Long term health effects of diving

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Possible Long Term Health Effects (LTH)

- Without recognized injury/accident
  - Aseptic/dysbaric osteonecrosis
  - Reduce pulmonary function
  - Neurological injuries

LTH

- Recognized LTH of trauma:
  - Noise induced hearing loss
  - Vertigo, tinnitus (inner ear barotrauma and DCS)
  - Neurological sequelae (DCS, CAGE)
  - Musculoskeletal problems

Does diving affect health?

Admission of 11,584 enlisted USN divers compared to non-diving controls

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Morbidity

- Hoiberg & Blood 1986:
  - 1977 USN diving-officers vs 1973 non-diving officers (ctrl group)
  - Hospitalisation rate
    - ↑ Neurological illnesses and joint problems
    - ↓ Airway disease
    - >20 dives/year:
      - ↑ Total hospitalisation rate
      - ↓ Alcohol/drug/substance abuse
      - ↓ Cardiac and circulatory organ disease
      - ~ Neurological illnesses
Dysbaric osteonecrosis (DON)

- First described 1911 (16 years following discovery of X-ray)
- Aseptic necrosis of metaphyses of long bones
  - Distal femur
  - Proximal humerus
  - Proximal tibia
- Classification: FICAT 0-4
- Usually asymptomatic

DON (contd)

- Etiology:
  - Free gas: DCS, VGE ("Silent bubbles")
  - Correlation between DON and years of diving, diving depth and previous DCS.
  - Fat emboli
  - Plate aggregation
  - Gas-osmosis: Increased intramedullary pressure
  - Oxygen (ROS)?
  - Still unresolved!

- Increased cancer risk?
  - Probably not!
- Prevalence:
  - 1981 UK: 4.2%
  - 1993 Norway: 1-2%?
  - Currently: Concern mainly in developing countries (Turkish sponge diver – prevalence 70%)
- Consequence
  - None unless symptoms

Military diving and DON

- Available reports
  - Bolte et al 2005
    - 32 mil divers vs 28 ktrl
    - Skeletal MRI
    - 1 DON in each group (NS)
  - Yildiz et al 2004
    - 25 instructors in SET
    - Skeletal x-ray and MRI
    - No DON
  - Uzun et al 2008
    - 106 mil divers
    - MRI
    - No DON

Humerus DON

DON (contd)

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Reading more?
Changes in pulmonary function

- After deep dives (Cotes, Reed, Thorsen):
  - Reduced diffusion capacity (temporary) (TLCO)
  - Pos. correlated to hyperoxia
  - Pos. correlated to VGE
  - Increased TLC (temporary – 4-6w)
  - Reduced mid-expiratory flowrates (FEF25-75%)
    - Permanent
    - Reduced work capacity (VO2Max)
    - Temporary

Pulmonary function

- Cross-sectional studies (Cotes, Reed, Suzuki, Thorsen, ++):
  - FVC ↑, FEV1 ↓↑
  - FEF25,75%, FEF75%, TLCO ↓
  - Suggest dysfunction of small airways
  - Loss of elastic tissue
  - FEV1, TLCO and mid-expiratory flowrates negatively correlated to length of diving career

Lung function

- Longitudinal studies (Reed, Thorsen, Skogstad, Fitzpatrick, Tetzlaff, LeMaitra):
  - MEF25, MEF50, FEF25-75% ↓
  - Variable results with respect to FVC and FEV1
    - Older studies: Slight reduction compared to controls
    - Newer studies show no effect
  - Mid- and end-expiratory flowrates negatively correlated to diving career

Mechanisms

- Immersion
- Hyperoxia
- Depth (gas density?)
- VGE

Effects of diving on lung function

- 3-6-12 y follow-up of 83-77-37 inshore occupational divers (Skogstad et al, Aviat Space Environ Med 2008;79:883-7)
  - Prospective controlled study
  - Ctrl group: Firefighters
    - ~40 dives/y (median)
    - Static and dynamic spirometry + TLCO
    - FVC, FEV1, TLCO NS
    - Small but statistic. signif. change in FEF25-75 (exposure dependent)
  - 10-25 y follow-up of NZ occupational divers
    - No additional effect of diving on FVC, FEV1 or FEV1/FVC. Small additional reduction in PEF, not clinically significant (N=232), (Sames 2018)

Military diving and lung function

- GER Combat swimmers (CC oxygen breathing)
  - Tetzlaff et al 2005
  - 39 divers followed up for 5y
  - Spirometry
  - No significant difference compared to control group
- "Regular" divers and submarine personnel
  - Tetzlaff et al 2006
  - 469 mil divers, 123 submariners (ctrl group)
  - ≈3 spirometry measurements
  - No signific. difference between divers and ctrl group
    - Smoking accelerates FEV1 reduction
    - Most prominent in divers with initial high FEV1
Neurological LTH effects of diving

- 156 occupational divers
  - 40 deep divers
  - 23 air divers
  - 9.7 y of diving (1-29)
  - 51% had experienced DCS
- Medical history, clinical examination (EEG, MR, EP)

Todnem et al 1991

Results

- Air divers and sat. Divers had more neurological symptoms and findings than the control group.
- Total dive exposure, neurological DCS and age were risk factors
- Suggests a possible relationship between occupational diving and neurological LTH

Todnem et al 1991

Neuropsychological examinations

- 421 USN divers
- 20-50 y (Median 30)
- Extensive neuropsychological examinations at varying intervals of diving carrier.

