MSK Conditions and Diving

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Level I Diving Medicine, May 2025

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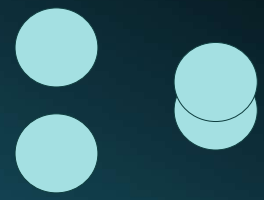
Diver Performance

- Mental Fitness
  - Neurological
  - Cognitive
  - Psychiatric
- Physical Fitness
  - Cardiovascular
  - Musculoskeletal
  - Neurological



- Fitness in one of these affects the others…

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Charting a Course…

- Performance Context for Divers
- Arthritis and Diving
  - Osteoarthritis vs Auto-immune Arthitides
- Connective Tissue Diseases and Diving
  - Ehler-Danlos, Marfan's, Systemic Sclerosis, Raynaud's, Lupus
- Common MSK complaints in Divers
- Ageing and Diving
- Case Example

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Diver Performance

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"The industry standard is for a diver to be able to put on all equipment, enter the water, swim, be able to self-rescue or rescue a buddy if required, exit the water, and remove all equipment without assistance."

Anne Strysniewicz, DIVERS ALERT NETWORK, https://dan.org/alert-diver/article/autism-and-diving/

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Performance Requirements

- Work in Water
  - Morrison and Zander, Defense R&D and Shearwater, 2008
  - Combined effect of cold, pressure and gloves:
  - 30% loss of grip strength
  - 60% loss of tactile sensitivity and dexterity
- Trim 
- Adjust her/his own equipment (AROM, dexterity)
- Have situational awareness (including ability to turn one's body and neck at regular periods)

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General Approach

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General Approach to Comorbidities and Diving

- 1) Condition or treatment → ↑ risk for dive-related injury
- 2) Diving → exacerbate the condition
- 3) Condition or treatment → ↓ physical fitness
- 4) Condition or treatment → ↓ ability to respond to emergency
- 5) Can the condition present a diagnostic dilemma with a diving injury?

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Question 1: What Type of Diving?

- Increased physical and mental demands:
- Special Circumstances → Recreational → Professional → Scientific → Technical → Public safety → Commercial → Military
- Recreational – can choose not to dive that day
- Recreational – accepting risk for a leisure activity…
- Scientific Diving and onwards are supervised, regulated, and monitored

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Question 2: Stage of Diving Career?

- Beginner vs Experienced Diver

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Question 3: Severity of Disease?

- Pre-existing vs new onset disease?
- What are the limitations?
  - What joints?
  - To what degree?
- Extra-articular manifestations?

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Arthritis and Diving

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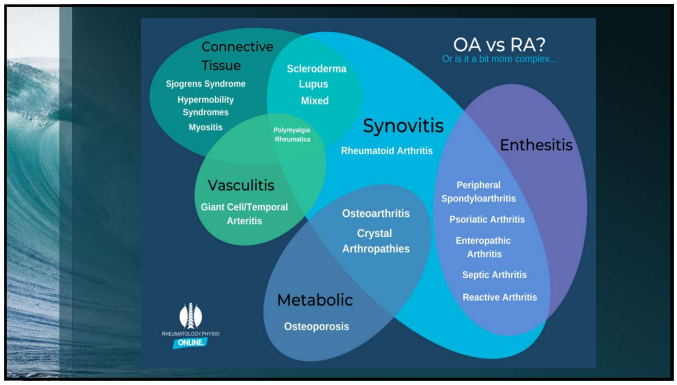

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Arthritis → Increased risk for Decompression Sickness?

DCS: bubble disease + inflammatory consequence

The bubbles contact endothelium → inflammatory cascade, including platelet aggregation and leukocyte activity.

There is pro-inflammatory gene upregulation.

Gene upregulation also in divers without DCS (Magri, K et al.)

? a continuum of inflammation from subclinical to clinical?

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Arthritis and Decompression Illness

- Pre-existing inflammation → exacerbate the inflammatory cascade triggered by bubbles
- Pro-inflammatory condition → microparticles → bubble formation

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Arthritis and Diving – Concerns:

- Pre-existing arthritis → rest and inactivity → increased risk of injury when resuming diving
- Axial Loading → worsening symptoms
  - Yes, neutral buoyancy, but...

