Short communication

Underwater working times in two groups of traditional apnea divers in Asia: the Ama and the Bajau

Erika Schagatay, Angelica Lodin-Sundström and Erik Abrahamsson

Key words
Breath-hold diving, freediving, spearfishing, performance, indigenous divers, diving research

Abstract
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Introduction: Traditional apnea diving for sea harvesting for a living continues in some communities in Asia, the outcome being dependent on the total underwater working time. We studied dive and surface interval durations and daily time spent submerged by Japanese Ama and the Phillipine Bajau.
Methods: Diving and surface interval durations were timed, and daily in-water working time noted for 14 female Ama (mean age 60 years) during sea-mollusc collection, and five male Bajau divers (mean age 38 years) during spearfishing, using direct observations and depth-time recorders.
Results: In the Ama, mean (SD) dive duration was 38 (8) s, with mean surface interval duration of 38 (8) s, at depths of 5–12 metres' sea water (msw), and diving constituted 50 (4)% of the total immersed working time, which was limited to 4 h per day by fishing regulations. In the Bajau, mean dive duration was 28 (9) s, with surface intervals of 19 (8) s, at depths of 5–7 msw, and diving was 60 (6)% of the total working time. Diving patterns in Hegura-Ama were similar to those previously reported, with up to 2 h per day spent under water. The Bajau total working time of 2–9 h per day suggests that some divers may spend more than 5 h per day submerged, which is the greatest daily apnea diving time reported in humans.
Conclusions: We conclude that natural human diving ability in these two groups of traditional apnea divers allows efficient sea harvesting at shallow depths and that the outcome does not seem to be limited by total daily apnea time.

Introduction

Harvest diving on shallow seabeds has most likely been a major source of food for humans since ancient times. This natural diving continues in some communities in East and South East Asia, and its outcome is dependent on the time spent submerged and, for harvesting diving, on the resulting bottom working time. Thus, whilst in competitive apnea diving the aim is to produce one single dive of maximal duration, distance or depth, the harvest diver instead strives to produce the longest possible underwater working time per day in order to collect a sufficient catch. A strategy to make this possible is to limit apneic duration per dive to within the time allowed by accessible oxygen stores, thereby limiting accumulation of lactic acid and other by-products of hypoxia requiring prolonged surface intervals.

The Ama of Japan and related Hae Nyo of Korea have been extensively studied, and their physiology and diving patterns have been documented in several publications, and the metabolic cost and thermal consequences of repeated diving have been measured.[1–3] As these groups are active in relatively cold water, their diving may be restricted by their sensitivity to cold, and elevations of metabolism could negatively influence apneic duration.[3] When originally no suits were used, the Ama were considered to be among the most cold-resistant of humans, but the introduction of wetsuits has led to de-acclimatisation.[4] Many studies have concerned their time spent working under water, reporting varying degrees of efficiency and daily underwater and bottom times.[5–7] One group reported to spend a considerable portion of the day submerged is the Ama at Hegura Island.[7] On this island, there are now few permanent residents but during the fishing season about 60 Ama divers stay and work there. One of our aims was to visit this group to observe whether such diving was ongoing and the total daily underwater times produced.

The Asian Sea People, or Sea Nomads, are spread across vast areas of South-East Asia, and include several possibly related groups, e.g., the Orang laut in Riau, the Moken in Thailand and Burma, and the Bajau in eastern Indonesia, Phillipines, and eastern Malaysia.[8] These communities, which rely predominately on marine resources, either migrate in house boats, or have stilt-house settlements in shallow near-shore areas or on land. Although many accounts exist in the literature of the Sea People as "*excellent divers*", detailed information about their diving methods and patterns is rare. One group, studied in Indonesia by one of the authors in the late 1980s, was found to spend approximately 50% of their working time under water.[9] Little if any equipment was used during diving, often only wooden goggles (Figure 1, left). A generation earlier, no goggles were used, and even today many children dive without any equipment, and may develop superior underwater vision.[10] Nowadays, some groups are using basic freediving equipment.

Figure 1
Bajau diver, Indonesia (left), Ama diver, Japan (right) (Photos E Schagatay)

We wished to document and compare diving patterns in the Ama and Bajau, a major focus being to determine how great a proportion of the working time was spent under water and how much underwater time per day was achieved by these apnea divers.

