New Zealand

What do we know about Underwater Hockey?

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Underwater hockey (UWH) (and underwater rugby - UWR)

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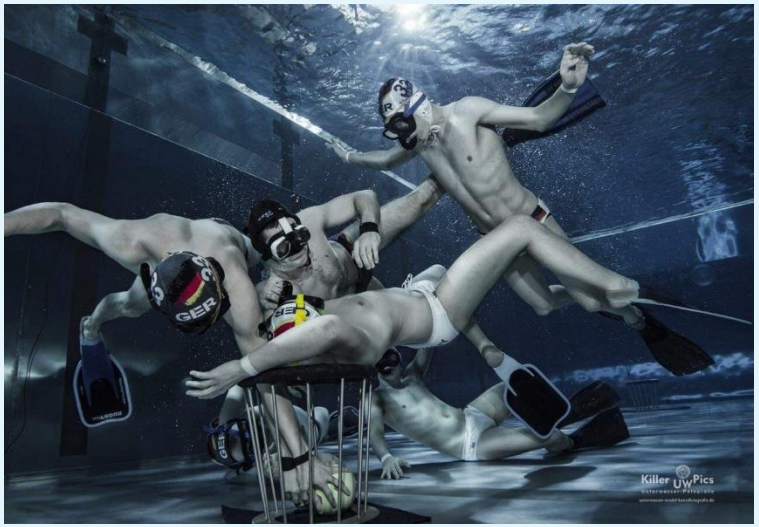
- UWH
  - Mid 1950s, UK & France
  - Over 40 countries
  - Schools to masters (12–73)
  - CMAS-administered
  - 25 x 15 m, 2–3 m depth
- UWR
  - 1961, northern Europe
  - Over 20 countries
  - 22 x 12 m, 3.5–5 m depth

UWH–1963 (UK); UWR–1974 (Sweden)
Stopped in 2010 – ChCh quake!



Breath-hold diving
Mammalian adaptations

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"*For an air-breathing mammal to spend 4−8 months at sea, 90% of this time submerged, one cannot fail to be impressed.*"

(Sheila Thornton, Otago Univ, on the elephant seal. *Undersea Hyperb Med. 2004; 31: 81-95.)*

3 main mechanisms:

- Enhanced O_2 stores
- Buffering products of metabolism
- Circulatory reduction/redistribution

These responses differ from terrestrial animals quantitatively rather than qualitatively

- Metabolic down-regulation at cellular level postulated – complex cellular biochemical issue

Breath-hold diving
Apnoea time

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Voluntary BH has two phases:

the ‘easy-going’ phase ends at ‘physiological’ breaking point (involuntary inspiratory muscle contractions start)

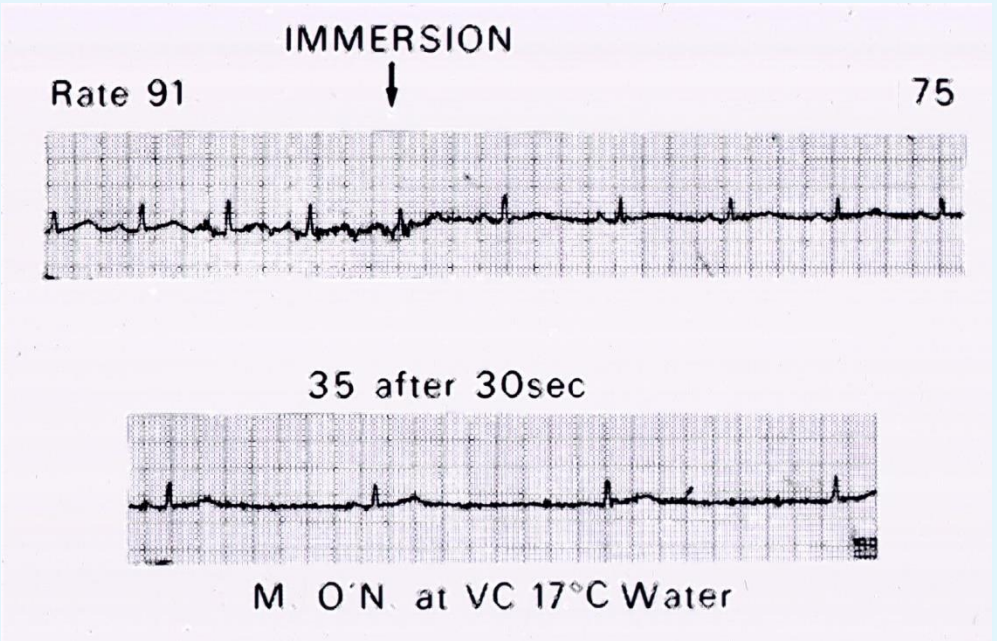
BH terminated at the ‘conventional’ breaking point

