New Pearls of Wisdom in Diving Literature

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Disclosures

- None

Objectives

- Review of five articles published in the diving literature in the past year
- Briefly discuss main pearls from each article, as well as limitations and areas for future research
  - Not intended to be a journal club or in-depth criticism of each article
- Aimed to pick articles that were both relevant to clinical practice and research

Very few exercise-induced arterialized gas bubbles reach the cerebral vasculature

Otto Barak, Dennis Madden, Andrew Lovering, Kate Lambrechts, Marko Ljubkovic, Zeljko Dujic

Medicine & Science in Sports & Exercise. March 2015.

Decompression Induced Bubble Dynamics on Ex Vivo Fat and Muscle Tissue Surfaces with a New Experimental Set Up

Virginie Papadopoulou, Sotiris Evgenidis, Robert Eckersley, Thodoris Mesimeris, Costantino Balestra, Margaritis Kostoglou, Meng-Xing Tang, Thodoris Karapantsios

Colloids and Surfaces B: Biointerfaces. Vol 129. 2015.

- Bubbles are routinely observed after diving and thought to be part of the pathophysiology of DCS, but has been difficult to model bubble growth
- Previous animal models have required that the animals be taken out of the the chamber and the tissues cannot be observed in real time
- Often have to inject bubbles in these models because the bubbles are hard to localize

Background

Hypothesis and Goals of Study

- “Set up to allow for the first time real time observation *during* decompression of bubble growth from desorption of inert gases out of solutions on tissue substrates”
- Hypothesize that the hydrophobicity of adipose tissues may facilitate bubble growth during decompression

Decompression induced bubble dynamics on ex vivo fat and muscle tissue surfaces with a new experimental set up. Papadopoulou et al.