- Extra-articular organ involvement (lungs and heart) → increased risk of injury
- Medications!
  - Disease Modifying
  - Pain Medications

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Osteoarthritis

- Wear and tear, limited to joints
- Onset is with advancing age – ie usually presents later in the diving career

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Osteoarthritis

- Interpret the patient's mobility, pain patterns, investment in their fitness
- Axial Loading
- Confounding of DCS diagnosis need to be considered
- Arthroplasty – if fully healed and able to weight bear – should be okay to resume diving

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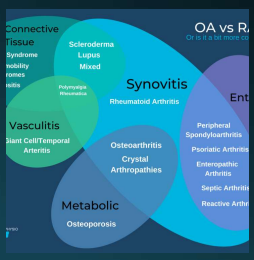
Rheumatoid and Psoriatic Arthritis

- NOT compatible with occupational diving
- Autoimmune conditions
- RA focus is synovium, but extra-articular manifestations
- Psoriatic can affect tendons and muscles



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Rheumatoid Arthritis

- Process targets synovium
- Leads to progressive bony and chondral erosion

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Rheumatoid Arthritis

- Complications – 40% of patients, 8% serious
  - Cardiovascular – pericarditis (50% of cases); myocarditis; endothelial dysfunction, CAD, arrhythmias
    - Heart Failure is primary cause of death for RA patients
  - Lung
    - 80% of patients have lung involvement
    - Responsible for 20% of the mortality
    - Pulmonary Fibrosis, ILD, Airway disease (60% of patients), bronchitis

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Rheumatoid Arthritis

- Splenomegaly
- Chronic Pain → inactivity, psychomorbid, narcotics, sleep disorders
- Osteoporosis via enhanced osteoclastic activity

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Psoriatic Arthritis

- In 20% of psoriasis patients
  - 68%, skin involvement precedes joint involvement
  - 15% coincident onset
  - 17% joint involvement before/without skin involvement
- Complex etiology – genetic and environmental factors

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Psoriatic Arthritis

- 5 Subtypes:
  - Oligoarticular < 5 small/large joints
  - Polyarticular – similar to RA, RF negative
  - Distal – IP joints predominate
  - Arthritis Mutilans – aggressive and destructive, residual deformities
  - Spondyloarthritic – SI and Spondylitis
- Complications
  - Ocular – Uveitis – usually bilateral
  - Enthesitis, Dactylitis, Tenosynovitis

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Medications for RA/PA

- Methotrexate – lung toxicity is a consideration
- Corticosteroids – increased O2 Toxicity risk
- Hydroxychloroquine – lowering of seizure threshold; 4% have neurological disturbances – visual changes, headaches, somnolence; cardiomyopathy
- Leflunomide – immune-suppressant and bleeding risk – weigh the benefits of disease suppression against the risks – for example, this would not be ideal for Public Safety divers in contaminated waters
- Biologics – not enough information, again, but immunosuppressant

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Connective Tissue Disorders and Diving

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Connective Tissue Diseases

- We will briefly discuss:
  - Ehler-Danlos
  - Marfan's
  - Systemic Sclerosis
  - Raynaud's Phenomenon
  - NOT compatible with Occupational Diving
  - Rarely compatible with Recreational Diving

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Ehler-Danlos

- Genetic disorder affecting collagen formation
- Actually a group of inherited or de novo mutations
- Clinically, 13 subtypes, 5 clinically significant:

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Ehler-Danlos – 5 Types

- 1) classical EDS – autosomal dominant, Type V and I collagen deformity
  - Clear family history
  - Hypermobility of joints and skin, easy bruising, skin fragility
- 2) classic-like EDS – autosomal recessive,
  - Same as above, but can include hand/foot muscle atrophy, foot deformities, axonal polyneuropathy, cavitary prolapse
- 3) cardiac-valvular EDS – AR pattern,
  - Valvular disease
  - Pectus deformations
  - Joint dislocations

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Ehler-Danlos – 5 Types

- 4) Vascular EDS – AD pattern, Type I collagen
  - Arterial rupture, uterine rupture in the 3rd trimester, carotid-cavernous sinus fistulae
  - Possible spontaneous pneumothorax, hip dislocation
- 5) Hypermobile EDS – no known gene mutation, pure clinical diagnosis – expert diagnosis