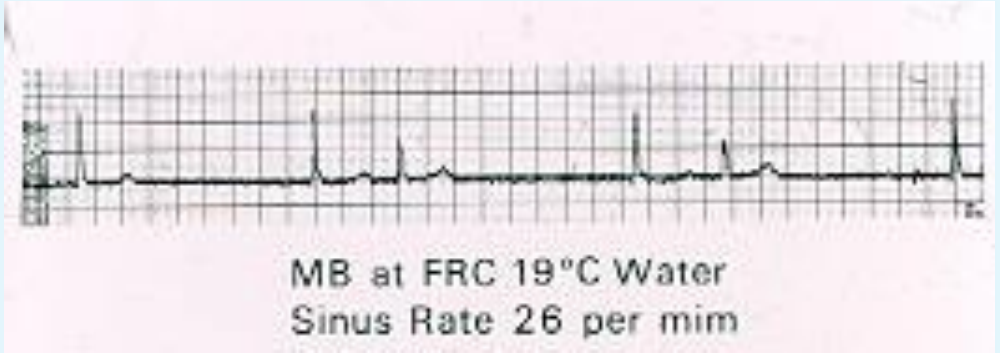
Apnoea time is dependent on:

- Metabolic rate
- CO_2 storage capacity
  - Hyperventilation
- O_2 stores – big lungs primarily (+ spleen)
- Physiological/psychological tolerance to hypercapnia and hypoxia

Face immersion – the ‘Diving Reflex’

- Note ectopics in lower tracing
- Factors contributing to arrhythmias include:
  - Cold water
  - Distension of the heart 2^{O} to central blood redistribution
  - Subendocardial ischaemia (possibly from large ↑BP)
  - High vagal tone





Breath-hold diving
'Diving response'

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The 'diving response' in man:

- ↓ Heart rate
- ↓ Cardiac output
- Peripheral V/C
- ↑ BP (pronounced in man)
- ↑ Brain & heart blood flow
- ↑ Haematocrit (↓spleen)
- ↑ Anaerobic metabolism

