

Original articles

Recreational diving-related injury insurance claims among Divers Alert Network Japan members: Retrospective analysis of 321 cases from 2010 to 2014

Yasushi Kojima^{1,2,3}, Akiko Kojima¹, Yumi Niizeki^{1,2,4}, Kazuyoshi Yagishita^{1,2}

¹ Divers Alert Network Japan (DAN Japan) / Japan Marine Recreation Association, Yokohama, Japan

² Hyperbaric Medical Center, Medical Hospital of Tokyo Medical and Dental University, Tokyo, Japan

³ Tokio Marine & Nichido Medical Service Co. Ltd., Tokyo, Japan

⁴ Department of Orthopaedic Surgery, Soka Municipal Hospital, Saitama, Japan

Corresponding author: Dr Yasushi Kojima, Divers Alert Network Japan (DAN Japan) / Japan Marine Recreation Association, 4-43 Honcho, Naka-ku, Yokohama-city, Kanagawa 231-0005, Japan
kojihbo7@tmd.ac.jp

Key words

Decompression illness; Decompression sickness; Diving incidents; Epidemiology; Injuries; Risk; Trauma

Abstract

(Kojima Y, Kojima A, Niizeki Y, Yagishita K. Recreational diving-related injury insurance claims among Divers Alert Network Japan members: Retrospective analysis of 321 cases from 2010 to 2014. *Diving and Hyperbaric Medicine*. 2020 June 30;50(2):92–97. doi: 10.28920/dhm50.2.92-97. PMID: 32557409.)

Introduction: Monitoring trends in diving-related injuries enables implementation of effective safety measures. Divers Alert Network Japan (DAN Japan) membership includes insurance covering recreational diving-related injuries and fatalities. Use of claim data provides both a known denominator and demographic data about injured members.

Methods: The study analysed 325 insurance claims reported to DAN Japan from 2010 to 2014. Four fatalities were excluded, leaving 321 claims for analysis. Claimants were divided into three age groups: young adults (< 40 years); middle-aged (40–59 years) and older adults (≥ 60 years). The total injury claims rate (ICR), decompression illness (DCI) rate (DCR) and trauma rate (TCR) were calculated. Differences between the sexes within each age group were analysed.

Results: The total number of DAN Japan member-years in the period was 80,617, with a mean age of 45 years. Claims were made by 153 males and 168 females with a mean and median age of 46 years. Trauma was the most frequent reason for a claim (113 cases, 35%), followed by DCI (109 cases, 34%). The ICR (per 10⁴ member-years) was 39.8 (95% confidence interval 35.5 to 44.2) and the TCR was 14.0 (11.4 to 16.6). For every age group, the ICR and TCR were significantly higher for females than males. The DCR was 13.5 (11.0 to 16.1) and did not significantly differ between the sexes.

Conclusions: The incidence of trauma-related diving injuries exceeds that of claims related to DCI. Females appear to have a higher risk of injury than the general diving population.

Introduction

Recreational diving is popular in Japan, with more than 40,000 new divers certified each year.¹ The mean age of Japanese divers is unknown; however, the mean age of Divers Alert Network Japan (DAN Japan) members has increased from 38 years in 2004 to 47 years in 2014.² This increase in the mean age of DAN Japan members may bring an increase in diving-related injuries. It is essential to monitor the trends in diving-related injuries to plan effective interventions for optimising diving safety. Diving-related fatalities have been investigated in various areas,^{3–6} whilst the frequency of decompression illness (DCI) (a dive-related injury) has been estimated by many researchers.^{6–9} A recent study evaluated both diving-related and non-diving-related injuries recorded by a recreational diving business;⁹ however,

there are limited data available on diving-related injuries other than DCI.

