

Scuba-related injuries presenting to United States emergency departments: paediatric and adult patterns

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Keywords

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Abstract

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Introduction: Scuba diving is a popular sport that carries risks unique to the underwater environment. Paediatric emergency department presentations for scuba diving injuries are incompletely characterised, particularly in comparison with adults.

Methods: We retrospectively analysed scuba-related injuries recorded in the National Electronic Injury Surveillance System (NEISS) from 2005–2024. We estimated national paediatric emergency department presentations using NEISS weights and compared injury categories and hospitalisation rates between paediatric and adult patients.

Results: We identified 68 paediatric cases, corresponding to an estimated 122 paediatric scuba-related emergency department presentations annually. Trauma was the most common injury category (41.2%), followed by otitis (17.6%) and ear, sinus, ocular, or dental barotrauma (16.2%). Hospitalisation was most common among patients with possible decompression sickness or arterial gas embolism (DCS/AGE) (42.9%) and drowning/aspiration (25.0%). Compared with adults, paediatric patients were less often hospitalised (10.3% vs 21.4%, $P = 0.038$), more likely to present with traumatic injuries (41.2% vs 26.1%, $P = 0.010$), and less likely to present with possible DCS/AGE (10.3% vs 25.0%, $P = 0.006$).

Conclusions: Among patients presenting to United States emergency departments with scuba-related injuries, paediatric patients most commonly had trauma, otitis, or ear, sinus, ocular, or dental barotrauma. Paediatric divers were also less likely than adults to experience DCS/AGE injuries and were less likely than adults to require hospitalisation. Our data describes emergency department presentation patterns rather than overall injury risk among paediatric scuba divers.

Introduction

Scuba diving is a popular sport with inherent hazards. Historical surveys estimated that approximately three million people in the United States participate annually, although contemporary participation may differ from these pre-COVID estimates.¹ Most were casual participants completing one to seven dives per year.¹ In addition to trauma and musculoskeletal injuries common to many sports, scuba diving carries risks related to changes in ambient pressure, inert gas bubble formation, and environmental hazards.

Diving injuries may occur during descent, at depth, or during ascent. During descent, rising ambient pressure requires equalisation of gas-filled spaces; failure to equalise the middle ear can cause pain, haemorrhage, or tympanic membrane rupture. Middle-ear barotrauma is among the most common diving complications and may be especially relevant in paediatric divers.^{2–3} During ascent, trapped gas expands as ambient pressure decreases according

to Boyle's law. Breath-holding or impaired gas escape can cause pulmonary overinflation syndromes, including pneumothorax, pneumomediastinum, subcutaneous emphysema, and arterial gas embolism.⁴

Decompression sickness (DCS) occurs when inert gas comes out of solution during or after decompression, forming bubbles in tissues or the circulation. Manifestations may be musculoskeletal, cutaneous, lymphatic, neurologic, vestibular, cardiopulmonary, or constitutional. Although traditionally divided into Type I and Type II disease, this classification may oversimplify the clinical spectrum.⁵ Treatment often requires recompression in a hyperbaric chamber.⁶

In addition to pressure-related injuries, the diving environment itself poses significant hazards. Equipment failure or injury underwater can lead to hypoxia, aspiration, drowning, and death. Marine animal encounters, while uncommon, may also result in serious injury.

Adult scuba-related morbidity and mortality in the United States and Canada have been described, but paediatric data remain limited.⁷ Prior paediatric studies have used different data sources, shorter study periods, or lacked direct comparison with adult emergency department presentations.⁸

The Professional Association of Diving Instructors (PADI) offers diving experiences for paediatric divers as young as eight years of age; however, even younger divers may participate in 'backyard' scuba diving outside formal training offered by professional associations.⁹ Serious injuries, including arterial gas embolism, can occur even during shallow-water pool dives when appropriate safety measures are not in place.^{10–11} Paediatric divers may be more likely to sustain diving injuries if they do not fully understand or appreciate the hazards of scuba diving and its unique physiological risks.