Enhanced by cold water

Ascent hypoxia

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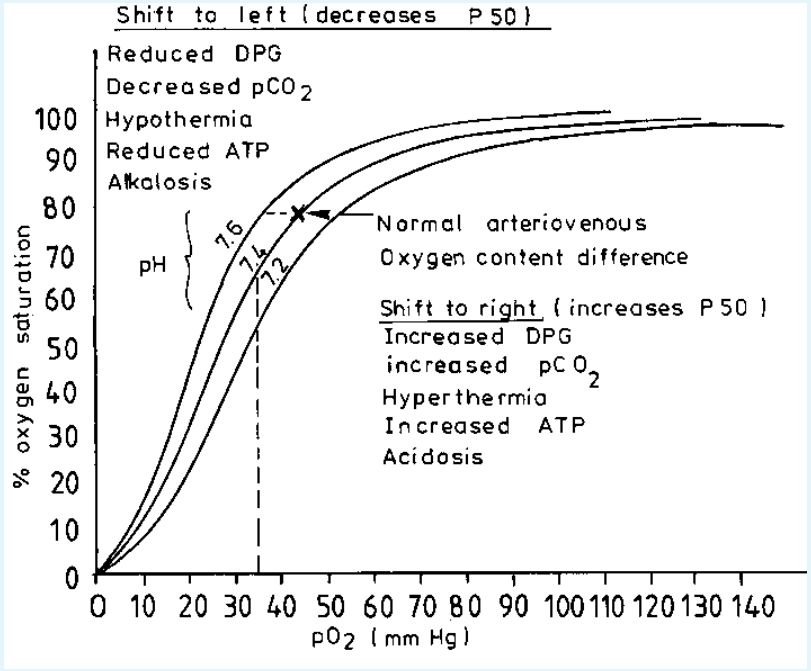
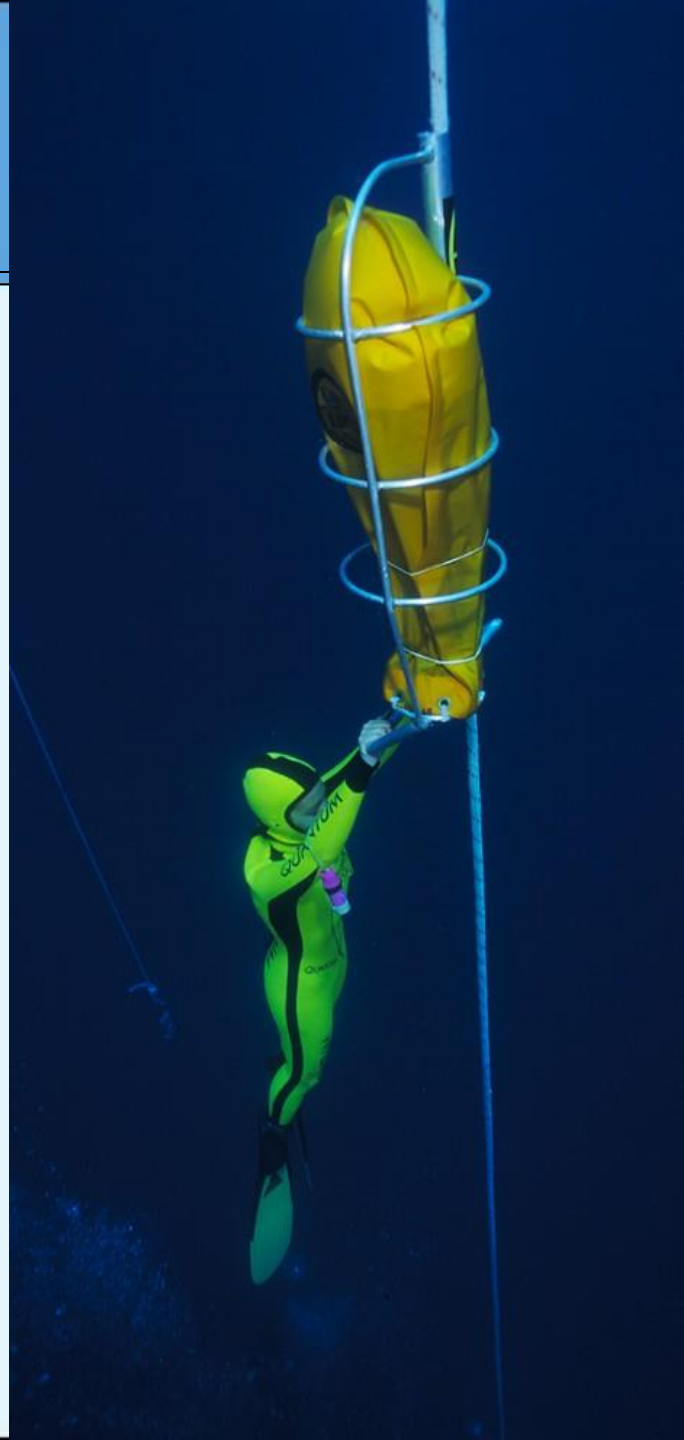
Breath-hold diving
Apnoeic (ascent) Hypoxia

- ‘Ascent hypoxia’ is usually explained in terms of changes in PO_2 & PCO_2
- OK for CO_2 as ventilatory drive determined by CSF [PCO_2]
- Inadequate for O_2 due to the non-linearity of Hb-O_2 dissociation curve





