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The Indigenous Fisherman Divers of Thailand: Diving-Related Mortality and Morbidity

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The Urak Lawoi are indigenous fishermen on Thailand's west coast. The population includes an estimated 400 divers who dive using surface-supplied compressed air. In a cross-sectional survey conducted among the 6 major communities of Urak Lawoi, questionnaire-based interviews were administered to active divers, ex-divers, and families or colleagues of divers who had died in the previous 5 years. Six deaths resulting from diving-related accidents were identified, indicating a diving-related mortality rate of approximately 300 per 100,000 person-years, while in the same 5-year period 11 divers had been disabled owing to diving-related events, indicating a diving-related disabling event rate of approximately 550 per 100,000 person-years. Among 342 active divers interviewed, one third reported having suffered from decompression illness, although based on reported current symptoms over 50% were classified as suffering from recurring non-disabling decompression illness. Physical examination conducted on a subset of 98 active divers revealed the presence of spinal injury (clonus, raised muscle tone, and heightened reflexes) and of joint damage (pain in one or more joint, crepitus, or restricted movement) in 24 and 30% respectively. Improved primary prevention and medical treatment are needed to reduce mortality and morbidity among this population.

indigenous divers Thailand mortality morbidity decompression illness

1. INTRODUCTION

A group of 400 men between the ages of 11 and 62 earn their living by diving using compressors to gather fish, seashells, and other marine products on Thailand's west coast. A research project, in partnership with the Ministry of Public Health, has been active since 1996 addressing the occupational safety and health risks associated with this activity.

The target population is a group of indigenous fishermen divers known as the Urak Lawoi (Gold, Geater, Aiyarak, Wongcharoenyong, & Juengprasert, 2000). The Urak Lawoi, along with another group of indigenous people living to the north of Phuket, are known as the Sea Gypsies. The Urak Lawoi live in nine villages in three provinces between Phuket Island and the border with Malaysia. As some of the villages are quite small, with fewer than 10 divers, the project has created six geographical groupings or communities, three in Phuket Province, one in Krabi Province, and two in Satun Province. There are approximately 400 active divers at any one time based on interviews of heads of all villages. Only males dive. They normally start diving when they finish compulsory education and continue to dive until the age of 50 unless they are unable to do so (Gold et al., 2000).

Casual observations in the Urak Lawoi villages reveal a number of working-age men with various degrees of physical disability. These disabilities are consistent with the known effects of decompression illness, suggesting

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The opinions and assertions contained within this article should not be construed as representing those of the International Labour Office.

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that occupation-related morbidity may be frequent among this population and a possible common cause of mortality and morbidity. However, there are no registries of divers, injuries, diseases, or deaths for this minority population. Therefore this study sought to document the prevalence of diving-related morbidity and estimate diving-related mortality rates among divers within this population. A subsidiary objective was to link diving practices with recurring morbidity among current divers.

2. METHODS

Information regarding mortality and morbidity among the target population was obtained using questionnaire-based interviews and physical examination between 1996 and 1997.

2.1. Sampling

Three subsets of the diving population were examined: active divers, ex-divers who had stopped diving as a result of diving-related disability, and divers who had died due to diving-related accidents or illness. It was attempted to recruit all currently active divers in six communities (Rawai, Koh Siray, and Sapam in Phuket Province; Koh Lanta in Krabi Province; Koh Li Peh and Koh Boulon in Satun Province) into the study. This was done during repeated visits to each community by local healthcare workers with the assistance of the village heads and diving boat owners or leaders.

- *Mortality.* To ascertain a history of diving and death within this population, it was necessary to first determine who had died, whether or not the deceased was a diver, and whether or not the death was diving-related. With information ascertained from the chief of the village, the healthcare workers interviewed the family or colleagues of males over the age of 11 who had died within the 5 years prior to the survey within the six communities.
- *Disabling morbidity.* The health care workers, through the chiefs of villages and dive leaders, sought out those males who had been diving using a compressor but had stopped.
- *Morbidity.* The entire sample of current compressor-divers was used to identify morbidity that was not sufficient to cause the diver to stop diving at the time of the study.

- *Physical examination.* A physical examination was conducted on an availability subset of 98 currently active divers identified in Rawai, Koh Siray, Sapam, and Koh Lanta communities over a 1-month period.