Methods

Participants were divers among the Japanese Ama at Hegura Island and the Bajau in Davao in the Phillipines, which were visited during 2009–2010. Ama studies occurred in August and Bajau studies in March–April. All participating divers were professional divers from a young age. The divers and the village head were asked for their permission to record their diving patterns in a way that would not affect the work of the divers. Divers were observed during the entire diving shifts as a basis for total working time, but registrations of diving and surface interval durations were done during shorter periods. There was no selection of 'the best' divers, as has been the case in some previous studies, but all divers willing to participate were included.

Fourteen female Ama (mean age 60 years, range 38–77) were studied during sea-mollusc collection on the south-west coast of Hegura Island. The main catch was awabi (abalone) and sasae (turbo) shells, which are the most profitable species to collect, and for which collection is restricted by the local fishing cooperative to three months per year and 4 hours per day during this season. Diving cycles were recorded during 20–120 min per diver. Divers used full wetsuit, mask, rubber fins, weightbelt, cotton gloves, and a tool for removing the awabi shells (Figure 1, right).

Diving cycles were also measured for 5 male Bajau divers (mean age 38 years, range 16–48) during spearfishing for 20–60 min of diving per diver, which was part of a full day of diving activity. During the study, divers used goggles and swimming trunks, one or two, short, homemade, wooden fins, and one diver used a wetsuit.

Dive times and surface intervals were recorded, and depth and time for ascent and descent were measured. Data were collected via observations from the boat and in the water as well as using depth-time loggers (Sensus Ultra, ReefNet Inc, Ontario, Canada) recording time and depth at 1 s intervals. Mean water temperature was approximately 23^{O}C in Japan and 26^{O}C in the Phillipines.

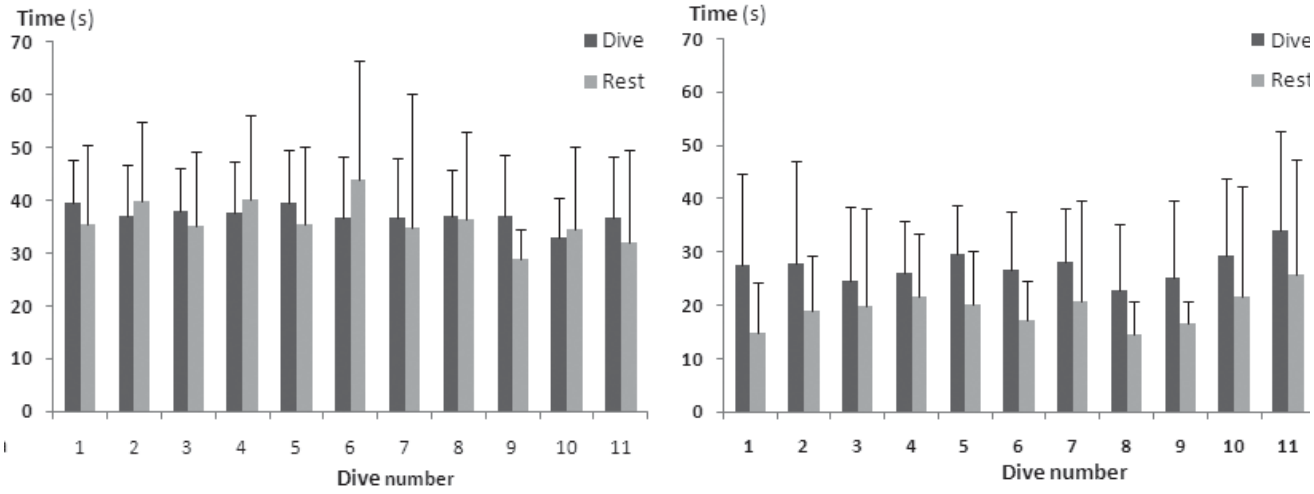
Statistical analysis

At least 11 consecutive dives and surface intervals were successfully collected for each diver and used for analysis. Dive times and surface intervals were compared within groups using paired Student t-tests and between groups using unpaired Student t-tests. Descent and ascent times were calculated for the Ama, but dives were not clearly divided into descent, bottom time and ascent in the Bajau.