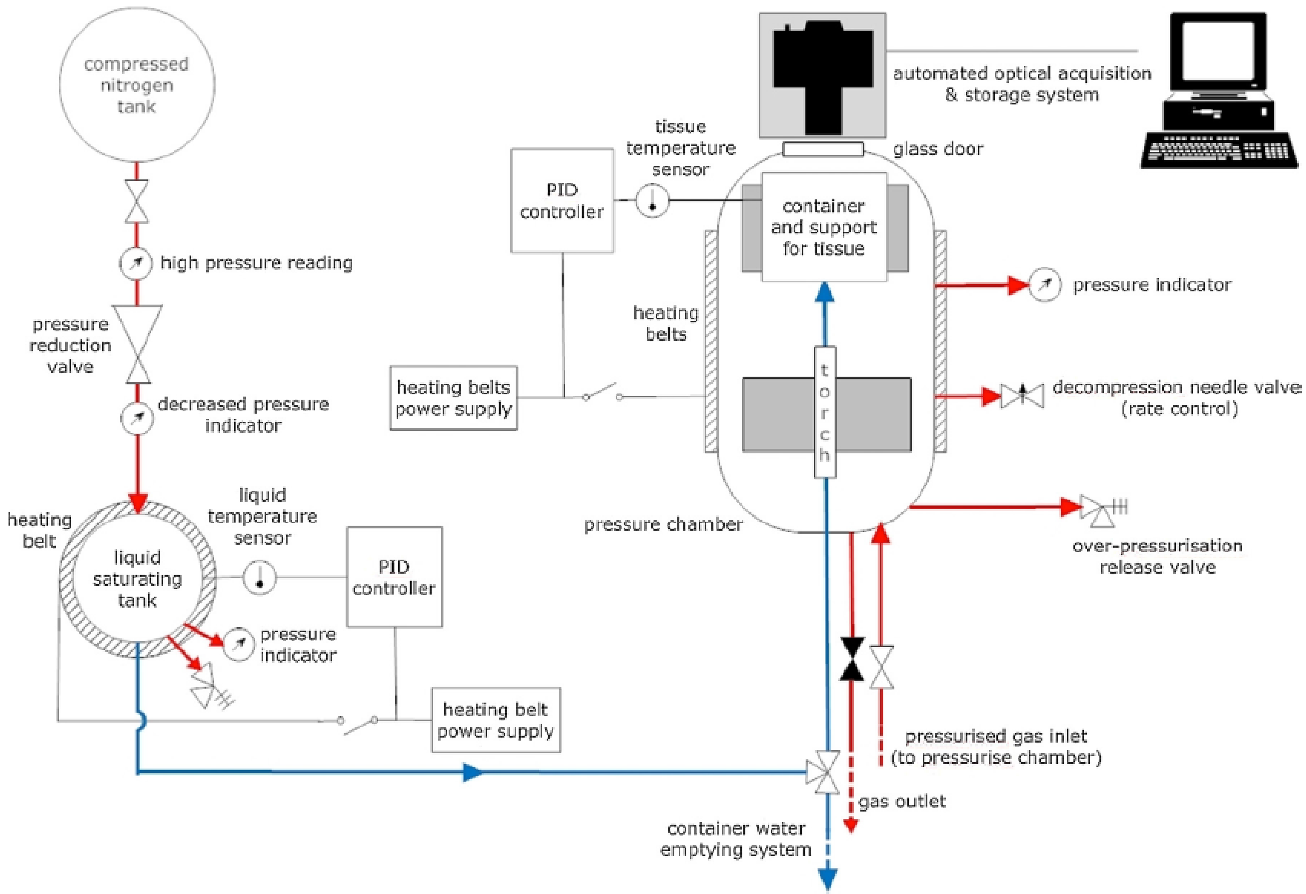


Fig. 1. Top view schematic of experimental set-up, showing liquid (in blue) and gas (in red) pressure flow systems. (For interpretation of the references to color in this figure legend, the reader is referred to the web version of this article.)

Methods

Decompression induced bubble dynamics on ex vivo fat and muscle tissue surfaces with a new experimental set up. Papadopoulou et al.

Methods

- 22 experimental set ups (11 adipose, 11 muscle), covered with nitrogen distilled water and decompressed from 3 bar to 0 bar at 1 bar/min
- Automatic recording with camera every 5 seconds to observe bubble growth (both rate and density)