2.2. Questionnaires

Based on field observations, a series of four questionnaires was designed, translated, and piloted following a World Health Organization (WHO) methodology (Lutz, Chalmers, Hepburn, & Lockerbie, 1992). Separate questionnaires were developed to elicit responses from chiefs of villages, active divers, disabled divers, and the family or co-workers of deceased divers. In all questionnaires, most of the questions were closed and a few open. Other questions were both open and closed, that is, the interviewer had the ability to fill in a response that was different from the given responses (Lutz et al., 1992). Sixteen healthcare workers from the provincial medical offices and the subdistricts and villages where the Urak Lawoi reside were trained in administering the questionnaire. These healthcare workers were selected, as they are normally well aware of the health patterns within the village. All interviews were conducted in the Thai language. The questionnaires addressed some basic demographic information, diving practices, awareness of risk and attitudes towards risk, and the morbidity of decompression illness, which is defined as decompression sickness and pressure-related injuries or barotrauma. Diving practices (Gold et al., 2000a), issues related to attitudes and awareness of hazards (Gold et al., 2000b), and educational and informational interventions (Gold et al., in press) are addressed in separate papers.

2.3. Identification of Diving-Related Mortality

As the Urak Lawoi are indigenous people living in rural villages, post-mortem examination is uncommon. In defining diving-related deaths, certain clinical signs and symptoms that are directly related to diving practices and not normally found in the population were used. Each death was considered according to causes or reported signs and symptoms likely to be diving-related. The circumstances surrounding each death were examined in order to determine those that were diving-related. These included paralysis and sudden death.

2.4. Identification of Diving-Related Disabling Morbidity

Village and subdistrict health-care workers, knowledgeable about disabled individuals in the villages, worked with the village chiefs to identify divers who had stopped diving due to disabling morbidity resulting from diving. Those who had never used a compressor or those who were injured by mechanisms other than diving were excluded. With a view to differentiating between divers who had suffered serious morbidity and divers who had stopped diving for other reasons, if the diver indicated he had changed jobs (for reasons other than injury or illness resulting from diving) or had not had any difficulty when diving, he was not considered as part of the group of disabled divers. For this group, the definition of disabling morbidity includes cases where diving has led to a condition including paralysis, difficulty in breathing, blurred vision, headaches, and other manifestations associated with decompression illness as a consequence of which a diver could no longer dive. By subtracting the year the diver stopped diving from the diver's age, the age at which injury was sustained could be estimated.

2.5. Identification of Diving-Related Morbidity Among Active Divers

2.5.1. Interview

Divers were asked several questions about selected signs and symptoms relative to diving-related illness. The following areas were explored: whether the diver often experienced joint pain, tingling, loss of sensation, or inability to move as a result of his diving, and whether the diver had ever experienced and recovered from decompression illness. (Within this population, decompression illness refers to a situation leading to paralysis, unconsciousness, or other severe signs and symptoms [Aiyarak, 1991]). A composite outcome variable for the presence of recurring, non-disabling decompression illness was created and cross-tabulated against variables related to demographics, experience, and practices. The composite variable was constructed as follows: Frequent inability to move or frequent weakness as a result of diving was classified as probable; frequently experiencing pain or tingling or loss of sensation or one-sided weakness but not weakness or inability to move was classified as suspected; and none of the above manifestations was listed as not suspected. A variable ranking of the expected risk of

developing decompression illness was created according to the model proposed by Gerth and Vann (1996) using the reported pattern of diving on the last day of diving.

2.5.2. Physical examination

Two senior medical students from the United Kingdom, under the supervision of the Ministry of Public Health, carried out physical examinations. The results of the assessment were later verified by a follow-up examination of a number of selected examinations on the basis of available divers in two villages by an experienced diving medical practitioner.

The physical examination included the tympanic membrane, an examination of shoulder, hip, knee, and ankle joints for pain, crepitus, and restricted movement, lower limb neurology, clonus, lower limb power, reflexes, sensation, and coordination. The physical examination data were used to group divers into two morbidity categories: damage to joints and spinal injury. A composite variable of joint damage was developed in which the presence of pain on movement, crepitus, or restricted movement in more than one joint indicated diving-related joint damage. Spinal injury was assessed by the presence of clonus, increased tone, and heightened reflexes. A composite variable was developed in which the presence of any of the three CNS (central nervous system)-related signs indicated potential central nervous system damage.