As diving-related injuries range from mild to severe, it is difficult to accurately determine the incidence. Membership with DAN Japan automatically includes basic insurance, covering losses from recreational diving-related injuries and fatalities. Questionnaire surveys generally tend to identify cases involving milder injuries rather than the injuries involved in treated cases and insurance claims. The present study focused on the relatively severe diving-related injuries reported in DAN Japan insurance claims, as it is important to understand and to prevent such injuries. Use of claims data also provides a known denominator, which enables better statistical analysis.

Methods

The study protocol was approved by the Institutional Review Board of DAN Japan and the Japan Marine Recreation Association (approval number: R01363). The study was conducted in accordance with the principles of the Declaration of Helsinki. The present study retrospectively reviewed the insurance claims submitted to DAN Japan from 01 January 2010 to 31 December 2014. The claims data were provided by DAN Japan in a single Excel™ database, under the condition that each claim report was de-identified and given a case identification number. The only demographic data were the sex and age of each claimant. The collected data included the injury date, diving location, diagnosis and course of treatment. Some claims reported the occurrence of injuries at two or more body locations at the one time. However, not all claims accurately reported every diagnosis; for example, 'contusions of the upper body' indicates that injuries occurred at more than one site, but does not identify the actual injury sites. In the present study, one main diagnosis was considered for each claim. For example, for a claim in which the diver incurred a dental injury after hitting their head on the gas cylinder during boat-diving entry, the case was counted as a dental injury rather than a head contusion.

Each case was classified as either a diving disorder or a non-diving disorder. Diving disorders were defined as DCI, barotrauma, and hazardous marine life injury. Non-diving disorders included other injuries such as fractures and sprains that occurred at any time during the diving trip, including on the diving boat; non-diving disorders were further classified into two groups: trauma and others. Cases that could not be categorised into a specific group due to incomplete diagnostic information were classified as unknown.

The total number of DAN Japan member-years during the study period was calculated as the sum of the total number of members at the end of each of the five years. The total injury claims rate (ICR), DCI claims rate (DCR), and trauma claims rate (TCR) were calculated. Prevalence was calculated as the number of claims divided by the number of member-years and was converted to the number of injuries per 10⁴ member-years. This means that, if one diver was continuously a DAN Japan member from 2010 to 2014 and was injured three times but only made two insurance claims, she/he would be counted as having two injury cases and contribute to five member-years in the dataset. The renewal rate of DAN Japan members during the assessed period was around 90%. However, as all personal information other than sex and age had been deleted from the database, it was not possible to identify whether multiple claims had been made by the same member. For the DCI claims, the time between the onset of symptoms and initiation of recompression therapy was recorded.

STATISTICAL ANALYSIS

Divers were clustered into three age groups: young adults (< 40 years), middle-aged (40–59 years), and older adults (≥ 60 years). The ICR and 95% confidence interval (CI) were calculated for each age group and compared with the middle-aged group, which comprised 57.6% of the DAN Japan member-years during the study period. The rate ratio (RR) of the ICR was calculated as the ratio of the ICR of each age group with respect to the middle-aged group. The rate difference (RD) of the ICR was calculated as the difference between the ICR for each age group and the middle-aged group. The same RR and RD calculations were made for the DCR and TCR. In addition, a cross-tabulation table of sex with respect to the total number of injuries, DCI, and trauma was created. The chi-squared test was used to assess the differences between males and females within each age group. The significance level for statistical analysis was set at $P < 0.05$. Data analyses were performed using IBM SPSS Statistics ver.23.0 (IBM Japan, Ltd.).