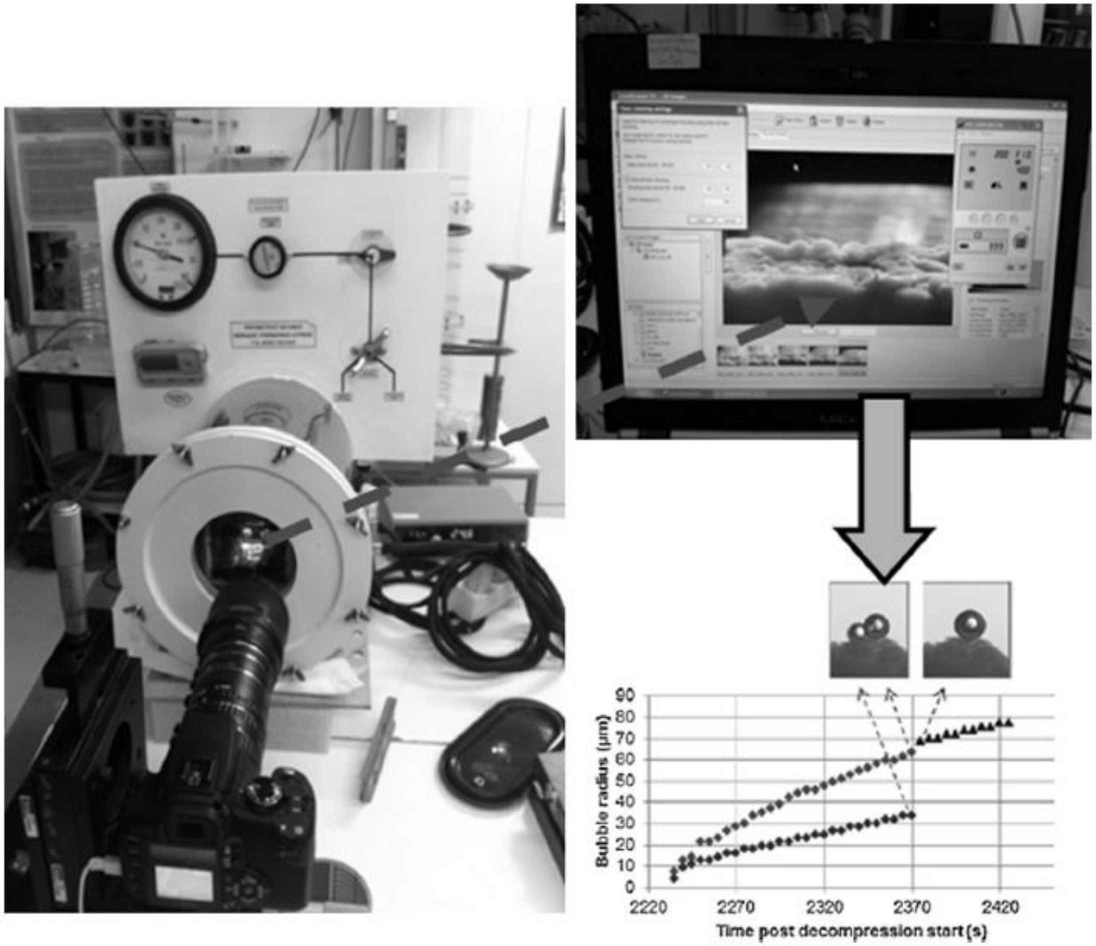


Fig. 2. Photograph showing the optical acquisition system and the temperature controlled small pressure chamber, as well as an example result.

Methods

Decompression induced bubble dynamics on ex vivo fat and muscle tissue surfaces with a new experimental set up. Papadopoulou et al.

- Observed cyclic growth from nucleation sites
  - Bubble starts growing from a preferential site until it detaches and floats, then another bubble grows from the same site, etc
- Tissues showed significantly different bubble densities

Results

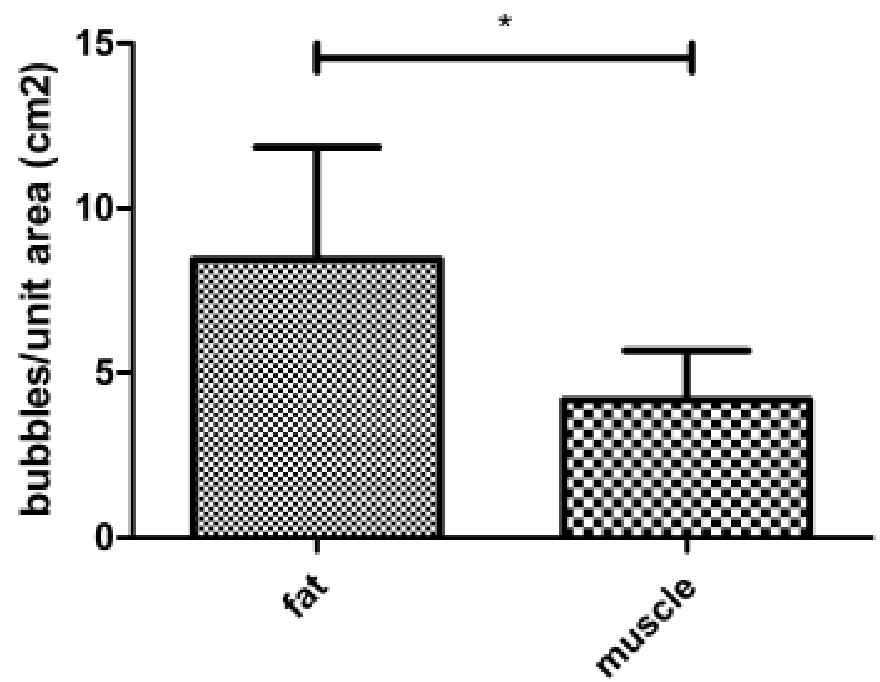


Fig. 4. Bubble density comparison between fat ($n = 11$) and muscle ($n = 11$) tissue substrates.

Results

Decompression induced bubble dynamics on ex vivo fat and muscle tissue surfaces with a new experimental set up. Papadopoulou et al.

- Observed cyclic growth from nucleation sites
  - Bubble starts growing from a preferential site until it detaches and floats, then another bubble grows from the same site, etc
- Tissues showed significantly different bubble densities
- Similar growth rates
- Significantly different bubble detachment sizes

Results

Decompression induced bubble dynamics on ex vivo fat and muscle tissue surfaces with a new experimental set up. Papadopoulou et al.