2.6. Statistical Analysis

Results were analyzed using Epi Info 6 (Dean et al., 1995) and STATA 5.0 (Stata Corporation, 1997) software. During analysis, the open questions were closed by grouping responses. Crude (bivariate) odds ratios and 95% confidence intervals were calculated to explore the relationships of history of decompression illness, occurrence of recurring, non-disabling decompression illness, evidence of joint damage, and evidence of spinal injury with community, age of the diver, and duration of diving of current divers. Associations between recurring non-disabling decompression illness and current diving practices and demography were also explored using multivariate logistic regression.

3. RESULTS

Interviews were conducted with 9 heads of villages, 342 active divers, 26 disabled divers, and the families or colleagues of 29 males who had died over the past 5 years. The distribution of divers by age is presented in Figure 1.

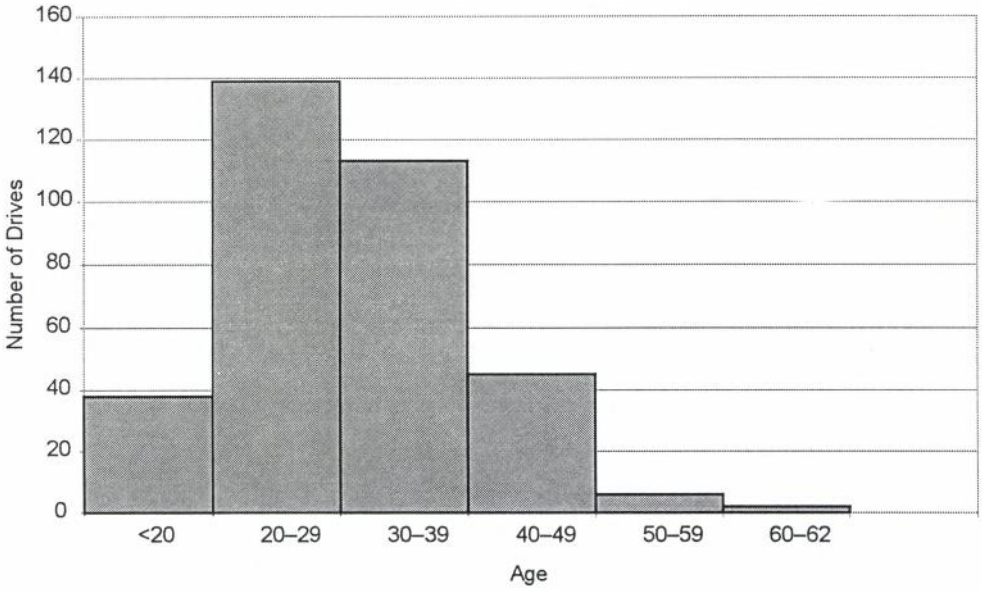

Figure 1. Age distribution of currently active divers surveyed.

3.1. Diving-Related Mortality

The results of the survey of deceased divers indicated that there had been 29 deaths of males over the age of 11 within the last 5 years among the whole Urak Lawoi population and that of these 29 deaths, 13 had dived using a compressor (Table 1). Based on the estimated population of approximately 400 divers at any one time, the mortality rate for the population of divers was therefore 13/400 for the 5-year period. Six of the deaths were directly attributable to diving leading to an occupational death rate of 6 deaths per 400 divers over 5 years or 1.2 deaths per year, equivalent to 300 deaths per 100,000 person-years.

TABLE 1. Deaths Among the Diving Population Over a 5-Year Period (1992–1996)

Reference Number	Age at Death	Year of Death	Cause or Circumstances of Death	Was Death Diving-Related?	Profile of Last Dive (Time/Depth)*
01	65	1994	Semi-paralysis, hemoptysis	No	
02	61	1996	Diabetes, hypertension, tuberculosis	No	
03	70	1993	Fell into water drunk while securing boat to dock	No	
04	22	1994	Complications of diving-related paralysis and amputations	Yes	30/50
05	40	1992	Paralysis after diving	Yes	20/40
06	53	1993	Paralysis after diving	Yes	60/40
07	36	1994	Acute onset of chest pain and hemoptysis after diving	Yes	30/50
08	18	1996	Death within 5 min of surfacing	Yes	10/60
09	30	1993	Death in the water during a dive	Yes	60/60
10	23	1995	Seizure after drinking	No	
11	26	1995	Drug-related death	No	
12	55	1994	Acute asthma attack	Uncertain	
13	25	1995	Murder in a discotheque	No	

Notes. *—time in minutes, depth in meters of seawater.