Paediatric divers may also differ from adults in supervision, training pathway, dive depth, medical screening, experience, and exposure patterns. We therefore hypothesised that paediatric and adult patients presenting to emergency departments after scuba-related incidents would differ in injury patterns and hospitalisation rates. This study characterised paediatric scuba-related emergency department presentations from 2005–2024, estimated national paediatric presentation counts using NEISS weights, and compared paediatric and adult injury patterns and hospitalisation rates.

Methods

This study met criteria for institutional review board exemption because it used publicly available, deidentified data without patient contact or protected health information. Exemption (26-003659) was received on April 3, 2026.

We performed a retrospective analysis of scuba-related injuries presenting to emergency departments (EDs) in the United States. We extracted data from the National Electronic Injury Surveillance System (NEISS).¹² The NEISS is a publicly available database that collects statistics on consumer product-related injuries. At participating hospitals, a professional research coordinator records information including patient demographics, injury setting, body part injured, and the product or activity associated with an injury. Reports also include a short narrative describing the events leading to the injury and, in some cases, an emergency department diagnosis. Approximately 100 hospitals across the United States form a representative sample from which national estimates can be calculated. The participating hospitals are selected and maintained by the Consumer Product Safety Commission as part of the NEISS sampling frame; they were not selected by the study authors.

Each NEISS case is assigned a sampling weight based on hospital stratum and emergency department volume. We summed these weights to estimate national emergency department presentations during the study period. We

calculated mean annual presentations by dividing the national estimate by the length of the study period in years.¹³

We queried the NEISS database for all records assigned the scuba diving product code (product code 1275) from January 1, 2005, through December 31, 2024. Case identification was based solely on the NEISS product code. We divided the cohort into paediatric (age ≤ 18 years) and adult (age > 18 years) sub-cohorts. Narratives and diagnosis fields were manually reviewed, and each case was assigned to a prespecified injury category (Table 1).

We categorised injuries using the NEISS narrative, diagnosis field when available, body part, disposition, and contextual details such as reported depth, ascent history, or aspiration. Categories included trauma; ear, sinus, ocular, or dental barotrauma; pulmonary barotrauma; possible DCS or arterial gas embolism (AGE); otitis; marine animal injury; drowning/aspiration; immersion pulmonary oedema; other medical presentations; and undifferentiated post-dive symptoms. Otitis included otitis externa and otitis media when specified. Undifferentiated post-dive symptoms included chest pain, musculoskeletal pain, or central nervous system symptoms when the available information was insufficient to support a more specific diving-related diagnosis.

We grouped DCS and AGE because NEISS narratives often lack sufficient detail to distinguish them reliably, and both may present after ascent with neurologic, cardiopulmonary, or systemic symptoms requiring urgent evaluation. Because these conditions differ in mechanism, severity, prognosis, and management, the combined category should be interpreted as a pragmatic surveillance classification rather than a definitive clinical diagnosis.

A professional diver with more than 10 years of experience reviewed the narratives. Cases with insufficient detail were classified conservatively, and uncertain cases were adjudicated by a physician investigator.

We reported descriptive statistics for our cohorts including age, sex, race, injury type, maximum reported depth when available, and disposition (hospitalisation, fatality, treated and released/discharged from the ED, or left without being seen). Fatalities were retained if recorded in NEISS disposition; however, NEISS captures only deaths associated with ED presentation and should not be considered a comprehensive fatality surveillance system for scuba diving.

We calculated weighted national estimates of ED presentations using the NEISS-provided weight for each case and compared paediatric and adult injuries during the study period. Categorical variables, including sex distribution, hospitalisation, fatality, and injury category, were compared using Fisher's exact test. All comparative statistical analyses were performed on unweighted data. Weighted data were used only to generate descriptive national estimates. Survey-weighted comparative analyses were considered; however,

Table 1

Injury-classification definitions and representative paraphrased NEISS (National Electronic Injury Surveillance System) narratives for scuba-related emergency department presentations, United States, 2005–2024