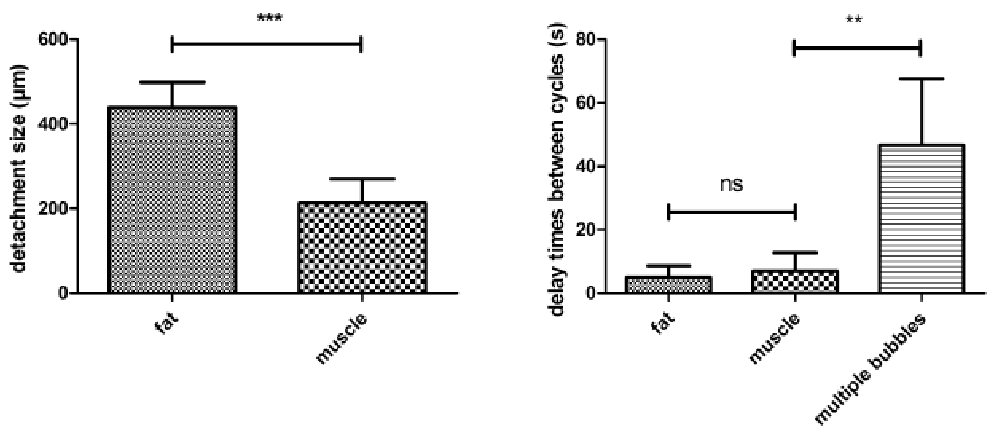


Fig. 6. Bubble radius at detachment (left, fat $n = 8$, muscle $n = 7$) and delay times between bubbles growing from same nucleation site (right, fat $n = 7$, muscle $n = 6$ and multiple $n = 6$), for muscle and fat tissue substrates.

Results

- Developed an experimental set up that allows for studying decompression induced bubble growth
- Decoupled effects tissue gas absorbance and tissue surface and still observed a difference in bubble formation
  - Implies that the difference between muscle and fat is not solely due to fat tissues absorbing more inert gas

Discussion and Conclusions

Decompression induced bubble dynamics on ex vivo fat and muscle tissue surfaces with a new experimental set up. Papadopoulou et al.

- The clinical significance of these findings has yet to be determined

Limitations

- Muscle and adipose tissue were observed to have different characteristics of bubble growth and detachment
- This experimental model may be able to be reproduced with variations of temperature, gas, liquid, and tissue

Take Home Points

Decompression induced bubble dynamics on ex vivo fat and muscle tissue surfaces with a new experimental set up. Papadopoulou et al.

High Intensity Cycling Before SCUBA Diving Reduces Post-Decompression Microparticle and Neutrophil Activation

Dennis Madden, Stephen Thom, Ming Yang, Veena Bhopale, Marko Ljubkovic, Zeljko Dujic

European Journal of Applied Physiology, Vol 14, 2014

Background

- The role of exercise and DCS is not yet clear
  - some evidence suggesting that pre-dive aerobic exercise may be protective
- Annexin V-positive microparticles have been correlated with the development of vascular injuries and DCS symptoms after diving in mice
- Little info on the effect of High Intensity Training (HIT) on subsequent diving

- Compare VGE and MP counts and sub-types in a dive preceded by anaerobic cycling (AC) compared to control dive (CON)
- Hypothesized that AC would have similar effects to aerobic exercise on MPs and minimal impact on VGE production

Hypothesis and Goals of Study

- 10 healthy male divers
- Completed control dive and three days later completed exercise protocol followed by dive
- 18 meters for 41 min, water temp 11 C
- Blood drawn and echoes performed after dive (15, 40, 80 and 120 min)

Methods

High intensity cycling before SCUBA diving reduces post-decompression microparticle production and neutrophil activation. Madden et al.

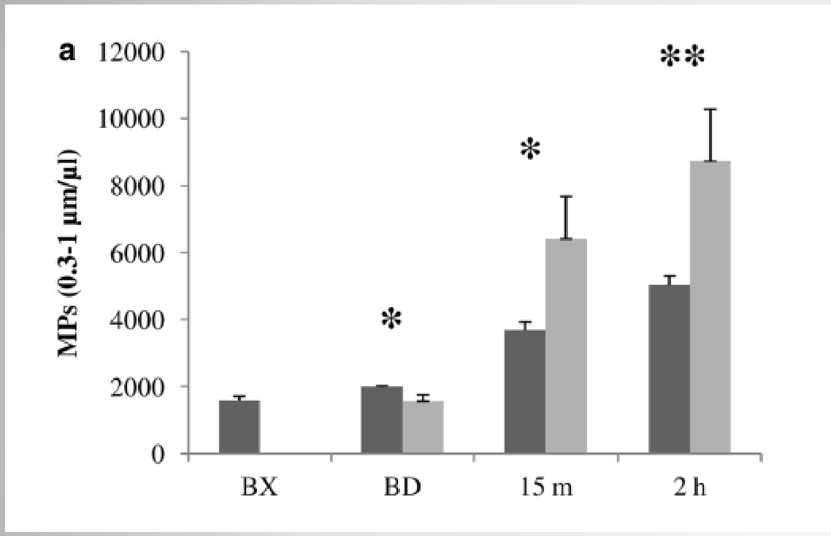
- 30 seconds maximal effort with 4 minute active recovery x 4 cycles
- Moderate intensity heart rate and swimming during dive