TABLE 2. Disability Among the Diving Population (1996, $n = 26$)

Reference Number	Age	Year of Injury	Age at Injury	Onset of Diver-Reported Problem	Parts of Body Affected	Immediate Cause	Estimated Profile of Last Dive (Time/Depth)*
01	35	1993	31	20 min post surfacing Difficulty breathing, numbness	Legs, feet, or both	Diving profile	80/50
02	43	1994	41	1 day post surfacing Inability to move, numbness	Legs, feet, or both	Diving profile	60/50
03	57	1981	42	Less than 1 hr on surface Paralysis, loss of consciousness	Legs, feet, or both	Diving profile	60/40
04	43	Changed jobs					
05	38	1981	23	Less than 1 hr on surface Sleepiness, loss of consciousness	Legs, feet, or both Lower body	Diving profile	60/58
06	42	1984	30	Less than 1 hr on surface Dizziness, loss of consciousness	Lower body	Equipment failure	60/48
07	27	1993	24	Less than 1 hr on surface Dizziness, loss of consciousness, joint pain	Legs, feet, or both	Surfacing too fast	15/55
08	32	1994	30	Less than 1 hr on surface Double vision, blurred vision, loss of consciousness, headache	Legs, feet, or both	Surfacing too fast	25/40
09	38	—	—	3–12 hrs post surfacing Difficulty breathing, numbness in both legs	Legs, feet, or both	Unknown	60/40
10	39	1993	36	1-3 hrs post surfacing Fatigue, headache, vomiting, joint pain	Legs, feet, or both	Difficulty breathing	45/25
11	38	1993	35	Less than 1 hr on surface Numbness, dizziness, headache	Legs, feet, or both	Surfacing too fast	13/60

TABLE 2. (*continued*)

Reference Number	Age	Year of Injury	Age at Injury	Onset of Diver-Reported Problem	Parts of Body Affected	Immediate Cause	Estimated Profile of Last Dive (Time/Depth)*
12	25			Still diving			
13	59	1995	49	5 min post surfacing Inability to move, numbness, inability to move	Whole body	Surfacing too fast	15/70
14	29	1992	25	—	—	None	—
15	26	1993	23	On ascent Dizziness, lethargy, insufficient air	Head or neck	None	30/25
16	60	1976	40	—	—	—	—
17	33	1994	31	On the bottom Muscle pain, headache	—	Diving profile	30/100
18	48	1986	38	—	—	—	—
19	40	1979	27	—	—	Surfacing too fast	—
20	51	1977	36	Less than 1 hr on surface Earache, body pain	Whole body	Unknown	25/60
21	49	1976	29	On ascent Headache, pain in arms	Arms, hands, or both	Surfacing too fast	30/50
22	40	—	—	Less than 1 hr on surface	Arms, hands, or both; legs, feet, or both	Surfacing too fast	120/40
23	34			Never had problem diving			
24	58	1991	53	On ascent Nose bleed, confusion	Head	—	20/50
25	32			Never had problem diving			
26	46	1998	36	On ascent Chest pain	Whole body	Compressor failure	25/50

Notes. *—time in minutes, depth in meters of seawater; — — no reply

3.2. Diving-Related Disabling Morbidity

Twenty-six divers who had stopped diving were identified in the villages covered by the project. Of the 26, 1 had stopped diving due to a change in jobs, one was found to be still diving, and 2 indicated that they had never had a problem while diving (Table 2). Of the 22 remaining divers, the average age at time of injury was 34.5 years and the range was from 23 to 53 years. Following the injury, 13/19 (68.4%) had immediately ceased diving. The reported cause of the injury was related to the diving profile such as diving too deep, 26.3% (5/19); surfacing too fast, 36.8% (7/19); equipment failure, 10.5% (2/19); insufficient air, 5.3% (1/19); not known, 10.5% (2/19); and no cause 10.5% (2/19).

