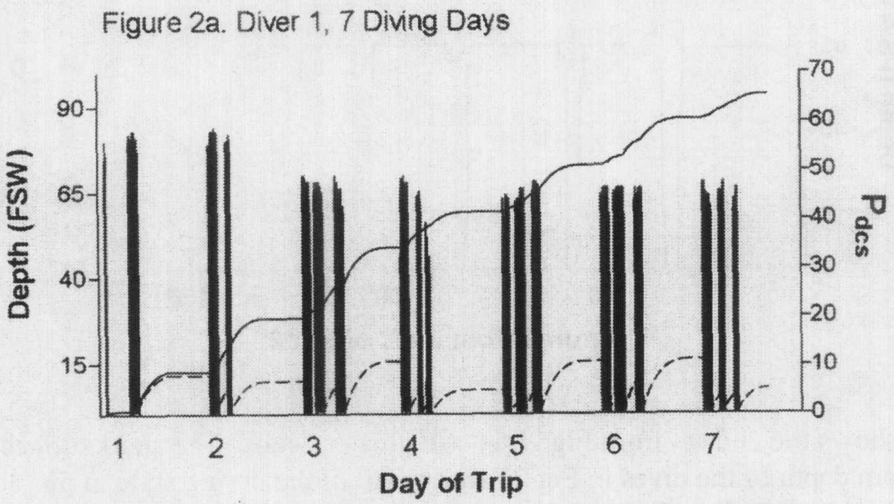


The mean depth is 67 ± 7 FSW (range by diver 64 ± 5 to 68 ± 7 FSW). This may be an overestimate since the calculation assumes that the diver spent the entire 15-second interval at the maximum interval depth, whereas it is likely that a portion of many intervals was spent at less than maximum interval depth. Mean time at depth is 20.6 ± 6.3 minutes (range by diver 19.1 ± 8.8 to 21.9 ± 3.7 minutes). Dive days 1-2 were at the initial fishing bank, while days 3-7 (open circles) were a continuation at the second fishing bank. Of 64 dives carried out on days 1-2, all but one were to mean depths ≥ 73 FSW while for dive days 3-7, 90% of mean depths were between 60 and 70 FSW and none of the 304 dives were to mean depths >70 FSW.

The dive computers recorded minimum water temperature for every dive that followed a surface interval > 10 minutes. Resulting water temperature averaged 80 ± 1°F (26.6 ± 0.5 °C). No diver complained of being cold or stated that water temperature affected his diving and the observer did not observe any diver shivering.

Figure 2 illustrates a typical man-day of diving.

Figure 2a-c. a). Recorded 7-day dive profile completed by diver 1, with corresponding estimated cumulative DCS probability (**P_{DCS}**) and conditional DCS probability (**cP_{DCS}**) profiles. **P_{DCS}** (solid line) at the end of 7 days was 65.5%. Highest **cP_{DCS}** (dashed line) was 11.2% on day 6. b) Dive and **cP_{DCS}** profiles for the 3-set dive day 6 of the profiles in 2a. Surface intervals between sets 1-2 and between 2-3 were 81.0 and 161.0 minutes, respectively. Values for **cP_{DCS}** reached 2.9, 5.5 and 11.2% in sets 1, 2 and 3, respectively. c) Set 2 detail from panel b. Mean depth, time at depth and surface intervals averaged 65 ± 7 FSW, 23.7 ± 4.9 minutes and 2.6 ± 0.5 minutes, respectively.



Divers worked in "sets", each defined as a group of dives separated by surface intervals < 48 minutes. **Figure 2a** shows the 7-day depth, **P_{DCS}** and **cP_{DCS}** profiles for diver 1.