Results

Ama divers were swimming slowly during most of the dive time and speed of descent and ascent was approximately 0.8 m s^{-1}. Ama divers used vertical dives to the bottom, and during most of the dive they were actively swimming looking for and collecting shells, which were placed into a floating basket on return to the surface. Divers rested hanging on to this float during surface intervals. Mean (SD) dive duration was 38 (8) s, with a surface interval duration of 38 (8) s (not significant, Figure 2a). Maximum diving depths were between 5 and 12 (mean 7.5) metres' sea water (msw). Diving constituted 50 (SD 4) % of the total immersed working time which was limited to 4 h per day. All divers spent 4 h in the water. About half of the dive time was bottom time used to collect molluscs.

Figure 2
Mean (SD) dive and surface rest interval durations in 11 consecutive dives by 14 Ama divers (left), 5 Bajau divers (right)



Bajau divers were swimming at varying depths looking for, shooting and retrieving fish, with time spent at the surface for resting, reloading the rubber sling harpoon and taking care of the fish when one was caught. Most dives were without catch. Bajau mean (SD) dive duration was 28 (9) s with surface intervals of 19 (8) s (Figure 2b). Surface interval times were significantly shorter than the dive times ($P < 0.001$). Maximum diving depths were between 5 and 7 (mean 6) msw. Submerged diving time was 60 (SD 6) % during the periods of observation, which were part of a total working time of 2–9 h a day. Mean dive times and surface intervals were shorter in the Bajau than in the Ama (both $P < 0.001$). Most of the diving time was spent hunting.

Discussion

Our observations of daily underwater times in Hegura-Ama in 2009–2010 are similar to those reported in 1995, with approximately 100 min per day spent under water in the unassisted type of diving (cachido), and 120 min in the assisted dives (funado).[7] The unassisted divers in our study, with an average age of 60 years, were thus able to produce at least the same total daily dive time as the 25-years younger divers in the 1995 study. However, the mean dive duration of 38 s in the present study was shorter than that reported in 1995 (60 s), as was the mean depth shallower, leading to a longer bottom time per dive in the 1995 study, as travel speeds were similar. However, the dive duration (37 s) and depth (7 m) produced by male Ama from Chikura were similar to those of our study, but these divers spent more time at the surface.[6]

In interviews, the Ama stated that, before the introduction of time limitations by fishing regulations, divers commonly made two dive shifts per day, interrupted by a midday break to eat, rest and warm up, with a total in-water time of 6–8 h per day (conversations with divers, 2009). This suggests that the daily dive time seen in these Ama divers may not have reached the maximal possible time. However, it is not clear if 50% underwater time could be produced throughout a full diving day; it could be that the restricted fishing time pushes the diver to produce longer dives than if a longer total working time were allowed. This will be studied further.

The Bajau produced shorter dives and much shorter surface intervals than the Ama, but spent a surprisingly high percentage of the working time submerged, 60%, with most of the time actively fishing. This is, to our knowledge, more than that reported for any other group of natural breath-hold divers. This is in the range of the percent underwater time seen in some species of marine mammals, e.g., the sea otter.[11] Few previous recordings exist from the Bajau, among which some divers were found to spend 9 h per day in the water. If they dive with the same percentage of time under water across entire working days, this means some divers would spend more than 5 h per day submerged. Observations by one of the authors in 1988 in several groups of divers in Indonesia revealed immersed working times of 2–4 h per day in some groups, while one group of Bajau in Sulawesi had working times of approximately 6 h per day on average, with individuals spending up to 10 h per day in the water.[9]

In Bajau as well as in the Ama, both female and male divers exist, though, in the Ama, a greater proportion of the divers are female, whilst among adult Bajau, predominantly men dive. We believe genders can be directly compared as no clear gender differences with respect to diving performance have been reported, and the division of labour may be mainly traditional or socio-economic in nature.[12]

The more pelagic diving profiles during spear fishing at shallower depths in the Bajau allowed a greater portion of the dive time to be spent actively working compared to the Ama, who lose valuable dive time for descent and ascent to

the harvesting depths. In the Korean unassisted divers, diving to similar depths (4–7 m) as the Bajau, and with similar dive durations (29 s), the intervals between dives were apparently longer, as total non-diving time spent in the water was reported to greatly exceed the diving time.[6] In most previous studies, however, little focus has been directed toward the surface interval duration. We believe that the surface interval duration is most relevant both to determine the efficiency of human natural diving in a biological context, and to address questions concerning optimisation of recovery.