The divers reported that they had been healthy prior to the disabling injury. When asked about personal health problems they had been informed about by a health care worker or a doctor prior to the event, 89.5% (17/19) reported none; 1/19 (5.3%) reported circulatory problems; and 5.3% (1/19) reported eye problems. Thirty percent (6/20) reported taking medication before the event, whereas 70% (14/20) denied doing so.

It is widely known that the administration of first aid such as 100% oxygen can reduce the potential for serious injury. Immediate first aid was provided on the boat for 57.9% (11/19) of the divers. First aid provided (as listed by the divers) included massage, 47.4% (9/19); a hot-water bottle, 5.3% (1/19); and painkillers 5.3% (1/19). Twenty-six point three percent (5/19) of the divers reported having received in-water recompression as a treatment for decompression illness. Depth of recompression was reported to be 10 m and reported times ranged from 60 (2/3) to 120 min (1/3).

Among these diving-related disabling events, 11 were known to have occurred within the previous 5 years. Again basing a calculation on a total of approximately 400 divers at any time, the approximate rate of diving-related non-fatal disabling events was 550 events per 100,000 person-years, or about twice the estimated diving-related mortality rate.

3.3. Diving-Related Morbidity Among Active Divers

Regarding selected manifestations of decompression sickness, 79.8% (265/332) often reported experiencing joint pain, 76.2% (179/235) tingling, 67.2% (221/239) loss of sensation, and 7.0% (22/316) inability to move.

Thirty-six percent (121/336) of the divers reported having experienced decompression illness (Table 3), generally understood by the divers to refer to paralysis, unconsciousness, or other serious signs and symptoms. Using univariate analysis, community of residence as well as age and years of diving were associated with the reported history of decompression illness. Divers living in Phuket Province (with the exception of Sapam community) were more likely to report a history of decompression illness (Table 3). Probabilities of having a history of decompression illness also increased with age (P-trend = .0004) and years of diving experience (P-trend = .004).

TABLE 3. Reported History of Decompression Illness(DCI)

			Reported History of DCI			
Variable	Level	Number	Proportion	Percentage	Crude Odds Ratio	95% Confidence Interval
			Demographics			
Age group	13–19	38	7/38	18.4	1	
	20–29	138	43/135	31.9	2.1	0.8–6.0
	30–39	113	44/110	40.0	3.0	1.1–8.6
	40–49	45	22/45	48.9	4.2	1.4–13.6
	50–62	8	5/8	62.5	7.4	1.1–56.1
Community	Rawai	98	47/98	48.0	1	
	Koh Siray	83	33/83	39.8	0.7	0.4–1.4
	Sapam	18	4/17	23.5	0.3	0.1–1.2
	Koh Lanta	49	13/49	26.5	0.4	0.2–0.9
	Koh Li Peh	65	19/63	30.2	0.5	0.2–1.0
	Koh Boulon	18	1/18	5.6	0.1	0.0–0.5
			Experience			
Years diving	0–9	105	31/103	30.1	1	
	10–19	155	49/153	32.0	1.1	0.6–2.0
	20–29	64	35/62	56.5	3.0	1.5–6.1
	30–45	14	6/14	42.9	1.7	0.5–6.3

However, when recurring non-disabling decompression illness was assessed based on specific reported manifestations, almost all current divers (325/332) were classified as currently experiencing suspected (39.5%) or probable (58.4%) decompression illness (Table 4). Demographic, experience, and practice factors independently associated with experiencing probable recurring

TABLE 4. Recurring, Non-Disabling Decompression Illness Among Currently Active Divers

		Suspected		Probable				
Variable	Level	Proportion	Percentage	Proportion	Percentage	Crude Odds Ratio	95% Confidence Interval	Combined Percentage
Demographics								
Age group	13–19	16/36	44.4	17/36	47.2	1.0		91.7
	20–29	52/133	39.1	79/133	59.4	1.6	0.7–3.7	98.5
	30–39	46/112	41.1	64/112	57.1	1.5	0.7–3.4	98.2
	40–49	15/43	34.9	28/43	65.1	2.1	0.8–5.7	100.0
	50–62	2/8	25.0	6/8	75.0	3.4	0.5–37.3	100.0
Community	Rawai [ab]	38/95	40.0	55/95	57.9	1.0		97.9
	Koh Siray [a]	27/85	31.8	57/85	67.1	1.5	0.8–2.9	98.8
	Sapam [c]	12/16	75.0	4/16	25.0	0.2	0.1–0.9	100.0
	Koh Lanta [a]	14/49	28.6	32/49	65.3	1.4	0.6–3.0	93.9
	Koh Li Peh [ab]	28/63	44.4	35/63	55.6	0.9	0.5–1.8	100.0
	Koh Boulon [bc]	10/17	58.8	6/17	35.3	0.4	0.1–1.3	94.1
Experience								
Years diving	0–9	43/99	43.4	53/99	53.5	1.0		97.0
	10–19	58/153	37.9	91/153	59.5	1.3	0.7–2.2	97.4
	20–29	25/62	40.3	37/62	59.7	1.3	0.6–2.6	100.0
	30–45	3/14	21.4	11/14	78.6	3.2	0.8–18.7	100.0