Group	Description	Representative NEISS narrative, paraphrased
Trauma	Abrasions, lacerations, fractures, contusions, and other mechanical injuries.	<i>A 16-year-old male struck his head twice on a scuba tank while diving.</i>
Ear/sinus/ocular/dental barotrauma	Tympanic membrane rupture, middle-ear or sinus barotrauma, subconjunctival haemorrhage, and dental barotrauma.	<i>A 13-year-old female experienced an ear pop during a scuba class and was diagnosed with a ruptured tympanic membrane.</i>
Pulmonary barotrauma	Pneumomediastinum, subcutaneous emphysema, pneumothorax, or alveolar haemorrhage attributed to pressure-related lung injury.	<i>A 20-year-old male developed chest pain while diving at 7.6 m and was diagnosed with pneumomediastinum.</i>
Possible decompression sickness or arterial gas embolism	An emergency department diagnosis of decompression sickness or arterial gas embolism, or rapid ascent followed by immediate compatible symptoms when a definitive diagnosis was not documented.	<i>A diver surfaced rapidly from 15.2 m and presented with altered mental status after the dive.</i>
Otitis	Otitis externa or otitis media when specified in the diagnosis or narrative.	<i>A 12-year-old male developed left ear pain after scuba diving at camp and was diagnosed with otitis.</i>
Marine animal injury	A bite, sting, envenomation, or contact injury caused by a marine animal.	<i>A 17-year-old female sustained a sea-urchin spine injury while scuba diving and subsequently developed a skin infection.</i>
Undifferentiated post-dive symptoms	Chest pain, musculoskeletal pain, or central nervous system symptoms after diving when the available narrative did not support a more specific diving-related diagnosis.	<i>A 13-year-old male developed discomfort in the elbows, hands, and knees during scuba lessons without sufficient information for a more specific diagnosis.</i>
Immersion pulmonary edema	A documented diagnosis of immersion pulmonary oedema.	<i>A 46-year-old female developed worsening dyspnoea during a dive to 22.6 m and was diagnosed with immersion pulmonary edema.</i>
Drowning/aspiration	Aspiration, submersion injury, drowning, or near drowning associated with scuba-related activity.	<i>A 14-year-old male became frightened while practicing regulator removal at a depth of 3.7 m during a scuba class, experienced a seizure, and was diagnosed with near drowning.</i>
Other medical presentations	Medical presentations temporally associated with scuba activity but not attributed to diving physiology.	<i>A 68-year-old male sustained facial burns when a cigarette ignited while he was wearing oxygen.</i>

small numbers within several paediatric injury categories limited the stability of weighted estimates. We therefore used unweighted case-level data for comparative analyses and weighted data only for descriptive national estimates. Accordingly, *P*-values reflect comparisons within the observed NEISS sample. All analyses were conducted in Python.

Results

COHORT

We identified 68 paediatric scuba-related emergency department visits in the NEISS sample from 2005–2024 (Table 2), corresponding to an estimated 2,442 national presentations during the study period, or 122 annually.

Table 2

Demographic characteristics and disposition of paediatric and adult scuba-related emergency department presentations in the NEISS (National Electronic Injury Surveillance System) sample, United States, 2005–2024; IQR – interquartile range

Variable	Paediatric (≤ 18 years)	Adult (> 18 years)	P-value
Observed cases, <i>n</i>	68	617	–
Weighted national estimate, 2005–2024	2,442	25,917	–
Estimated annual presentations	122	1,296	–
Male sex, <i>n/N</i> (%)	48/68 (70.6%)	454/617 (73.6%)	0.567
Median age, years (IQR)	13 (10–16)	40 (29–51)	–
Hospitalization, <i>n/N</i> (%)	7/68 (10.3%)	132/617 (21.4%)	0.038
Fatality, <i>n/N</i> (%)	0/68 (0.0%)	7/617 (1.1%)	1.000

Table 3

Injury patterns among paediatric and adult scuba-related emergency department presentations in the NEISS (National Electronic Injury Surveillance System) sample, United States, 2005–2024; **P* < 0.05; AGE – arterial gas embolism; DCS decompression sickness