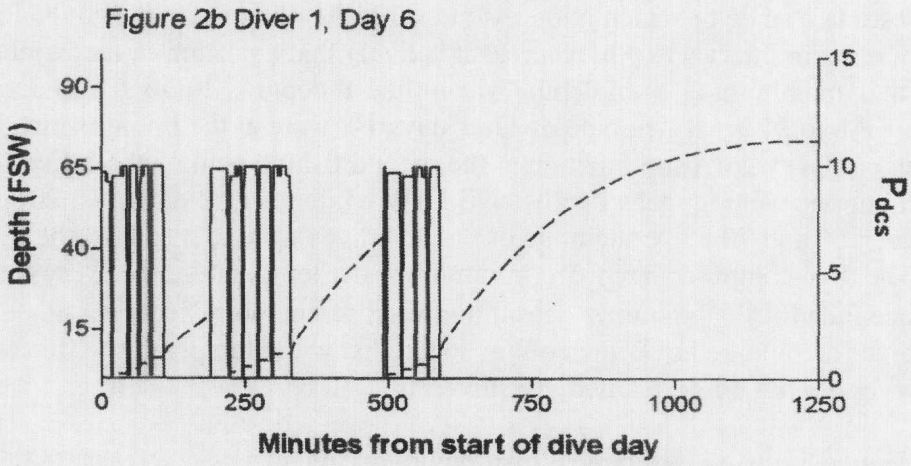


Figure 2b shows the depth and **cP$_{DCS}$** profiles for the 3 sets completed on day 6 of this 7-day profile.

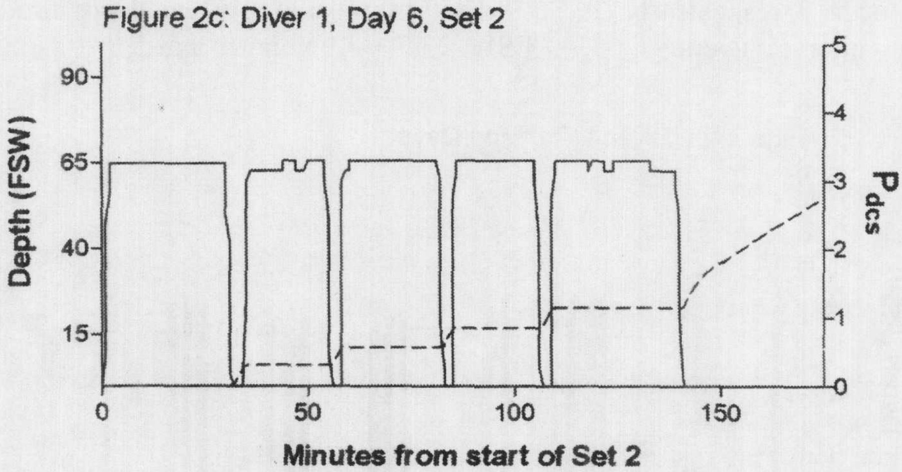


Figure 2c shows the 2nd set from Fig 2b in still greater detail. The short surface intervals and the flat bottom depth of the dives in Fig 2c are typical of the diving style in this analysis. For example, bottom depths in individual dives varied by only 7 ± 8 FSW over 368 dives.

In total, 87 dive sets were completed during 35 man-days of diving. There were 4 ± 1 dives per set with a maximum of 8 individual dives. Surface intervals within a set and total time at depth averaged 5.5 ± 5.2 and 87.1 ± 3.2 minutes, respectively. Diving started at 0600-0700 and ended around 1500-1600.

Table 1

Dive Data by Sets per Day

	Sets per day 1	2	3
N	2	14	19
Mean depth	64 ± 0	74 ± 8	64 ± 2
Maximum depth	70 ± 3	76 ± 8	66 ± 2
Time at depth/dive	19.1 ± 11.8	19.8 ± 3.5	20.8 ± 2.6
Total time at depth	60.4 ± 70.2	170.4 ± 68.3	266.8 ± 40.0
Tanks used	5 ± 5	8 ± 2	11 ± 2
Total dives	3 ± 2	8 ± 2	13 ± 2
Surface interval between dives (min.)	12.7 ± 7.8	5.2 ± 2.2	4.6 ± 2.3
Total surface interval between sets (min.)	-	197.4 ± 95.7	222.3 ± 23.3
Conditional risk (cPdcs)	3.6 ± 4.5	9.1 ± 3.0	10.3 ± 2.3

Table 1. Maximum depth, average depth, total time underwater, **cP_{DCS}**, between dive interval and between set interval listed by sets per day.

Table 1 shows the results for man-days of 1, 2 or 3 sets. Compared to dives undertaken during 3-set man-days, dives undertaken during 2-set man-days were deeper by 10 FSW in both maximum and averaged depth and shorter by an average of 96.0 minutes in total time at depth. An unpaired t test indicates that each of these differences is significant at $P<0.0001$. However, 9 of the 14 man-days with 2 sets occurred on dive days 1-2. When dive days 1-2 are excluded from the comparison, the differences narrow and lose significance. For days 3-7, the differences for both maximum and averaged depth narrow to < 1 FSW and the difference between total time at depth is reduced to 16.4 minutes; less for a 2-set man-day. These results suggest that the differences between 2-set and 3-set days are a result of dive site selection rather than differences in diving practice between 2-set and 3-set days.