TABLE 4. (*continued*)

Variable	Level	Suspected		Probable		Crude Odds Ratio	95% Confidence Interval	Combined Percentage
		Proportion	Percentage	Proportion	Percentage			
Practices								
Average days/month	0–9	29/77	37.7	47/77	61.0	1.0		98.7
	10–19	68/180	37.8	108/180	60.0	1.0	0.5–1.7	97.8
	20–30	34/75	45.3	39/75	52.0	0.7	0.4–1.4	97.3
Average dives/day	1–4	95/229	41.5	127/229	55.5	1.0		96.9
	5–14	32/91	35.2	59/91	64.8	1.5	0.9–2.5	100.0
	15–34	4/12	33.3	8/12	66.7	1.6	0.4–7.5	100.0
Diving profile	Low risk	48/121	39.7	71/121	58.7	1.0		98.3
	Moderate risk	39/107	36.4	65/107	60.7	1.1	0.6–1.9	97.2
	High risk	20/72	27.8	51/72	70.8	1.7	0.9–3.4	98.6
Yo–yo diving	No	67/159	42.1	88/159	55.3	1.0		97.5
	Yes	64/173	37.0	106/173	61.3	1.3	0.8–2.0	98.3
Decompression stop	Yes	76/190	40.0	110/190	57.9	1.0		97.9
	No	55/142	38.7	84/142	59.2	1.1	0.7–1.7	97.9
Measures time	Yes	65/172	37.8	101/172	58.7	1.0		77.3
	No	66/160	41.3	93/160	58.1	1.0	0.6–1.6	99.4
Measures depth	Yes	109/268	40.7	153/268	57.1	1.0		97.8
	No	22/64	34.4	41/64	64.1	1.3	0.7–2.5	98.4

Notes. a, b, c—communities not having a superscript letter in common differ significantly ($p < .05$) in the proportion of divers experiencing probable decompression illness.

TABLE 5. Indications of Joint Damage

		Joint Pain		Crepitus		Decreased Mobility	Index			
		1 Joint	>1 Joint	1 Joint	>1 Joint	1 Joint				
Variable	Level	Proportion		Proportion		Proportion	Proportion	Percentage	Crude Odds Ratio	95% Confidence Interval
Demographics										
Age group	13–19	3/6	0/6	0/6	1/6	0/6	1/6	16.7	1.0	
	20–29	6/35	6/35	3/35	1/35	0/35	8/35	22.9	1.5	0.1–78.7
	30–39	7/42	11/42	2/42	5/42	3/42	15/44	34.1	2.6	0.3–130.4
	40–49	0/8	3/8	2/8	3/8	1/8	5/8	62.5	8.3	0.5–471.1
	50–62	1/5	1/5	1/5	0/5	1/5	1/5	20.0	1.3	0.0–117.5
Community	Rawai	6/46	8/46	3/46	5/46	2/46	11/46	23.9	1.0	
	Koh Siray	7/31	4/31	4/31	4/31	3/31	10/33	30.3	1.4	0.4–4.2
	Sapam	2/8	3/8	0/8	1/8	0/8	3/8	37.5	1.9	0.3–11.6
	Koh Lanta	2/11	6/11	1/11	0/10	0/11	6/11	54.5	3.8	0.8–18.8
Experience										
Years diving	0–9	4/24	2/24	0/24	2/24	0/24	4/24	16.7	1.0	
	10–19	11/50	13/50	4/50	4/50	2/50	16/50	32.0	2.4	0.6–10.9
	20–29	2/18	4/18	3/18	3/18	2/18	7/18	38.9	3.2	0.6–17.9
	30–45	0/4	2/4	1/4	1/4	1/4	3/4	75.0	15.0	0.8–825.0