Injury category	Paediatric, <i>n</i> (%)	Adult, <i>n</i> (%)	P-value
Trauma	28 (41.2%)	161 (26.1%)	0.010*
Possible DCS/AGE	7 (10.3%)	154 (25.0%)	0.006*
Ear/sinus/ocular/dental barotrauma	11 (16.2%)	116 (18.8%)	0.742
Otitis	12 (17.6%)	73 (11.8%)	0.175
Drowning/aspiration	4 (5.9%)	35 (5.7%)	1.000
Undifferentiated post-dive symptoms	4 (5.9%)	37 (6.0%)	1.000
Other medical presentations	1 (1.5%)	17 (2.8%)	1.000
Marine animal injury	1 (1.5%)	12 (1.9%)	1.000
Pulmonary barotrauma	0 (0.0%)	8 (1.3%)	1.000
Immersion pulmonary oedema	0 (0.0%)	4 (0.6%)	1.000

The paediatric cohort was 70.6% male (*n* = 48) and had a median age of 13 years (interquartile range 10–16). Race was recorded as White in 52.9% (*n* = 36), Black/African American in 1.5% (*n* = 1), Asian in 1.5% (*n* = 1), and other in 2.9% (*n* = 2); race was unspecified in 41.2% (*n* = 28). Dive depth was reported for 11 cases, with a mean (SD) of 12.3 (8.4) m and a maximum of 29.9 m.

Trauma was the most common injury category (41.2%, *n* = 28), followed by otitis (17.6%, *n* = 12), ear/sinus/ocular/dental barotrauma (16.2%, *n* = 11), possible DCS or AGE (10.3%, *n* = 7), and drowning/aspiration (5.9%, *n* = 4). Undifferentiated post-dive symptoms occurred in four patients (5.9%); chest pain in two, musculoskeletal pain in one, and central nervous system symptoms in one. Marine animal injury and other medical presentations each occurred in one patient (1.5%). No paediatric cases involved pulmonary barotrauma or immersion pulmonary oedema.

Overall, seven paediatric patients (10.3%) were hospitalised. Hospitalisation occurred in three of seven patients with possible DCS/AGE (42.9%), one of four with drowning/aspiration (25.0%), and three of 28 with trauma (10.7%). No hospitalisations occurred among patients with otitis,

ear/sinus/ocular/dental barotrauma, marine animal injury, other medical presentations, or undifferentiated post-dive symptoms.

COMPARISON TO ADULT INJURIES

Paediatric patients accounted for 68 of 685 scuba-related emergency department visits (9.9%) from 2005–2024 (Table 3). Sex distribution was similar between paediatric and adult patients (70.6% vs 73.6% male, *P* = 0.567), but paediatric patients were less often hospitalised (10.3% vs 21.4%, *P* = 0.038). They were more likely to present with trauma (41.2% vs 26.1%, *P* = 0.010) and less likely to present with possible DCS/AGE (10.3% vs 25.0%, *P* = 0.006). Other injury categories did not differ significantly between groups. No paediatric cases of pulmonary barotrauma or immersion pulmonary oedema were identified, compared with eight and four adult cases, respectively. No paediatric fatalities were recorded, compared with seven adult fatalities (Table 2).

Discussion

Our study investigated paediatric scuba-related injuries presenting to emergency departments in the United States.

We hypothesised that paediatric divers would be more likely than adults to present with severe diving injuries because of differences in experience and understanding of diving physiology. Instead, paediatric patients in our cohort were less likely to be hospitalised or to present with DCS/AGE and were more likely to present with trauma. Rates of ear/sinus/ocular/dental barotrauma, otitis, and drowning/aspiration did not differ between groups.

These findings describe patterns among injured patients presenting to emergency departments and should not be interpreted as evidence that paediatric scuba diving carries lower overall injury risk. Potential explanations include structured paediatric safeguards, such as instructor supervision, age-based training limits, depth restrictions, medical screening, and staged progression to open-water diving. Adults may also have more variable exposure, dive profiles, comorbidities, training recency, and supervision. Because NEISS does not capture these factors, they remain possible explanations rather than conclusions derived from this study.