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Ehler-Danlos

Other important clinical features:

- Organ rupture – both solid and hollow viscus
- Tissue friability
- Dental – absence of gingiva, delayed dental eruption in infancy,
- Recurrent fractures

- Cardiovascular screening is important – consider valvular disease, cardiomyopathies, aneurysmal disease, etc.
- Get Rheumatology notes, Cardiology and Echo, CT Chest with contrast

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Marfan's

Hereditary connective tissue disorder characterized by tall slender disposition

1:5000 people, all races equal incidence

¾ people will have some inheritance pattern

- Mutation of a gene coding for fibrillin-1, which in turn leads to the overexpression of Transformation Growth Factor Beta – TGF-B, which is responsible for the clinical presentation

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Marfan's

- Cardiovascular – 9/10 people affected
  - Vascular – Aortic dilatation and dissection
  - Valvular – MV prolapse, AV regurgitation
- Spontaneous Pneumothorax
- Scoliosis

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Marfan's and Spontaneous Pneumothorax (SP)

- Karpman et al. 2011 Retrospective Cohort Study of Marfan's patients who had CT Imaging
- n = 166
- Prevalence of SP: 4-11%
  - Gen Pop 0.018%

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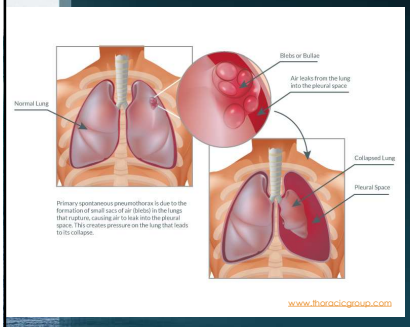

- 9.6% in the study population had blebs/bullae
- SP: 25% had them
- No SP: 2.7% had them
- p = 0.003

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Marfan's and Spontaneous Pneumothorax (SP)

- Smoking does not appear to be a RF
- ? Potential Risk Stratification with CT CHEST?
  - SP can occur without evidence of blebs/bullae
  - Blebs/bullae may not be the site of pleural leak
  - Blebs/bullae are present in the general population
- TAKE HOME: Marfan's – not compatible with diving.

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Arterial Dissection and SCUBA

- Can occur in a variety of sports
- Over the last 20 years, increasing awareness of a risk in SCUBA diving
- Absolute numbers are low, but relatively important cause of stroke in young patients
- Aortic, Carotid, Vertebral, Intracranial dissection
- ?? Are Connective Tissue Disorders a Risk Factor for Arterial Dissection??

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Arterial Dissection and SCUBA

- Sept, 2024, Pollock and associates looked at 19 cases in the literature
- 4 Aortic (3 fatal); 1 coronary; the rest cervical/intracranial
- 14 male; 5 female
- 1 osteogenesis imperfecta; 1 MS; 2 smokers; 2 HTN managed; 1 IHD
- The data is limited by inconsistent details regarding dive profiles, water conditions, equipment and timing
- There is likely underreporting of dissection

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Arterial Dissection - Implications

- Enough data to suggest that Arterial Dissection is a small but real risk in SCUBA
- Think about dissection in a collapsed diver with no untoward event
- Neck pain, unequal carotid pulses
- Horner's Syndrome - 6 of 8 patients with ICA dissections
  - Miosis (pupillary constriction – ipsilateral)
  - Ptosis (droopy eyelid)
  - Anhydrosis (reduced sweating unilaterally)
  - Ascending sympathetic nerve fibers are interrupted by the dissection

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Arterial Dissection and SCUBA

- Possible contributing factors:
  - Hypertension
    - Central redistribution
    - Increased PPO2 (vasoconstriction)
    - Constrictive gear
    - Breathing circuit resistance – increased gas density
  - Extended neck + equipment configuration?
    - Segment of cervical arteries that were predominantly involved NOT consistent with traction/shear force trauma
    - Rather, where the artery inserted through a bony aperture – implies pulse pressure issue?