Breath-hold diving
Ascent hypoxia

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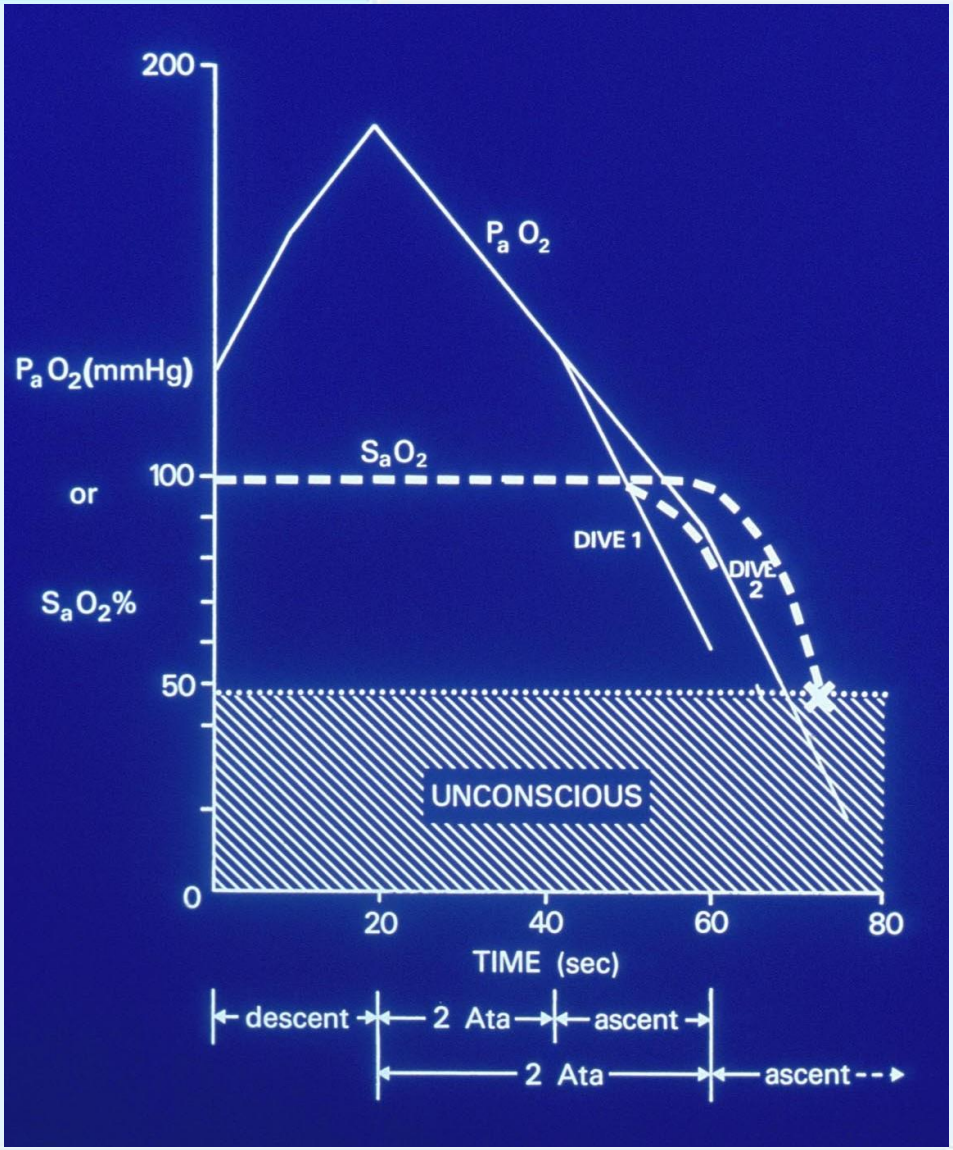
- PaO_2 and SaO_2 changes during 2 hypothetical BH dives to 9 m, one 20 sec longer than the other
- High initial P_aO_2 from pre-dive hyperventilation
- Steep fall in SaO_2 towards the end of the longer dive
  (non-linear Hb-O_2 dissociation curve)
- Transition to dangerous hypoxia during ascent can be very rapid;
- N.B. LoC can occur without descent!

(redrawn from data of Craig & Harley, 1968)



“Shallow-water blackout”

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- “*If you’re worried about shallow-water blackouts* [in UWH], *you might as well eliminate water polo, swimming and synchronized swimming because every one of those other sports have had shallow-water blackouts.*”

(Dr John Meisenheimer, Florida)

Underwater Hockey

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Underwater hockey equipment

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- Facemask (low profile, goggle type)
- Snorkel (short, wide, rigid)
- Water polo hat (ear protection cups)
- Glove (similar to cricket glove)
- Stick (hard plastic; black & white)
- Fins (large, flexible not rigid)
- Puck (1.5 kg; lead alloy, plastic-coated)
- Swimming togs!