All divers used 80 cubic foot capacity aluminum tanks filled to 2700 psi. Some tanks had 'J' valves installed but with release levers removed and the valve placed in non-reserve position so that the reserve air function was bypassed. It was a common practice for divers to terminate dives when breathing resistance increased, signaling an empty tank. However, over 35 man-days, divers averaged 1 ± 2 more dives per day than tanks used (10 ± 4 versus 9 ± 3 respectively; range –4 to 5), suggesting that divers often terminated dives for other reasons, possibly including a full product bag.

Probability of Decompression Sickness

We estimated the cumulative probability of decompression sickness (**P_{DCS}**) for each diver's 7-day dive profile, and the conditional probability (**cP_{DCS}**) (5,6) after each dive set. Figure 2a, for example, shows the 7-day dive profile and the corresponding estimated **P_{DCS}** and **cP_{DCS}** profiles for diver 1. Values for **P_{DCS}** for all 5 divers averaged 67.4% at the end of 7 days.

Table 2

Reported Joint Pain and Maximum cP_{DCS} for 35 Man-days

Diver	1		2		3		4		5	
day	DCS	cP_{DCS}	DCS	cP_{DCS}	DCS	cP_{DCS}	DCS	cP_{DCS}	DCS	cP_{DCS}
1	-	8.1	-	10.3	-	3.7	-	*0.4*	-	7.0
2	-	6.9	-	9.9	-	12.1	-	5.2	-/ls	10.7
3	-/rs^	**10.9**	-/bs^	**11.9**	-	**9.2**	-	7.0	-	**10.9**
4	-	**5.0**	-	**10.6**	-	**9.3**	-	8.9	-	**11.7**
5	-/bs^	**10.8**	-	**7.0**	-	**11.6**	-	**12.9**	-	15.0
6	ls/bs	**11.2**	-/re	**13.3**	-	**11.6**	-	**12.2**	-	**10.6**
7	bs/-	**5.3**	re/re	12.4	-	*6.8*	-	10.6	-	**10.0**

Table 2. DCS symptoms and maximum cP_{DCS} by diver and dive day. For man-days with 3, sets, cP_{DCS} is printed in bold. Diver 3 on day 7, and diver 4 on day 1, undertook 1 set only and these are printed in italics. Key for table is as follows: / = pre first dive, post last dive separator, r = right, l = left, b = bilateral, s = shoulder, e = elbow, - = no symptoms reported or observed, ^ = onset prior to last dive set. Ambiguous symptoms of headache, low back pain and diarrhea are not included here.

Values for cP_{DCS} for each diver are shown in **Table 2** and were always highest after the last set on any dive day. The mean maximum daily cP_{DCS} is 9.6%. Diver 5 incurred the highest daily cP_{DCS} (15.0%) on day 5 after a total underwater time of 85 minutes in the first dive set and 196 minutes in the second. The second set consisted of 8 dives to a mean depth of 64 $\pm$ 1 FSW separated by an average surface interval of 4.7 $\pm$ 6.0 minutes (range 1 to18 minutes).

For the 19 man-days that included 3 dive sets, cP_{DCS} following the last set averaged 10.3 $\pm$ 2.3%. Surface intervals taken after the first and second set on these days averaged 99.5 $\pm$ 21.6 and 122.8 $\pm$ 34.3 minutes, respectively. Dives on these days had a mean depth of 64 $\pm$ 4 FSW, with mean underwater times of 99.2 $\pm$ 16.6, 87.3 $\pm$ 24.3, and 80.3 $\pm$ 27.3 minutes for the respective three sets. In comparison, the PADI Recreational Dive Planner (9,10) allows 45, 33 and 36 minutes bottom times for three 65 FSW dives separated by these average surface intervals, while the United States Navy Standard Air Tables (11) allow 50, 13 and 19 minutes bottom times for three 60 FSW dives separated by these intervals. These PADI and US Navy dive profiles incur P_{DCS} estimates of 4.7 and 1.7%, respectively, with last dive cP_{DCS} estimates of 2.5 and 0.5%, respectively. Present decompression sickness risk estimates can also be compared to the 2.2% mean P_{DCS} under this model of dives to the USN Standard Air no-decompression limits (5).