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Arterial Dissection and SCUBA

- Small study size, inconsistent data → cannot draw conclusions on risk factors
- Connective Tissue Disease was NOT predominant in the case population
- However, there is a logical connection between CTDs and arterial dissection under normobaric conditions
- Postulate increased risk when submersed

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Systemic Sclerosis

Connective tissue disorder, rare, unknown pathogenesis

- Some familial clustering
- Some environmental/infectious triggers:
  - EBV, CMV, parvovirus B19
  - Exposure to silica dust, organic solvents
  - Smoking is NOT a RF
  - Bleomycin and cocaine can precipitate a sclerosis-like syndrome

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Systemic Sclerosis – 2 Types

1) Localized (scleroderma)
   a. Not associated with increased mortality
2) Systemic sclerosis
   a. formerly CREST: calcinosis, Raynaud's, Esophageal dysmotility; sclerodactyly, telangiectasia
   b. Increased mortality

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Systemic Sclerosis – Complications

MSK:

a. Arthritis
b. Overlap with RA in 5% of cases
c. Distal bone resorption and osteolysis in late stage
d. 10% of cases have an inflammatory polymyositis (poor prognostic indicator)

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Systemic Sclerosis - Complications

Lung:

a. Pulmonary HTN
b. Bibasilar pulmonary fibrosis (ILD)
   i. 50%-80% of cases, many asymptomatic
   ii. Onset usually 4-5 yrs after Dx
   iii. PFT – restrictive pattern, with possible DLCO decrease
c. Aspiration pneumonia from esophageal dysmotility

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Systemic Sclerosis - Complications

Cardiac:

a. Dilated cardiomyopathy
b. Pericarditis (rarely tamponade)
c. Arrhythmia

Psych:

a. 50% of patients have a comorbid mental health issue like Depression

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Raynaud's

15% of Raynaud's patients do NOT have an autoimmune condition

a. Common and early in Systemic Sclerosis
b. Digital vasospasms with cold exposure
c. Will affect dexterity
d. Diving: warm water and gloves – but don't forget thermoclines and prolonged exposure (long cooling times)

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Common MSK Complaints…

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Cramps

- Particularly common in divers and swimmers
- Usually calf, sole of the foot, but can involve: the thigh, upper arm or the abdomen
- RFs: low level of fitness; period of inactivity followed by activity; cold water; electrolyte and calcium disturbance; exhaustion
- Tx – slow passive extension/stretching of involved muscles
- Prevention – maintain a level of fitness, thermal status, hydration and sleep

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Temporomandibular Joint Pain

- Usually novice divers
- Ill-fitting mouthpieces, ill-configured regulator that tugs to the side
- Presents with pain over the TMJ, sometimes with clicking, trismus, tinnitus, vertigo
- RFs: new diver; Previous TMJ; diving in colder environments
- R/O: dental, sinus, vertigo differential
- Tx: Supportive therapy
- Prevention: equipment; experience and comfort with diving

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Lumbar Back Pain

- Lifetime prevalence in recreational divers is ~50%
- Heavy equipment
- Overweighted/weight distribution
- Improper trim/arching
- Associated factors (1 Dutch study):
  - Older divers (women tend to be younger and have a hx of pregnancy)
  - Prior hx of LBP or structural abnormalities (DDD)
  - Inactivity/activity

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Lumbar Back Pain

- Differentiate from Decompression Sickness
  - Timing/Onset of Pain
  - Presence of leg weakness/paralysis, urinary/bowel retention, saddle anaesthesia
  - Generally:
    - Other joint involvement
    - Lateralizing signs
    - Vertigo/disequilibrium
    - Mental fogginess
    - Cardiorespiratory symptoms
  - Previous MSK disease – quality/severity

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Compression Arthralgia

- presents as a cracking, popping, “gritty” and even painful feeling in the joints with deep diving
  - > 30 m, usually > 100 m
- Aggravated by fast compression, NEVER onset on decompression, but can extend to that phase
- Worse in air compression rather than water compression

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Compression Arthralgia

- Likely from inert gas difference between blood and synovial fluid and cartilage that causes as osmotic water shift from the joint to the blood.
- Self-limited:
  - As equilibration occurs over time, joint fluid balance is restored and the symptoms subside