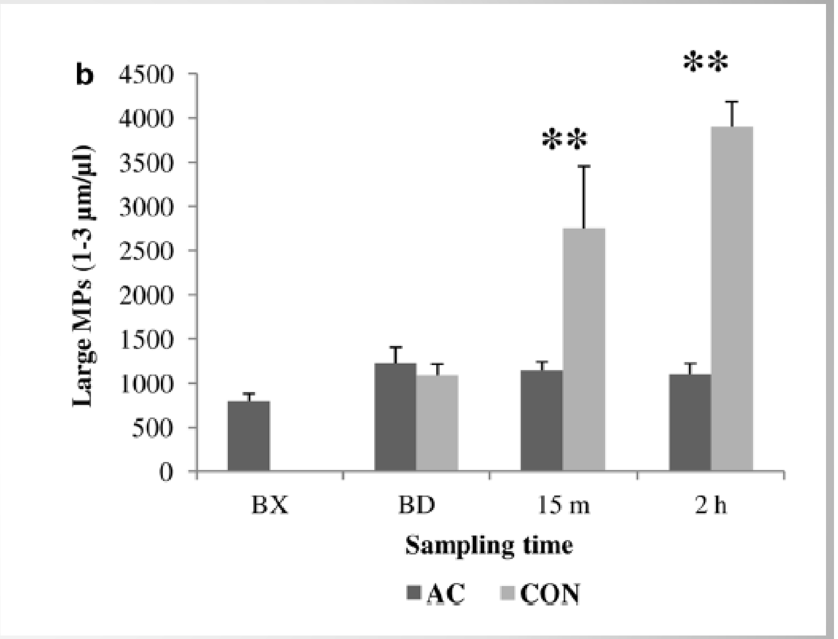
Methods-Exercise Protocol (HIT)

High intensity cycling before SCUBA diving reduces post-decompression microparticle production and neutrophil activation. Madden et al.

Methods-Microparticles

- MPs
  - Annexin V-positive particles, diameter <1 µm
- Enlarged MPs
  - diameter 1-3 µm
- Platelet Activation
  - CD41 and Annexin V-pos
- Neutrophil Activation and Platelet Interaction
  - CD66b and co-expression of CD41, CD18, or MPO


a
MPs (0.3-1 μm/μl)
12000
10000
8000
6000
4000
2000
0
*
*
**
BX
BD
15 m
2 h


b
Large MPs (1-3 μm/μl)
4500
4000
3500
3000
2500
2000
1500
1000
500
0
**
**
BX
BD
15 m
2 h
Sampling time
AC
CON

Results

Table 1 Descriptive statistics of VGE analysis following control (CON) and anaerobic cycling (AC) dives

	15 m post surface		40 m post surface		80 m post surface		120 m post surface	
	CON	AC	CON	AC	CON	AC	CON	AC
Max	4B	4B	4B	4B	3	4A	2	3
75th	4B	4A	4B	4A	3	3	2	2
Med	4B	3*	3	3	3	3	2	2
25th	3	2	3	2	3	2	1	1
Min	3	0	2	0	2	0	0	0