Decompression Sickness (DCS)

No neurological abnormalities were found on initial examination or during interviews prior to the start of diving operations. During diving operations, each diver was interviewed for symptoms of DCS prior to the first dive of each day and prior to the last set, but not following set 1 of a 3 set day due to limited time. Neurological examinations were performed on each diver at the end of the day and, in addition, prior to the last set if a diver reported any symptom.

Throughout the 11 days of diving, no neurological abnormalities were found in any of the eight divers.

Table 2 displays joint pain symptoms reported by divers with complete data over the 7 consecutive dive days that were followed by computer. Reports of joint pain were obtained at two points in a day; the first obtained prior to the initial set of the day and the second either between sets or after the last set. Over the 35 man-days, 10 occurrences of joint pain symptoms were reported in 3 of the 5 divers followed. Table 2 shows joint pain symptom reports repeated in the same diver in similar locations suggesting that they are continuations or execrations DCS developed earlier in the trip and not a distinctive pathologic event. For example, diver 1 showed left and right shoulder pain occurring on 5 reports, either separately or as bilateral pain that could be considered 2 distinctive events. Assuming that all repeated symptoms in a similar location are a continuations or execrations of DCS symptoms developed earlier in the dive trip, 5 distinctive symptoms were seen in these 5 divers over 7 days (14% of man days).

Over the 11 days of diving, the 5 divers with complete data gave a total of 13 reports of joint pain symptoms. When possible symptom continuation is accounted for, 8 symptoms were distinctive (15% of man days). The 3 divers with symptom data only gave a total of 16 reports of joint pain, which reduced to 7 distinctive symptoms (21% of man days). For all divers over 11 days, there were 29 occurrences reported, all but 4 located in the upper extremity, resulting in 15 distinctive symptoms of joint pain (17% of man days). Neither 100% oxygen nor recompression facilities were available on board for the treatment of DCS though the observer did treat one non-study diver with in water recompression using air.

Contrary to earlier reports that Miskito divers do not understand the causes of DCS (3), the initial survey given to these divers showed 7 understanding that DCS is related to depth and time underwater while 1 attributed DCS to ascent rate. On the other hand, 5 divers also believed that they could become seriously ill if observed underwater by the "liwa mairin" or woman water spirit (2). On day 6, diver 2 attributed right elbow pain to heavy use of a hammer underwater to break conch shells.

Diver 4 did not report any symptoms over the 7 days. He was, however, noted to be reluctant to discuss the presence or absence of symptoms and, in addition, was continuously and heavily intoxicated with marijuana such that the observer doubted he could give an accurate interview. Others denied symptoms even though they were noted to limp and self-administer acetaminophen (500 mg), a common aid supplied by the captain for DCS joint pain. The observer, a native Honduran familiar with Miskito culture, speculated that to report pain is considered a sign of weakness. Given the observed intoxication and the reluctance of these divers to discuss symptoms, existing symptoms may have been unreported.

DISCUSSION

This study is the first reported use of dive computers to record time-depth profiles performed by indigenous underwater harvesters diving on compressed air SCUBA. The results confirm earlier reports of diving practices with a high probability of injury in this population (3). Diving days were characterized by 1 to 3 sets of diving each day, multiple dives and short surface intervals within sets and rapid ascents without decompression.

Risks for injury also included the primitive nature of the diving and drug use. Divers used only an air tank, facemask and swim fins. They did not use depth gauges, underwater timing devices, thermal protection, buoyancy compensation or weight belts and few regulators included air supply indicators. During the trip, all divers were observed smoking marijuana.

Total data loss occurred in 3 of 8 dive computers employed despite precautions. Sampling interval was set at 15 seconds to allow the computers to operate over the entire 11 days of diving, but the computers were wet all day long and so remained powered up for 10-12 hours. Further, while underwater, they emitted alarms due to the aggressive profiles. These power demands likely hastened exhaustion of the computers' power supplies requiring unplanned battery replacement. While the loss of data suggests battery replacement as the source of error, the technician was aware of this potential problem and had practiced the battery replacement procedure beforehand.

Consistent with earlier observations (3), dive depth showed small variation across the dives. In Figure 1, 90 % of all dives on days 3 - 7 were to depths of 60 - 70 FSW, while mean depth varied between divers by just 2 FSW. Further, the difference between maximum and minimum depth averaged 7 $\pm$ 8 FSW between all dives. The data suggest that these divers tended to work at a constant depth on bottom terrain that is relatively flat. These observations may be in part explained by the habitat of the *Panulirus argus*, the species of lobster that is fished in Honduras and throughout the Caribbean. These species are often found in large groups hidden in crevices along the bottom where the ledge and sand meet (Michael Childress, personal communication).