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Strains and Sprains

- Heavy equipment: mobilized, transferred, lifted and carried
- Minor injury may present in the posterior rotator cuff, elbows, wrists, hands, lumbar spine
- Clinically differentiate from DCS – careful history and physical
- Pay attention to mechanism, timing of onset, relieving factors

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Parasthesias

- Strains and Sprains
- New wetsuit/compression
- Cold exposure
- Previous Disease (Carpal Tunnel, Ulnar Entrapment Syndrome)
- DCS rarely presents as isolated parasthesia in one limb

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Tank Carrier's Elbow

- Repetitive motion → lateral humeral epicondylitis
- Repeated wrist pronation and dorsiflexion
- Shorter people: aggravated by the need to flex the elbow for tank ground clearance
- May result in grip weakness

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Tank Carrier's Elbow

- Ultrasound – thickening of common extensor tendon
- Treatment – resting, compression. Occasional surgical repair of a tear.
- Prevention – carry tanks horizontally, with straps; maintain fitness

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Dysbaric Osteonecrosis

- Covered in depth in another presentation
- Long-term effect of diving

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Ageing and Diving

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Chronological vs Biological Age

- "looks younger than stated age"
- Individuals of same chronological age can vary greatly in their fitness, function, comorbidities and cognition.
- Interpret the patient's ***investment into their own fitness***

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Ageing

- Cardiovascular
  - Still the most important concern
  - Risk Factors are influenced by age
- Pulmonary
  - Increased stiffness
  - Increased CO2 retention, especially under exertion
  - Decreased diffusion capacity
- Medications
  - Surveys demonstrate that many divers continue to dive while on multiple medications

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Ageing

- Muscles and Joints
  - Arthritis
    - Reduced AROM
    - Chronic Pain
  - Reduced Muscle Mass:
    - Slowed metabolism
    - Comorbidities/chronic disease
    - Inactivity/Lifestyle

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Ageing Professional Divers

Sames et al., 2019, New Zealand

- Explored the reasons for the 77% attrition rate in professional divers
- Health was cited as reason for leaving only 3% of the time
- Most cited reason was work environment
- Incidentally: smoking is 4x more prevalent in quitters than stayers

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Ageing in Commercial Divers

- Professional Diving Academy – US Survey 2018
- Most US Commercial Divers > 50 yo transition to supervisory or client-advisory roles
  - Less physical demand
  - Leverage expertise and experience

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Ageing in Recreational Divers

- Buzzacott et al., 2022 – health and wellbeing of recently active recreational divers in the US
- Queried the Behavioural Risk Factor Surveillance System (BRFSS):
  - Largest self-reported survey in the World
  - Since 2011, collects data on SCUBA divers biannually
  - Authors compared regular SCUBA divers with matched controls

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Ageing in Recreational Divers

- Men ~80% of regular divers
- 44% Age > 50 yo; 18% Age > 60 yo
- More likely to have quit smoking in the last 10 years
- Less likely to have asthma, hypertension, dyslipidemia, obesity
- More likely to have high EtOH intake

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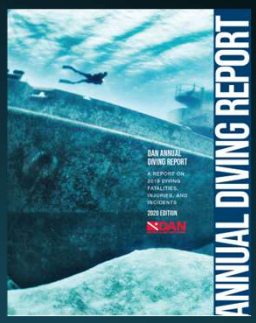
DAN 2020 Annual Diving Report



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"Most scuba fatalities occur in older divers and are related to health and fitness issues. A healthy lifestyle, staying fit, and regular medical checkups are pre-requisites for lifelong, healthy, participation in scuba diving." – p. 24.

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DAN 2020 Annual Report

80% deaths were male.

Average age 54 yo; Median 56 yo.

67% deaths > 50 yo

Age does not directly increase risk of fatality.

Indirect influence via reduced fitness, increasing comorbidity.