UWH players
CO_2 response

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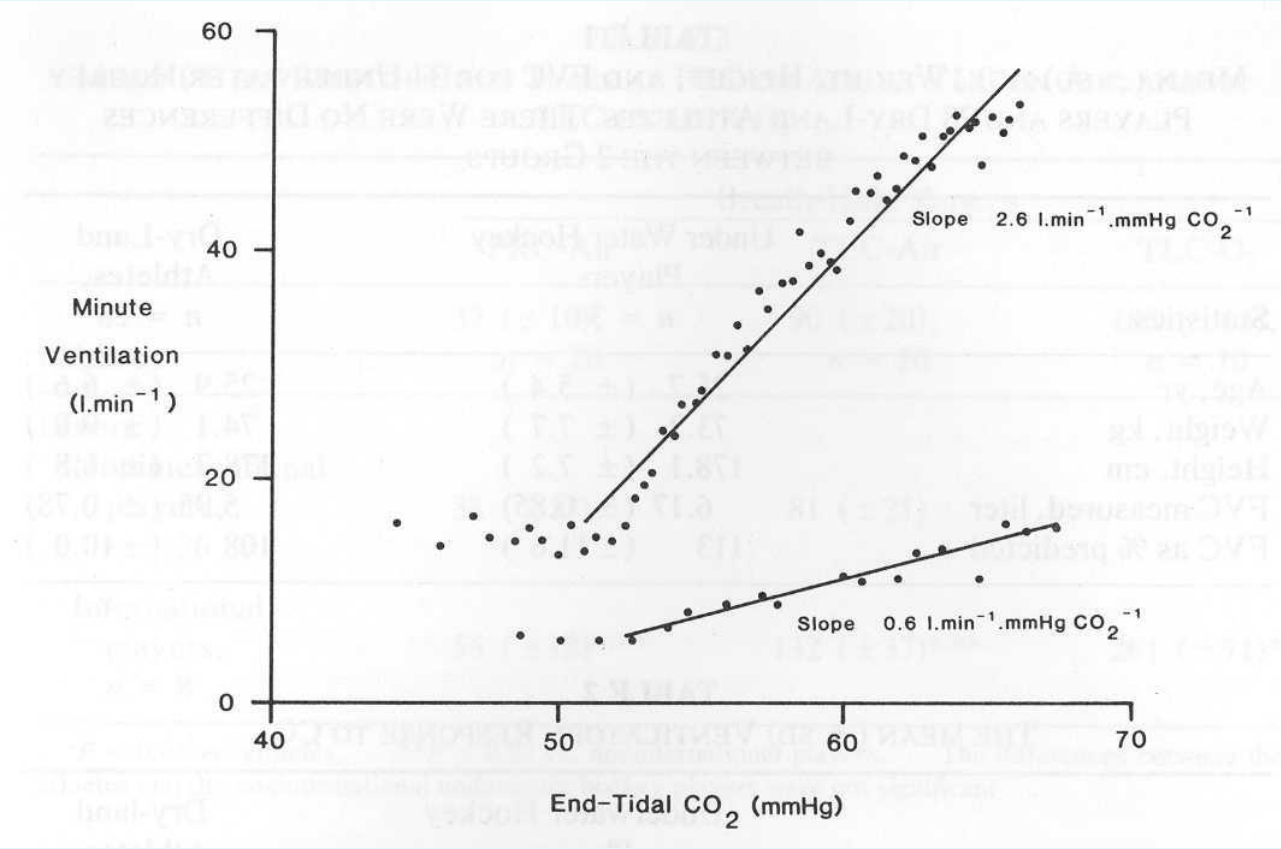
A 'normal' CO_2 response curve (upper curve) and that of an international UWH player (lower curve); not all BH divers have such low responses.