Curley 1994

Neuropsychological tests

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<td>Grip Strength</td>
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A: Two tests, no intermittent test  B: Two tests, incl intermittent test  C: >7y between test/retest  D: Deep dives

Curley et al. 1994

Conclusion

- In general no tendency suggesting impaired neuropsychological function in divers
- Good test/retest groups
- Large sample
- Sensitive statistical methods (paired tests)
Neuropsychological studies

• Cordes et al 2000
  – Neurological, neuropsychological and MRI examinations of military divers vs controls
  – No difference between the groups
    • A few neuropsychological test in which divers performed inferior

Norwegian off-shore divers

• 115 of 350 Norwegian off-shore divers were referred for extensive examinations at Haukeland University Hospital up to April 1st 2003.
  – Selected sample (expected inferior health)
  – 81 examined per July 2003
  • Age=52 years (35-66), 12 years since finished diving
  • 46 receiving disability benefits
  • 74 tx for DCS, 33 LOC
  • ~30% of the sample presented neural, Symptoms and/or findings (encefalopathy)
  • >4.5% of the population with COPD (spirometry)
  • 3.30% of the sample showed clinically significant reduced performance on neuropsychological tests (memory, speed, coordination, attention)

Neuropsychological tests

Summary

• Many case report and smaller observational studies have reported impaired neuropsychological performance after DCS
• No report has to yet documented with confidence neurophysiological impairment secondary to uncomplicated diving

British LTH study

• Questionnaire (Ross et al 2007)
  – 1540 divers vs 1035 off-shore workers <1991
  – Equal self-perceived health, SF 12, but
    • Divers reported more memory problems and musculoskeletal complaints
  – No difference in work status (employed/unemployed/social compensation)
  – Cultural difference/expectation difference between Norwegian and British divers?

Loss of ependyma
CNS histological changes

- "Non staining space occupying lesions"
  - Lacunae
- Hyalinisation of small vessels
- Loss of ependyma

Hyperintense white lesions

MRI findings

- Many and conflicting studies
- Majority of studies suggests
  - Increased incidence of cervical disk degeneration (Koch 1997)
    - Refuted by others (Bartch 2001)
- PFO and MRI
  - PFO is associated with ischemic lesions on MRI (Schwerzmann 2001, Koch 2008)
    - Refuted by others (Balestra 2016)
  - Closing of PFO reduce recruitment of ischemic lesions (Johannes 2012)

Reduced hearing

- Reported in prospective and cross-sectional studies (Molvar et al., Australia, 2011; Molvar, Australia, 2016; Schwerzmann et al., 2011; Goplen, 2011; Pelaia, 2009)
  - Reduced hearing in divers compared to control groups.
  - No difference to comparable groups of noise exposed workers (firefighters, workshop employed)
  - Minimal effects of dive exposure on hearing threshold (4 and 8 kHz)
  - "Conventional" noise-induced hearing loss? NB!
    - Hard hat diving helmet
    - Power tools
    - Surface decompression with oxygen

Effects on eye

- Fundus:
  - Fluorescein angiography
  - Polkinghorne 1988:
    - Statistically significant loss of pigment and microvascular changes in divers compared to control group
    - Normal vision
    - No difference between divers and control group
**Cardiovascular disease**

- Human studies:
  - Increased cardiac mass in occupational divers compared to recreational divers
  - Right ventricular hypertrophy in recreational divers compared to control
  - SMR 1.37-1.51 (cardiac and circulatory vessel disease incl ischemic heart disease in Swedish occupational divers hjert/karsykdom og iskemisk hjertesykdom) compared to expected 0.77-0.74 (Rosberg og Løving 1991)

**Cardiac function – military divers**

- Echocardiography (Boussouges et al 2007)
  - 22 (french) ml. Combat divers vs 22 fritidsdykkere
  - Doppler ultrasound
  - Increased left ventricular mass (209 vs 172 g, p<0,03)
  - Effect of physical conditionning?

**Diver’s hand**


**Skin**

- Diver’s hands (Ahlen et al 1995):
  - Examination of skin in Norwegian saturation divers
  - Loss of skin
    - Palm and sole
    - Usually after completed decompression, but may present in storage
    - Erythema/itching → flaking → Regeneration
    - Histology/immunohistology: Negative

**Skin (contd)**

- Diver’s hand (contd):
  - Etiology: Unknown
    - Substance in sea water (hotwater suit)?
  - Prophylaxis: Unknown
  - Treatment: None
  - Risk for later development of toxic hand excema/allergy: Possible

Keratolysis exfoliativa

**THANKS FOR YOUR ATTENTION... YOU MAY NOW CLAP... IF YOU HAVE ANY FURTHER QUESTIONS, MY FRIEND GOOGLE WILL ANSWER THEM**