TABLE 6. Indications of Spinal Injury

		Clonus		Tone		Reflexes		Index			
		1 Side	Bilateral	1 Side	Bilateral	1 Side	Bilateral				
Variable	Level	Proportion		Proportion		Proportion		Proportion	Percentage	Crude Odds Ratio	95% Confidence Interval
Demographics											
Age group	13–19	0/6	0/6	0/6	0/6	0/6	0/6	0/6			
	20–29	2/34	5/34	1/34	2/34	0/34	1/34	7/34	20.6	1.0	
	30–39	1/44	4/44	2/44	2/44	2/44	3/44	10/44	24.4	1.1	0.3–3.8
	40–49	0/8	2/8	1/8	1/8	0/8	0/8	3/8	37.5	2.3	0.3–15.4
	50–62	0/5	1/5	1/5	0/5	0/5	1/5	2/5	40.0	2.6	0.2–26.7
Community	Rawai	1/46	6/46	2/46	2/46	2/46	4/46	12/46	26.7	1.0	
	Koh Siray	2/31	4/31	1/31	2/31	0/31	1/31	7/31	22.6	0.9	0.3–2.7
	Sapam	0/8	2/8	0/8	1/8	0/8	0/8	2/8	25.0	1.0	0.1–5.8
	Koh Lanta	0/10	0/10	1/10	0/10	0/10	0/10	1/10	10.0	0.4	0.0–3.3
Experience											
Years diving	0–9	1/24	3/24	1/24	1/24	0/24	1/24	5/24	20.8	1.0	
	10–19	1/49	5/49	1/49	3/49	2/49	3/49	10/49	20.4	1.0	0.3–4.2
	20–29	1/18	3/18	2/18	1/18	0/18	1/18	6/18	33.3	1.9	0.4–9.7
	30–45	0/4	1/4	0/4	0/4	0/4	0/4	1/4	25.0	1.3	0.0–20.2

decompression illness were explored using multivariate logistic regression. However, evidence of association was found only for community of residence (p likelihood ratio test = .011), with current divers in Koh Siray and Koh Lanta significantly more likely to suffer from recurring non-disabling decompression illness than those in Koh Boulon and Sapam. Although not statistically significant, among the sample of current divers those who were older, had dived for longer, or reported high risk dive profiles had higher percentages of probable recurring non-disabling decompression illness (Table 4).

All of the 98 divers given a physical examination were active divers. Joint damage is shown in Table 5. Pain in one or more joints at rest or with manipulation was present in 38.8% (38/98) of the divers examined. Crepitus in one or more joint was found in 18.4% (18/98) and restricted movement in one or more joint among 5.1% (5/98). In a univariate analysis, the probability of having joint damage increased with years of diving (p-trend = .015) but there was little evidence for an association with age (p-trend = .152). Differences among the communities of residence were not statistically significant, probably due to the small numbers available. However, within the sample examined, the percentages of divers with joint damage were higher among the communities of Sapam and Koh Lanta than among those of Rawai and Koh Siray.

Indications of spinal injury are shown in Table 6. Clonus was present in 15.5% (15/97), most of whom (12/15) had bilateral clonus. Raised muscle tone in the lower limbs was found in 10.3% (10/97) of divers, half of them (5/10) bilateral. Reflexes were graded on a scale 0 to + + +. Heightened reflexes (+ + +) were found in the knee of 6.2% (6/97) divers, among whom 4 were bilateral, and in the ankle of 4.1 % (4/97) of divers, among whom 3 were bilateral. Ten point seven percent (9/84) of divers showed a Babinski sign, 5 of them bilateral. In univariate analysis there was little evidence of a trend of increased probability of having spinal injury with increasing age (P-trend = .089), and no evidence of an association with years of diving (P-trend = .433).

4. DISCUSSION

This study has revealed high estimated mortality rates among the Urak Lawoi divers as well as high prevalence of disabling and non-disabling morbidity as a result of diving.