(Davis et al, 1987)

UWH players
CO_2 response

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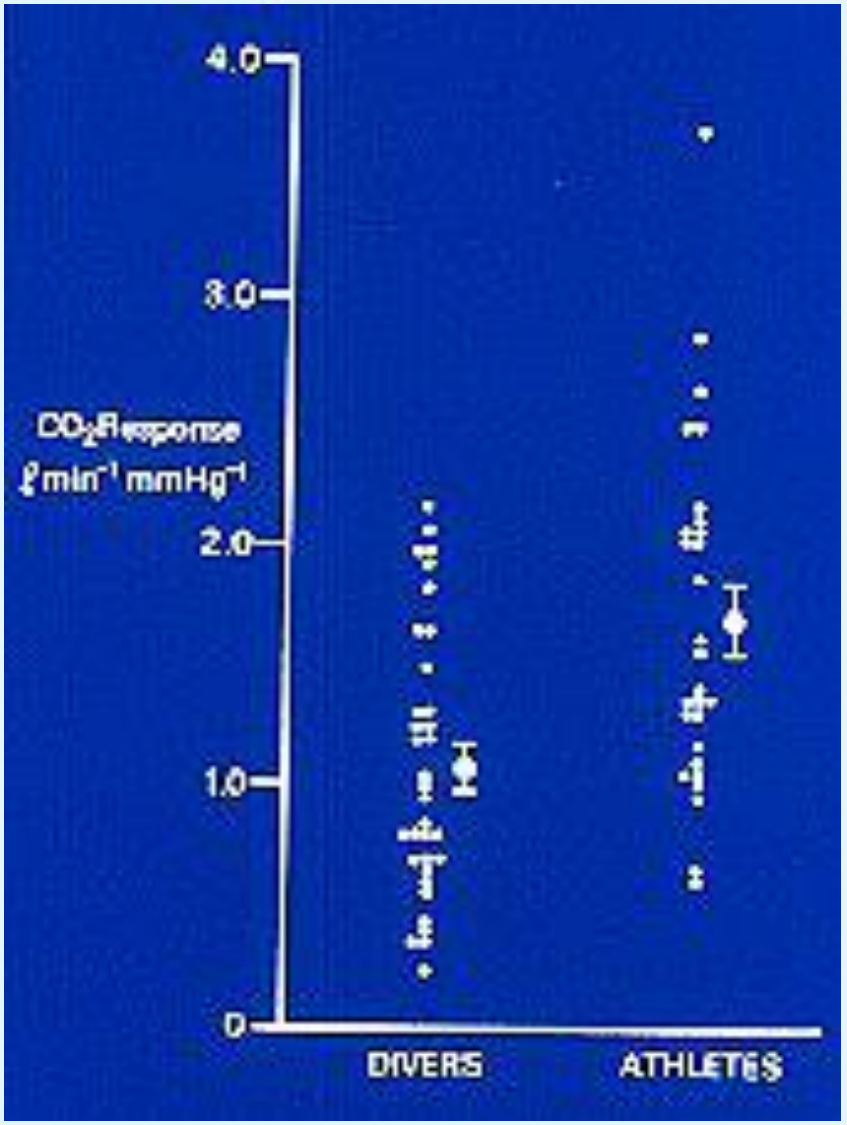
- UWH players vs. athletes ($P < 0.05$)

  1.08 ± 0.55 vs. 1.68 ± 0.72 L.min^{-1}.mmHg CO_2^{-1}

  (Davis et al, 1987)
- Later unpublished work confirmed this difference & UWH players and athletes had lower responses than non-athletes (typical mean 2.5−3.0 L.min^{-1}.mmHg CO_2^{-1})
- Other studies confirm these observations
- No data on hypoxia responses in divers at rest or during exercise ex. at 4 Ata

  (our attempts were not satisfactory)



UWH players
Apnoea times

	Breath-Hold Time, s		
	FRC-Air	TLC-Air	TLC-O_2
Athletes	37 (±10), n = 20	90 (±20), n = 20	185 (±66), n = 10
Divers			
Noninternational players, n = 26	38 (±13)	81 (±21)	—
International players, n = 8	55 (±18)*,**	132 (±37)*,**	261 (±71)*

*$P < 0.01$ vs. athletes. **$P < 0.02$ vs. noninternational players. The differences between the athletes and the noninternational underwater hockey players were not significant.