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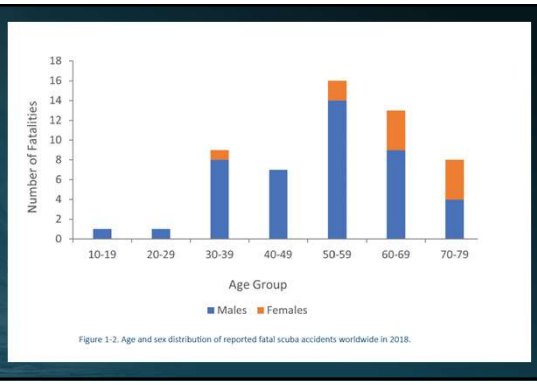

Figure 1-2. Age and sex distribution of reported fatal scuba accidents worldwide in 2018.

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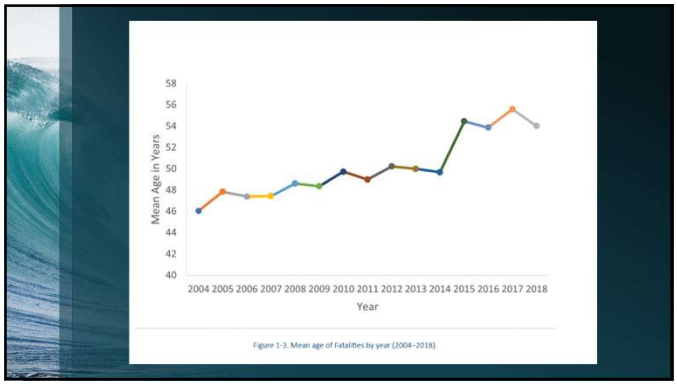

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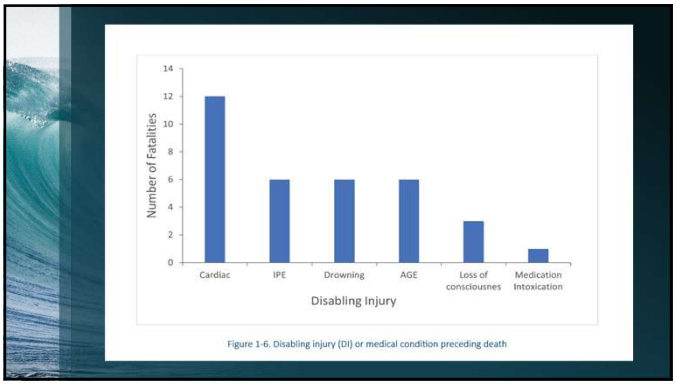

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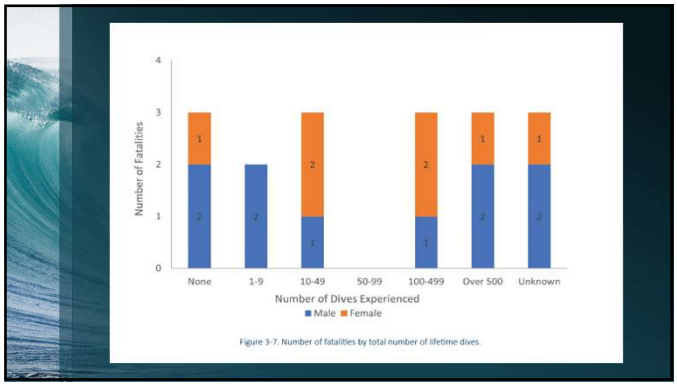

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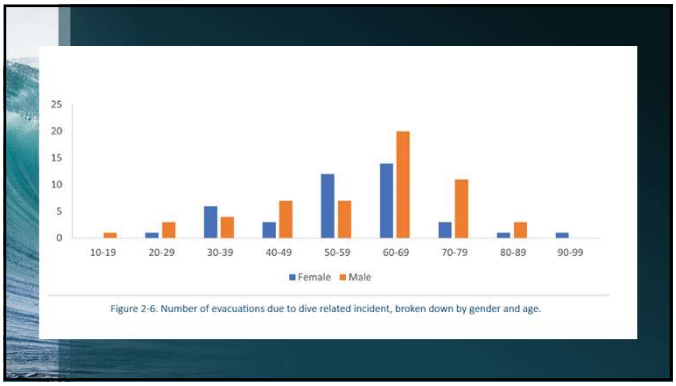