Results

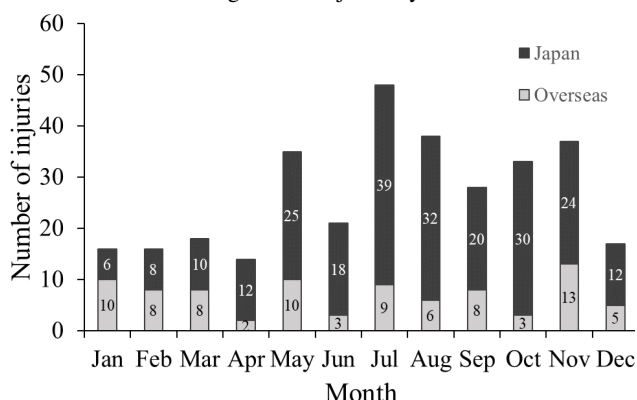
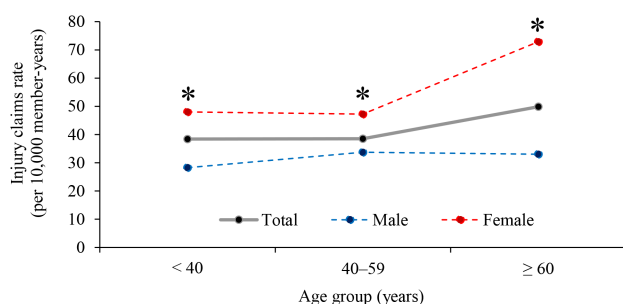
The total number of DAN Japan member-years during the study period was 80,617. Males accounted for 59% of DAN Japan members, and the mean age was 45 years. There were 325 recreational diving-related injuries and fatalities reported to DAN Japan for insurance claims. After excluding four fatalities, 321 diving-related injuries were analysed. The diving-related injuries were incurred by 153 males and 168 females (mean and median age 46 years, range 20–77 years).

The diving location was in Japan in 236 cases and overseas in 85 cases. Many of the Japan-based injuries occurred in summer and autumn. In contrast, overseas injuries occurred evenly throughout the year (Figure 1). Table 1 shows the distribution of diving-related injuries. Diving disorders accounted for 168 cases (52%) of injuries, while non-diving disorders accounted for 132 cases (41%). Within the diving disorder category, DCI was the most common type of injury (109 cases, 34%). Among non-diving disorder categories, trauma was the most common type of injury (113 cases, 35%) and also the most common type of injury overall, followed by DCI.

Fracture and dislocation accounted for 43 cases of trauma (38%). Other common injuries reported in trauma cases were sprain, contusion, wound, ligamentous injury and dental injury (Table 2). The location of fractures and dislocations was the lower limb in 20 cases, the upper limb in 12, ribs in seven, spine in three, and unknown in two; one case involved two fractures that occurred at the same time and were dealt with as a single claim. The causes of fractures and dislocations varied; six cases were related to ladders, while eight were related to issues with gas cylinders.

Figure 1

Distribution of diving-related injuries by month and location

**Figure 2**Distribution of the total injury claims rate by three age groups (young adults, middle-aged and older adults) and sex; * $P < 0.05$, females versus males

The ICR was 39.8 per 10^4 member-years (95% CI 35.5 to 44.2). The DCR was 13.5 per 10^4 member-years (95% CI 11.0 to 16.1). The TCR was 14.0 per 10^4 member-years (95% CI 11.4 to 16.6.). Table 3 shows the ICR, DCR, and TCR estimates for each age group and the corresponding RR and RD in comparison with the middle-aged group. Although the ICR did not significantly differ between age groups, the highest ICR of 49.9 per 10^4 member-years (95% CI 35.6 to 64.1) was seen in the older adults group, with a RR of 1.3 (95% CI 0.9 to 1.8) and a RD of 11.3 per 10^4 member-years (95% CI -4.0 to 26.7). The lowest TCR of 9.3 per 10^4 member-years (95% CI 5.5 to 13.1) was seen in the young adults group, with a RR of 0.6 (95% CI 0.4 to 1.0) and a RD of -6.2 per 10^4 member-years (95% CI -11.4 to -1.0).

Figure 2 shows the total ICR by sex and age group. For every age group, the ICR was significantly higher for females than males. The DCR did not significantly differ between males and females in each age group (Figure 3). Figure 4 shows that for every age group, the TCR was significantly higher for females than males.