(Davis et al, 1987 – still the largest data set comparing BH divers with athletes)

Factors influencing apnoea times

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- Mechanical
  - Big Lungs – clear correlation
  - Lung packing
- Physiological
  - Large spleen – clear correlation
  - Tolerance to hypercapnia (not altered by repetitive apnoeas)
  - Tolerance to hypoxia – poorly studied
  - Blood volume shift to lungs with immersion
- Psychological
  - Motivation/relaxation
- Genetics
- Training
  - Increasing $\dot{V}O_{2max}$/repetitive apnoeas (CO_2 tables) - ?role

Breath-hold diving
Apnoea time

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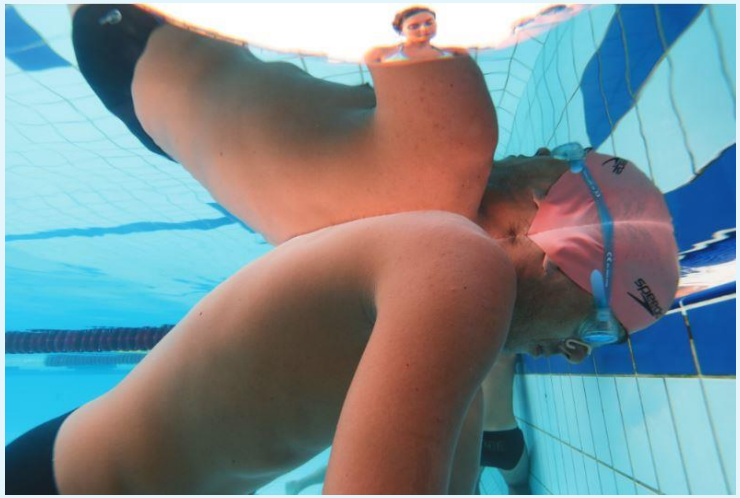
- BH time prolonged short term by BH series with short surface intervals (likely due in part to splenic contraction)
- Claims made for static apnoea training:
  - Boosts CO_2 tolerance
  - Helps to ‘deal’ with hypoxia !
  - Coping with diaphragm contractions
  - Helps to suppress urge to breathe
  - Builds mental fortitude and discipline.
- Motivation probably the strongest factor



Respiratory, cardiovascular & metabolic responses

- AS: HR 192 ± 8.7 $b.min^{-1}$ interspersed with bradycardia (89 ± 28.5)
- AS: Intermittent BH during dry-land exercise at 65% VO_{2max} induces hyperventilation, ↓ PCO_2 & ↑ [Lactate]
- ↑ [Lactate] in BH disciplines & AS:
  - highest in 'constant weight, no fins'
  - least in AS − ?shorter apnoeic times with intermittent breathing
  - No data in UWH players

Investigating UWH & UWR

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Laboratory: (elite players vs. matched athletes; male/female)

- BH times; face immersion bradycardia
- Hypoxia & CO_2 responses at rest/exercise (fixed work rate)
- Training: Intensive/repetitive apnoea/respiratory muscle

During play:

- Patterns of BH
  - *Lengths (5 sec − 1+ min?)*
  - *Surface intervals (relation to 'fitness'/$\dot{V}O_{2max}$)*
  - *Total BH duration in game*
  - *?Differences between playing positions*
- HR & O_{2sat} changes
- PCO_2 & [Lactate] changes (balance of aerobic/anaerobic exercise)

Underwater hockey injuries

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- Hypoxic LoC (training riskier than play)
- Facial trauma: espec. nose**, teeth**, lips**
- Sinus & middle ear** barotrauma
- Eye – conjunctival haem, (?visual)
- Shoulder – dislocation, “swimmer’s shoulder”**, elbow, wrist
- Hand – fractures** (thumb, index finger), dislocations
- Rib fractures**, pneumothorax
- Haemoptysis (pulm. cap. Stress – 1 case)
- Minor cuts & bruises**
- External ear & skin infections, athlete’s foot**
- 3 MIs, all in men with known heart conditions

** personal injuries

So … Why play UWH?

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- UWH maintains water skills
- Sport-specific exercise for scuba diving fitness & safety
- Played at all ages

  (ChCh club 12–73 y.o.)
- Team sport
- Wide range of skills involved
- And … it's fun!