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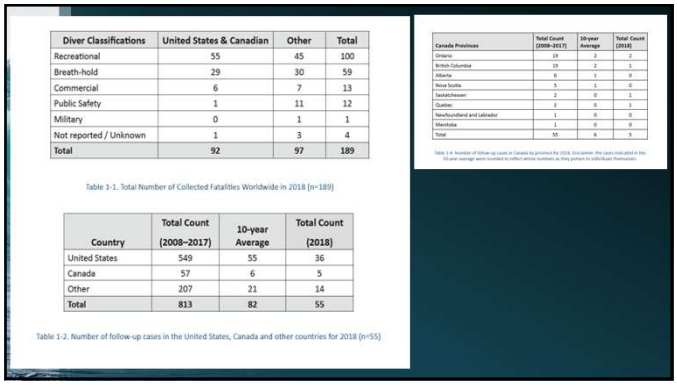

Diver Classifications	United States & Canadian	Other	Total
Recreational	55	45	100
Breath-hold	29	30	59
Commercial	6	7	13
Public Safety	1	11	12
Military	0	1	1
Not reported / Unknown	1	3	4
Total	**92**	**97**	**189**

Table 1-1. Total Number of Collected Fatalities Worldwide in 2018 (n=189)

Country	Total Count (2008–2017)	10-year Average	Total Count (2018)
United States	549	55	36
Canada	57	6	5
Other	207	21	14
Total	**813**	**82**	**55**

Table 1-2. Number of follow-up cases in the United States, Canada and other countries for 2018 (n=55)

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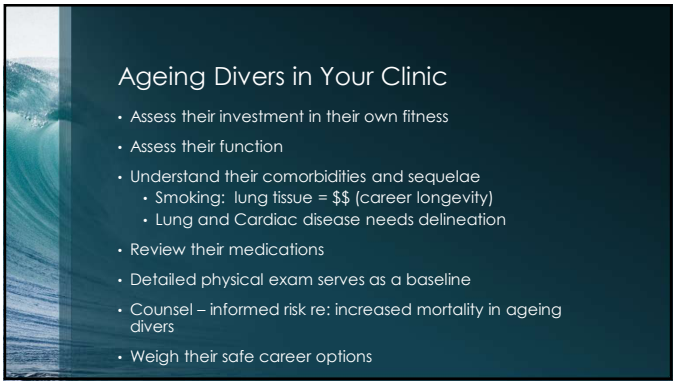

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A Case

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Thought Exercise – Case Example

- Expedition to Cocos Island, CR
- 48 h boat ride from civilization
- 1 week expedition to tag Hammerhead sharks
- 2 dives a day
- EAN 32
- Max 32m; Mean 26m

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Professor has L shoulder pain

- 60 yo M Marine Biologist
- 1000s of logged dives
- First expedition in 2 years
- No previous DCS/Dive Injury
- Previous L shoulder RC partial-thickness tear – no Sx
- OA L shoulder

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Mid-week

- Over the week, aggravated pain in the L shoulder
- Worse with lifting himself and equipment into zodiac
- Naproxen 400 qHS – resolved by AM
- Returns by midday

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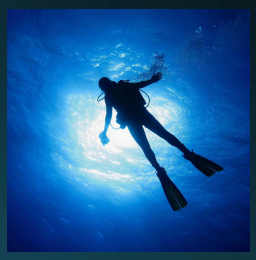
Today

- Onset of pain after first dive (first SI)
- Worse than previous pain
- Different than usual shoulder pain
- NSAIDs on mothership – partly better
- Much better on 2nd dive (at depth)
- Returned with a vengeance after



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DDx

? OA

- Prev injury
- Inc pain over the week
- Inactivity/activity
- Worse with lifting

? DCS

- Inc Severity
- Changed quality
- Timing (after dive)
- Better at depth!
- Worse after repeat dive

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MSK and Diving

- 1) Condition or treatment → ↑ risk for dive-related injury
- 2) Condition or treatment → ↓ physical fitness
- 3) Condition or treatment → ↓ ability to respond to emergency
- 4) Diving → exacerbate the condition
- 5) Can the condition present a diagnostic dilemma with a diving injury?
- 6) Context: 3 Axes…

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Thank You

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