Only 20 (18%) of the 109 reported DCI cases underwent recompression within 24 hours. Recompression was performed within one week in 71 cases (65%), within two weeks in 89 cases (82%), and within one month in 98 cases

Table 1

Distribution of diving-related injuries by type of injury

Injury type	n (%)
All types	321 (100)
Diving disorders	168 (52)
Decompression illness	109 (34)
Barotrauma	39 (12)
Marine animal injuries	20 (6)
Non-diving disorders	132 (41)
Trauma	113 (35)
Other	19 (6)
Unknown	21 (7)

Table 2

Distribution of diving-related traumatic injuries by injury type

Injury type	n (%)
Fracture / dislocation	43 (38)
Sprain	14 (12)
Contusion	12 (11)
Open wound	11 (10)
Ligament injury	4 (4)
Dental injury	3 (3)
Head injury	2 (2)
Muscle injury	2 (2)
Other	6 (5)
Unknown	16 (14)

(90%). In one case, recompression was performed on the 48th day after the onset of symptoms. In two cases, no recompression was performed. There were three cases where it was unknown when recompression was performed, whilst in five cases it was unknown whether or not recompression was performed. The DAN Japan hotline service was used in only 16 DCI cases (15%). Among the DCI claims, payment for residual disability was confirmed in only one case.

Discussion

In the present study, the DCR was 13.5 per 10^4 member-years, which is similar to the previously reported DCI rate among insured DAN USA members of 20.5 per 10^4 member-years.¹⁰ The importance of claims data is that we had a known denominator, which allows for better cross-regional comparisons of diving injury incidence. However, insurance is not automatically included in DAN USA membership, and so the denominators differed and the number of dives per year also differed. The DCI rate of 20.5 per 10^4 member-years was considered roughly equivalent to that of the British Sub-Aqua Club members (32.59 per 10^4 member-years) when the annual number of dives is taken into account (DAN USA 0.82 per 10^4 dives; British Sub-Aqua Club 0.88 per 10^4 dives).¹⁰

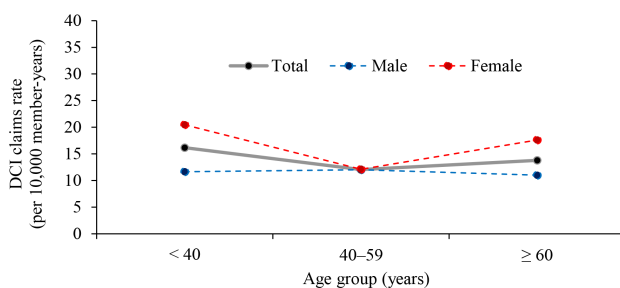
Table 3

Claims rate (per 10⁴ member-years) for injury, decompression illness (DCI) and trauma, rate ratio, and rate difference in young (< 40 years) and older (≥ 60 years) adults groups in comparison to the middle-aged (40–59 years) group. CI = confidence interval; Rate diff. = rate difference

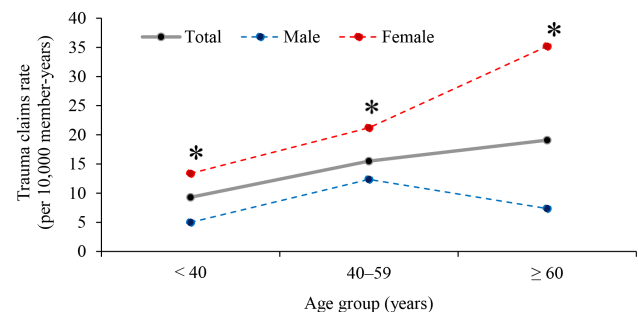
	Age group	Member-years	No. claims	Claims rate	95% CI	Rate ratio	95% CI	Rate diff.	95% CI
Injury	Young adults	24737	95	38.4	30.7 to 46.1	1.0	0.8 to 1.3	-0.1	-9.7 to 9.4
	Middle-aged	46452	179	38.5	32.9 to 44.2				
	Older adults	9428	47	49.9	35.6 to 64.1	1.3	0.9 to 1.8	11.3	-4.0 to 26.7
DCI	Young adults	24737	40	16.2	11.2 to 21.2	1.3	0.9 to 2.0	4.1	-1.8 to 10.0
	Middle-aged	46452	56	12.1	8.9 to 15.2				
	Older adults	9428	13	13.8	6.3 to 21.3	1.1	0.6 to 2.1	1.7	-6.4 to 9.9
Trauma	Young adults	24737	23	9.3	5.5 to 13.1	0.6	0.4 to 1.0	-6.2	-11.4 to -1.0
	Middle-aged	46452	72	15.5	11.9 to 19.1				
	Older adults	9428	18	19.1	10.3 to 27.9	1.2	0.7 to 2.1	3.6	-5.9 to 13.1