Estimated decompression sickness risks of the recorded profiles provide quantitative measures of decompression stress for comparison to the stresses accepted in modern recreational or military diving practice (10,11). These measures are direct indications of decompression sickness risks compared to those provided by other measures, such as "omitted decompression time" or "excess bottom time", that are not easily translated into increases in decompression sickness risks actually incurred by the diver. Finally, present use of conditional probabilities allows decompression sickness risks during specific portions of each profile to be considered, while including modeled influences of any preceding dive history in the profile. The resultant estimated $\mathbf{cP_{DCS}}$ values for the dive sets in the present profiles can thus be compared to the cumulative decompression sickness probabilities for the no-decompression limits for single dives in modern dive tables. Daily maximum estimated $\mathbf{cP_{DCS}}$ values for the dive sets recorded in present work routinely exceeded the mean $\mathbf{P_{DCS}}$ for dives to the USN Standard Air no-decompression limits by as much as 6-fold (Table 2). This result provides clear indication that the dives were considerably more stressful, from a decompression standpoint, than is accepted in modern diving practice.

It is important to note that the present dive profiles included features such as high numbers of repetitive dives over multiple days that are not represented in the laboratory data upon which the probabilistic model used here is based. Moreover, the severity of symptoms defining decompression sickness in these laboratory data is lower than that likely to be reported by these Miskito divers. As a result, the present decompression sickness risks estimates are obtained only by considerable extrapolation from the types of dive profiles to which the model is strictly applicable. Further, present estimates are confined to risks governed by factors intrinsic to the profile only, not to risks governed by diver history before undertaking the profile nor to other decompression related risks such as arterial gas embolism.

It is also possible that these results underestimate the aggressiveness of diving if the three divers with symptom data only were the most aggressive divers in the group. These three divers were the first to exhaust the battery life of their dive computers and reported a higher rate of joint DCS than the 5 divers with complete data.

Distinct DCS symptoms reported by the 5 divers with complete data occurred in 14% of man-days of diving (1.4% of all dives $\geq$ 46 FSW) and all reported symptoms occurred on man-days in which the set-by-set $\mathbf{cP_{DCS}}$ exceeded 10%. Due to logistic constraints, symptoms were only reported at the end of a set, though never at the end of the first set of a 3-set day because divers were unwilling to take time for interviews. Of those symptoms reported, half were reported prior to the last set of the day.

These results may be underestimating the true incidence in the group of 8 divers as a whole. The observer suspected that some divers did not report existing joint pain. Further, the incidence does not include the 3 divers with symptom data only who reported 7 distinct symptoms of DCS in 11 days where as the 5 divers with complete data reported just 1 additional distinct symptom. Interestingly, no neurological symptoms were found in the 8 divers monitored. The neurological examination was routinely given within an hour of the last dive and objective neurological symptoms may not have been as yet evident. Further, subtle neurological symptoms may have been denied, ignored by divers as insignificant or unrecognized due to intoxication. Since these divers average 12 years of diving (range 4 - 20 years) and we speculate that all are likely to have experienced DCS in the past, quite possibly on multiple occasions.

Repetitive dives of long duration with short surface intervals and persistent joint pain following that type of exposure are risk factors for dysbaric bone necrosis (12,13). Other reports of Miskito divers treated at a Honduran hyperbaric chamber have shown a high rate of both upper and lower extremity articular surface necrosis (4). In this study, joint pain, occurring primarily in the upper extremity, was common suggesting that these Miskito Indian divers are at risk for long-term bone necrosis.

The dive profiles undertaken by these divers are more stressful than accepted in modern recreational or military diving practice (10,11). The Miskito divers are not ignorant of the serious nature of DCS, as they see the consequences in their own experience and in those of their peers. However, they accept these risks and discomfort as a trade off for economic and social reasons beyond what a modern diver must consider (2).

In conclusion, this study demonstrates that Miskito Indian underwater harvesters dive highly stressful profiles characterized by multiple ascents and long dive times that produce a $\mathbf{cP_{DCS}}$ higher than encountered in proper exercise of modern diving practice. Divers reported frequent and persistent extremity pain but these complaints were not medically treated during the trip. We conclude that these divers are at high risk for DCS and may be at risk for delayed onset of dysbaric osteonecrosis.

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