Our findings were partially consistent with prior paediatric diving research. In a review of Divers Alert Network calls involving minors, final diagnoses were most often ear, nose, throat, or sinus conditions (32%) or musculoskeletal trauma (16%), while DCS and AGE accounted for 11% of cases.¹⁴ The proportion of possible DCS/AGE in our paediatric cohort was similar (10.3%), but trauma was more common (41.2%). This difference may reflect the data sources: emergency department surveillance captures routine injuries such as lacerations and fractures, whereas minor otic symptoms and equalisation problems may be more likely to prompt a DAN call, outpatient evaluation, or self-care. Buzzacott et al. likewise found mechanical trauma to be the most common injury category, although their reported DCS rate was lower than the overall DCS/AGE proportion in our combined cohort (6% vs 23.5%).⁷ Their stricter DCS definition may explain this difference and highlights the difficulty of distinguishing DCS, AGE, and undifferentiated post-dive symptoms from brief surveillance narratives.

Pulmonary barotrauma warrants specific mention despite the absence of paediatric cases in our cohort. Serious paediatric pulmonary barotrauma and AGE have been reported after shallow or first-time scuba exposure, including pool-based dives.^{10,11} In our study, pulmonary barotrauma occurred only among adults; however, this likely reflects the small paediatric sample, the rarity of the outcome, and the ED-based sampling frame rather than an absence of risk. Immersion pulmonary oedema was also absent in paediatric patients, which may be consistent with its association with older age and comorbidity, although this comparison is limited by small numbers.¹⁵

Current recommendations from medical organisations emphasise a cautious, highly supervised approach to

paediatric scuba diving. The South Pacific Underwater Medicine Society (SPUMS) recommends that paediatric divers younger than 10 years old should not scuba dive, and that all individuals under 15 undergo formal medical risk assessment and evaluation of physical and psychological maturity.¹⁶ They recommend against paediatric divers diving with epilepsy, congenital heart defects, insulin-dependent diabetes, structural lung disease, behavioral disorders, bleeding disorders, tympanostomy tubes, or migraine with aura. The Dutch Society for Diving and Hyperbaric Medicine (DSDHM) also provides guidance, recommending pool-based diving for paediatric divers aged 8–10, limited warm-water open-water diving for ages 10–12, and progressively broader participation after age 12 while still avoiding deep, cold, or high-risk dives and avoiding decompression dives until age 16.¹⁷ Although recommendations from the SPUMS and the DSDHM differ in specific age thresholds and restrictions, they provide a good framework for safe paediatric diving.

Our study has several limitations. NEISS was designed to capture consumer product-related injuries rather than diagnoses specific to diving physiology. As such, the brief, non-standardised narratives sometimes lacked enough detail to distinguish decompression sickness, arterial gas embolism, pulmonary barotrauma, immersion pulmonary oedema, and undifferentiated post-dive symptoms reliably. Although cases were classified conservatively, results depended on both emergency department recognition of diving-related diagnoses and reviewer interpretation of the available narratives. The paediatric cohort was also small, with 68 cases and seven hospitalisations over 20 years, limiting comparisons of rare outcomes; therefore, the absence of paediatric pulmonary barotrauma or immersion pulmonary oedema should not be interpreted as evidence that these injuries do not occur. NEISS also lacks exposure data, including the number of paediatric divers or dives, certification status, supervision, experience, training pathway, and dive profile, so this study cannot estimate absolute injury risk or determine whether paediatric diving is safer than adult diving. In addition, scuba exposure is not evenly distributed across the United States, and differences between coastal and landlocked regions may influence regional presentation patterns. Access to dive medicine professionals and hyperbaric consultation or treatment may also affect diagnostic recognition, transfer, and hospitalisation decisions. Additionally, the NEISS includes injuries related to scuba equipment that did not occur while in the water, such as an injury that occurred while moving dive equipment. We felt it was important to include these injuries because although they did not occur in the water, they are still a hazard of the sport. Lastly, the NEISS only captures fatalities associated with emergency department presentation and is not a comprehensive source for paediatric scuba-related mortality.

Conclusions

Contrary to our hypothesis, paediatric patients presenting to United States emergency departments with scuba-related injuries were more likely than adults to present with trauma and less likely to present with possible DCS or AGE. They were also less likely to be hospitalised. These findings describe emergency department presentation patterns rather than overall injury risk among paediatric scuba divers. Supervision and adherence to safe diving practices remain essential, and further research is needed to characterise paediatric scuba-related fatalities.

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