Figure 3

Distribution of the decompression illness claims rate by three age groups (young adults, middle-aged and older adults) and sex (no statistically significant differences)

**Figure 4**

Distribution of the trauma claims rate by three age groups (young adults, middle-aged and older adults) and sex; **P* < 0.05, females versus males



Japanese divers reportedly dive 60 times per year.¹¹ However, this figure includes both recreational divers and instructors. Instructors tend to dive more frequently than recreational divers, and many DAN Japan members are recreational divers, not instructors. Furthermore, even if a member is an instructor, an injury incurred while diving recreationally during a recreational dive trip is covered by the insurance. Recreational divers in Japan reportedly dive 34 times per year.¹² Using the figure of 34 dives per year, the DCR calculated in the present study of 13.5 per 10⁴ divers is adjusted to 0.4 per 10⁴ dives, which is half of the DCI rates reported in the above-mentioned studies. However, other studies have reported DCI rates of 0.53 per 10⁴ dives¹¹ and 0.57 per 10⁴ dives,¹³ which are similar to the estimate for the present study. Notably, the prevalence of DCI in three previous studies^{10,11,13} and the present study was based on retrospective self-reported data. However, the

prevalence of DCI reported in a New Zealand study⁹ was based on prospective field data, which makes this estimate more reliable. That study reported a DCR of 0.41 per 10⁴ dives,⁹ which is similar to the estimate for the present study.

The ICR in the present study was 39.8 per 10⁴ member-years. This can be converted to 1.17 injuries per 10⁴ dives using the same adjustment method as mentioned above. A previous study reported an ICR of 302 per 10⁴ dives, which was based on self-reporting rather than medical records.¹³ Another study using self-reported data found that DCI-like symptoms represent a small fraction of total diving-related injuries.¹⁴ These findings indicate that many injuries do not require medical treatment. Questionnaire surveys generally tend to identify more cases of mild injury than studies reviewing treated cases and insurance claims. The New Zealand study, based on prospective field data, reported an ICR of 5.7 per

10⁴ dives,⁹ which is five times higher than that calculated in the present study. However, many reported cases were minor injuries, suggesting that an insurance claim was not submitted in most cases.⁹ In addition, a study evaluating treated cases from a Scottish cold-water environment (Scapa Flow) also reported higher ICRs (4.4 and 7.6 per 10⁴ dives), mostly for DCI, than that calculated in the present study,¹⁵ suggesting that the ICR may vary in different diving locations. Variations in the diving location or type of diving can make comparative analysis problematic. This is important as the diving in Scapa Flow is deep, technical, drysuit diving. Therefore, comparisons of diving injury rates between specific cohorts must be made cautiously, as these rates are affected by multiple environmental variables as well as the type of diving.