The International Labour Office uses deaths per 100,000 workers per year to assess the rate of occupational fatalities. In Thailand, one of the more visible dangerous occupations is building-construction work. In 1995, there were 154 deaths of construction workers out of the 248,569 that were covered by the Workman's Compensation Fund (R. Thongmuang, personal communication, February 22, 1999) or 70 deaths per 100,000 workers. From this study, it can be estimated that the rate of occupational fatalities among the Urak Lawoi is 300 deaths per 100,000 workers per year.

Within this relatively young population, there is a considerable diving-related mortality and disabling morbidity. Based on the estimate of a total of approximately 400 active divers, the prevalence of diving-related disabling morbidity among divers and ex-divers is approximately 5.2% (22/422). Even among the currently active divers, almost 60% are probably suffering from recurring non-disabling decompression illness, and in a subset of 98 divers the prevalence of spinal injury was 22.7% (22/97) and of joint damage 30.6% (30/98).

Possible explanations for the apparent association of these prevalent conditions with age or years of exposure include (a) increased susceptibility with age, (b) cumulative effect of exposure, (c) increased probability of an injurious event with increased time at risk, and (d) a secular reduction in the absolute risk. With the limited data available in this study, it is not possible to distinguish these potential explanations for association.

Although the scientific literature contains certain information about hospital or decompression chamber-based diving-related mortality and morbidity for surface (air) supplied indigenous divers, there is limited information available on a population basis. Only Edmonds (1996) suggests, after a review of divers' log books, a diving-related morbidity, however the diving practices of the Australian pearl divers addressed by Edmonds are considerably different from the divers under study. There are several descriptions of diving practices and decompression sickness in groups of fisherman divers in Australia (Ganter, 1994; Wong, 1996), the continental USA (Butler, 1995), Hawaii (Kizer, 1982; Wade, Hayashi, Cashman, & Beckman, 1978), Japan (Kawashima et al., 1995; Mohri et al., 1995), Mexico (Jones, Ramirez, & Doty, 1993), the island of Pescadores (Lee et al., 1994), the Philippines (Ball, 1993), the Republic of Korea (Park & Hong, 1991), Singapore (How & Long, 1995), and the Territory of Hong Kong (Lam, Yau, & O'Kelley, 1985).

Differences in the prevalence of recurring non-disabling morbidity among the communities were not confounded by any of the diving practice

variables included in the multivariate analysis. It is possible, however, that other features of the diving practice, not recorded in this study, differed among the communities. A complication in examining these factors is that the Urak Lawoi may migrate, from time to time, from one village to another. Relationships between diving practices and morbidity was explored only for the composite variable of suffering from decompression illness on a regular basis, as the direction of causality in any association between current diving practices and the other morbidity variables (history of decompression illness, spinal injury, and joint damage) could not be ascertained.

An attempt was made to access every member of the three groups of the population concerned. It is likely that the attempt was somewhat less successful for the active diver group than for the other two groups. Nevertheless, based on the estimated population of the total of 400 active divers, the recruitment rate was approximately 85%. According to the heads of villages, the total number of active divers had not changed substantially over the previous 5 or more years. Our estimates of diving-related mortality and diving-related disabling event rates are unlikely to be in serious error as a result of changes in the size of the population at risk over time.

Prevalence estimates of reported experience of decompression illness and of recurring, non-disabling decompression illness among currently active divers, however, may be somewhat less informative both as a result of the healthy worker effect (Fox & Collier, 1976), whereby those members of the diving community most severely affected are gradually removed from the population of currently active divers, and possibly also owing to any bias in the group of active divers interviewed. Nevertheless, the Urak Lawoi population in Thailand is relatively closed, with migration confined almost entirely to change of residence to other Urak Lawoi villages. Divers who stopped diving because of disability or death were therefore readily identified in this survey. Bias may have been more serious, however, in the use of an availability sample of active divers for the physical examination. Divers with rather greater morbidity may have been more available and thereby be over-represented in the sample. If this is the case, the prevalence of joint damage and spinal injury among currently active divers may have been somewhat overestimated.

It is already reported that diving practices of the Urak Lawoi far exceed what would be considered safe in avoiding decompression illness by accepted standards for civilian and military diving. In view of the high levels of mortality and morbidity revealed in this study a primary approach to reducing mortality and morbidity appears to be to modify diving

practices. For decompression illness, rapid treatment can have a positive effect. It is also necessary therefore to ensure that adequate treatment can be given as rapidly as possible following a diving-related incident.

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