An important contributing factor allowing Bajau to spend a longer total time immersed may be the warmer water. Studies by Kang suggest that metabolic energy demand rises as a consequence of cold across a diving shift in Korean Hae Nyo, diving without suits.[3] Warm water could possibly also limit metabolism in favour of shorter recovery intervals after dives, although no such differences in dive durations between summer and winter were reported in Korean divers.[6] A study of the arterial blood gas tensions after dives in Korean Hae Nyo suggested that full recovery occurs within 15–20 s after dives of a mean duration of 62 s.[13] Thus, with the shorter dives produced by the Bajau, the interval observed would likely allow sufficient recovery.

Conclusions

Both Ama and Bajau showed efficient diving patterns with, on average, 50 and 60% of the dive time spent submerged. To our knowledge, the present study reveals the greatest proportion of time spent under water and the longest estimated total daily dive times reported for human natural apneic divers. We conclude that the natural human diving ability allows efficient sea harvesting at shallow depths and that the main limitation is not total apneic duration but other factors, possibly including water temperature, whereby the time in the water can be longer in the Bajau divers than in the Ama. Studies are planned to continue, focusing on diver fatigue and age-related diving performance.

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References

1 Rahn H, Yokoyama T. Editor. Physiology of breath-hold diving and the Ama of Japan. Publication no. 1341. National Academy of Sciences, Washington, DC: National Research Council; 1965.
2 Ferretti G, Costa M. Diversity in and adaptation to breath-hold diving in humans. Comp Biochem Physiol. 2003;136(Part A):205-13.
3 Kang DH, Kim PK, Kang BS, Song SH, Hong SK. Energy metabolism and body temperature of the ama. J Appl Physiol. 1965;20:46-50.
4 Park YS, Rennie DW, Lee IS, Park YD, Paik KS, Kang DH, et al. Time course of deacclimatization to cold water immersion in Korean women divers. J Appl Physiol. 1983;54:1708-16.
5 Hong SK, Rahn H, Kang DH, Song SH, Kang BS. Diving pattern, lung volumes, and alveolar gas of the Korean diving woman (Ama). J Appl Physiol**.** 1963;18:457-65.
6 Hong SK, Henderson J, Olszowka A, Hurford WE, Falke KJ, Qvist J, et al. Daily diving pattern of Korean and Japanese breath-hold divers (ama). Undersea Biomed Res. 1991;18:433-43.
7 Mohri M, Torii R, Nagaya K, Elsner R, Takeuchi H, et al. Diving patterns of Ama divers of Hegura Island, Japan. Undersea Hyperb Med. 1995;22:137-43.
8 Sopher D. The sea nomads: a study based on the literature of maritime boat people of Southeast Asia. Singapore: Lim Bian Han Government Printer; 1965.
9 Schagatay E. The human diving response – effects of temperature and training. Thesis submitted for doctorate. Lund: Department of Animal Physiology, University of Lund, Sweden; 1996.
10 Gislén A, Dacke M, Kröger R, Abrahamsson M, Nilsson D, Warrant E. Superior underwater vision in a human population of sea gypsies. *Current Biology. 2003;*13:833-6.
11 Bodkin JL, Esslinger GG, Monson DH. Foraging depths of sea otters and implications to coastal marine communities. Marine Mamm Sci. 1993;20:305-21.
12 Holm B, Schagatay E, Kobayashi T, Masuda A, Ohdaira T, Honda Y. Cardiovascular change in elderly male breath-hold divers (Ama) and their socio-economical background at Chikura in Japan. J Physiol Anthropol. 1998;17:181-7.
13 Qvist J, Hurford WE, Park YS, Radermacher KJ, Falke DO, Ahn DW, et al. Arterial blood gas tensions during breath-hold diving in the Korean ama. J Appl Physiol. 1993;75:285-93.

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Erika Schagatay, PhD, is Professor at the Department of Engineering and Sustainable Development and Swedish Winter Sports Research Centre, Mid Sweden University, Östersund, Sweden.
Angelica Lodin-Sundström, BSc, is a doctoral student at the Department of Engineering and Sustainable Development, Mid Sweden University and
Erik Abrahamsson, BSc, is a Masters student at the Department of Sociology, Division of Social Anthropology, Lund University, Lund, Sweden.

Address for correspondence:
Professor E Schagatay
Department of Engineering and Sustainable Development
Mid Sweden University,
Akademigatan 1, 83125 Östersund
Sweden
Phone: *+46-(0)63-165512*
Fax: *+46-(0)63-165700*
E-mail: *<Erika.Schagatay@miun.se>*