In the present study, the DCR was 13.5 per 10⁴ member-years, and the TCR was almost the same as the DCR. Fractures and dislocations accounted for most of the TCR. A recent study that evaluated diving-related injuries based on prospective field data also reported that trauma (35 cases) was more common than DCI (four cases),⁹ with a higher TCR (3.6 per 10⁴ dives) than the 0.4 per 10⁴ dives reported in the present study. However, among the 35 traumatic injuries reported in this previous study, only seven cases needed emergency care and 10 cases required consultation with a general practitioner,⁹ suggesting that this previous study included milder injuries than the present study. Thus, although DCI tends to be the focus of discussions about diving-related injuries, the findings from this and the present study indicate that it is also important to act to prevent other types of injuries.

Older age and the male sex are considered to be risk factors for diving-related fatalities.⁴ Our findings suggest that females may be at greater risk of injury than the general diving population. However, this cannot be definitively concluded from the present data, as this difference in the number of injury claims might simply reflect the differences between males and females in the number of dives and diving style. A similar trend was seen in the trauma category, and some fractures (such as distal radial fractures) are more common in middle-aged females than in males, possibly due to osteoporosis.¹⁶ Further research is needed to determine whether females are at greater risk of diving-related injuries than the general diving population.

In the present study, only 20 DCI cases (18%) underwent recompression within 24 hours, although at least 102 (94%) were eventually treated. A previous study reported that the number of cases with self-reported DCI symptoms is more than 25 times the number of treated DCI cases.¹³ This suggests that mild DCI symptoms may resolve spontaneously. In the present study, only one DCI case received payment for residual disability. Our findings suggest that even among cases of treated DCI, many cases were mild and/or responded effectively to delayed treatment.

The present study has the following limitations. Each insurance claim was made by DAN Japan members or their families, not by physicians. Thus, the accuracy of the diagnosis written in the document is unconfirmed. Furthermore, there might have been other diving-related injuries that were not reported to DAN Japan, and members may not be representative of all recreational divers in Japan. Finally, it is impossible to accurately determine the number of times that each diver dived, which would provide the injury rate per number of dives.

Conclusions

The ICR was 39.8 per 10⁴ member-years. DCI accounted for one-third of the total number of injuries, whilst trauma was the most common injury for which a DAN insurance claim was made. Compared with the general diving population, females may be at increased risk of diving-related injury, particularly injury due to trauma. It is important to take action to prevent injuries other than DCI. DAN Japan is considering what preventative interventions to implement.

References

- 1 Kojima Y. Japanese divers. In: Buzzacott P, editor. DAN annual diving report 2012–2015 edition. Durham (NC): Divers Alert Network; 2015. p. 108–11. Available from: <https://www.ncbi.nlm.nih.gov/books/NBK344435/>. [cited 2019 August 04]. PMID: 26937540.
- 2 Kojima Y, Kawaguchi H, Kojima A. Recreational diving-related fatalities in Japan, 2005–2015. In: Buzzacott P, editor. DAN annual diving report 2017 edition. Durham (NC): Divers Alert Network; 2017. p. 79–86. Available from: <https://www.ncbi.nlm.nih.gov/books/NBK487739/>. [cited 2019 August 04]. PMID: 29553634.
- 3 Ihama Y, Miyazaki T, Fuke C, Mukai T, Ohno Y, Sato Y. Scuba-diving related deaths in Okinawa, Japan, from 1982 to 2007. *Leg Med (Tokyo)*. 2008;10:119–24. doi: 10.1016/j.legalmed.2007.09.002. PMID: 18037330.
- 4 Denoble PJ, Pollock NW, Vaithyanathan P, Caruso JL, Dovenbarger JA, Vann RD. Scuba injury death rate among insured DAN members. *Diving Hyperb Med*. 2008;38:182–8. PMID: 22692749.
- 5 Buzzacott P, Schiller D, Crain J, Denoble PJ. Epidemiology of morbidity and mortality in US and Canadian recreational scuba diving. *Public Health*. 2018;155:62–8. doi: 10.1016/j.puhe.2017.11.011. PMID: 29306625.
- 6 Lippmann J. Review of scuba diving fatalities and decompression illness in Australia. *Diving Hyperb Med*. 2008;38:71–8. PMID: 22692688.
- 7 Ladd G, Stepan V, Stevens L. The Abacus Project: establishing the risk of recreational scuba death and decompression illness. *SPUMS Journal*. 2002;32:124–8. Available from: <http://archive.rubicon-foundation.org/7683>. [cited 2019 August 04].
- 8 Gilliam B. Evaluation of decompression sickness incidence in multi-day repetitive diving for 77,680 sport dives. *SPUMS Journal*. 1992;22:24–30. Available from: <http://archive.rubicon-foundation.org/9866>. [cited 2019 August 04].
- 9 Hubbard M, Davis FM, Malcolm K, Mitchell SJ. Decompression illness and other injuries in a recreational dive charter operation. *Diving Hyperb Med*. 2018;48:218–23.

- [doi: 10.28920/dhm48.4.218-223](https://doi.org/10.28920/dhm48.4.218-223). PMID: 30517953. PMCID: PMC6355312.
- 10 Denoble PJ, Ranapurwala SI, Vaithyanathan P, Clarke RE, Vann RD. Per-capita claims rates for decompression sickness among insured Divers Alert Network members. *Undersea Hyperb Med.* 2012;39:709–15. PMID: 22670551.
- 11 Nakayama H, Shibayama M, Yamami N, Togawa S, Takahashi M, Mano Y. Decompression sickness and recreational scuba divers. *Emerg Med J.* 2003;20:332–4. doi: [10.1136/emj.20.4.332](https://doi.org/10.1136/emj.20.4.332). PMID: 12835342. PMCID: PMC1726133.
- 12 Shibayama M. [The research which estimates the decompression failure (DCI) crisis number of the recreational diver]. *Komazawa Women's University Journal.* 2007;14:103–9. Japanese.
- 13 Ranapurwala SI, Bird N, Vaithyanathan P, Denoble PJ. Scuba diving injuries among Divers Alert Network members 2010–2011. *Diving Hyperb Med.* 2014;44:79–85. PMID: 24986725.
- 14 Monnot D, Michot T, Dugrenot E, Guerrero F, Lafère P. A survey of scuba diving-related injuries and outcomes among French recreational divers. *Diving Hyperb Med.* 2019;49:96–106. doi: [10.28920/dhm49.2.96-106](https://doi.org/10.28920/dhm49.2.96-106). PMID: 31177515. PMCID: PMC6704004.
- 15 Trevett AJ, Forbes R, Rae CK, Sheehan C, Ross J, Watt SJ, et al. Diving accidents in sports divers in Orkney waters. *Scott Med J.* 2001;46:176–7. doi: [10.1177/003693300104600608](https://doi.org/10.1177/003693300104600608). PMID: 11852632.
- 16 Sakuma M, Endo N, Oinuma T, Endo E, Yazawa T, Watanabe K, et al. Incidence and outcome of osteoporotic fractures in 2004 in Sado City, Niigata Prefecture, Japan. *J Bone Miner Metab.* 2008;26:373–8. doi: [10.1007/s00774-007-0841-1](https://doi.org/10.1007/s00774-007-0841-1). PMID: 18600404.

Acknowledgements

The authors thank Toshihiro Kakinuma (Orthomedico Inc.) for his assistance with the statistical analysis. We also thank Kelly Zammit, Edanz Editing (<https://en-author-services.edanzgroup.com>), for editing a draft of this manuscript.

Conflicts of interest and funding: nil

Submitted: 25 August 2019

Accepted after revision: 11 December 2019

Copyright: This article is the copyright of the authors who grant *Diving and Hyperbaric Medicine* a non-exclusive licence to publish the article in electronic and other forms.

Diving and Hyperbaric Medicine Journal is
on Facebook

Like us at:

<https://www.facebook.com/divingandhyperbaricmedicine/>