Median, maximal, minimal, and quartile data for bubble grades at rest

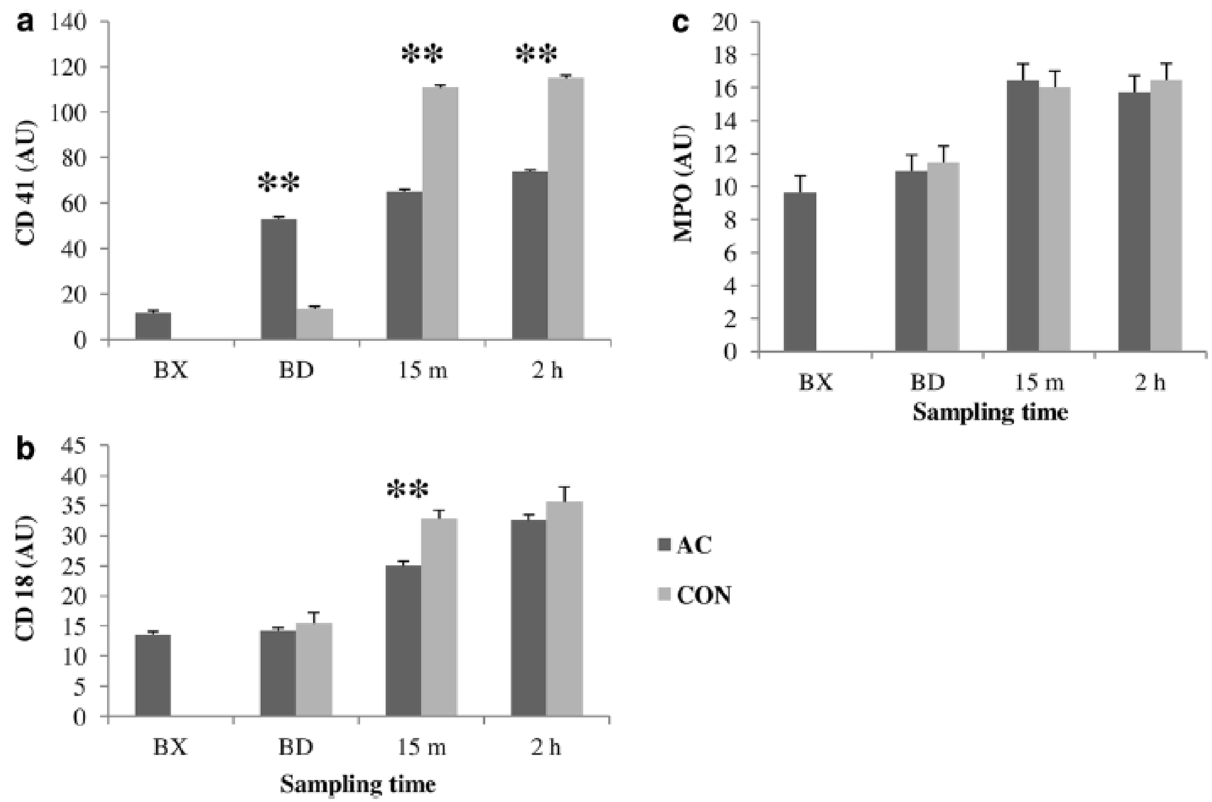
Non-parametric values presented as modified Brubakk scale for bubble grading

* $p < 0.05$ of median value of AC compared to CON at same time point

Results

High intensity cycling before SCUBA diving reduces post-decompression microparticle production and neutrophil activation. Madden et al.

Fig. 2 Geometric mean fluorescence representing neutrophil activation. Neutrophil activation identified by CD66b staining and co-expression of **a** CD41, **b** CD18, and **c** MPO shown as geometric mean fluorescence AU (arbitrary units) for each marker. *BX* sample taken before exercise (AC dive only). *BD* sample taken before diving, both dives. *$p < 0.025$, **$p < 0.01$, significance between expression at same time point between *AC* and *CON* dives



Results

- No significant differences in WBC, RBC, Hct, or platelets following the AC protocol and before diving
- WBC was significantly higher 15 min after surfacing in both groups
  - Magnitude was significantly higher following the AC dive
    Pre-dive values were also significantly higher in the AC group

Results

- Previous studies that have shown decrease in VGE load have been done in chambers
- Overall, there was less of an increase in MPs after diving in exercise arm
  - Decreased production or increased clearance?
- Possible that exercise could decrease population of pre-existing gas micronuclei prior to dive, leading to decreased MP and neutrophil response

Discussion and Conclusions

- Exercise arm done 3 days after control –is this enough time, or are there still effects from first dive
  - Crossover arm?
  - Each served as their own control

Limitations

The Impact of Predive Exercise on Repetitive SCUBA Diving

Dennis Madden, Otto Barak, Stephen Thom, Ming Yang, Veena Bhopale, Marko Ljubkovic, Zeljko Dujic

Clinical Physiology and Functional Imaging. Epub 2014.

- Would the effect of exercise on MPs seen in previous study continue in repetitive dive scenario?
- Wanted a comprehensive observation on the difference between repetitive dives with and without daily exercise performed before diving

Hypothesis and Goals of Study

Methods

- 16 divers (9 males, 7 females)
- Total of 6 dives, two sessions of three dives
- Same dive profiles as previous study
- 20 min of jogging warm up, followed by 40 min of running intervals

The impact of predive exercise on repetitive SCUBA diving. Madden et al.

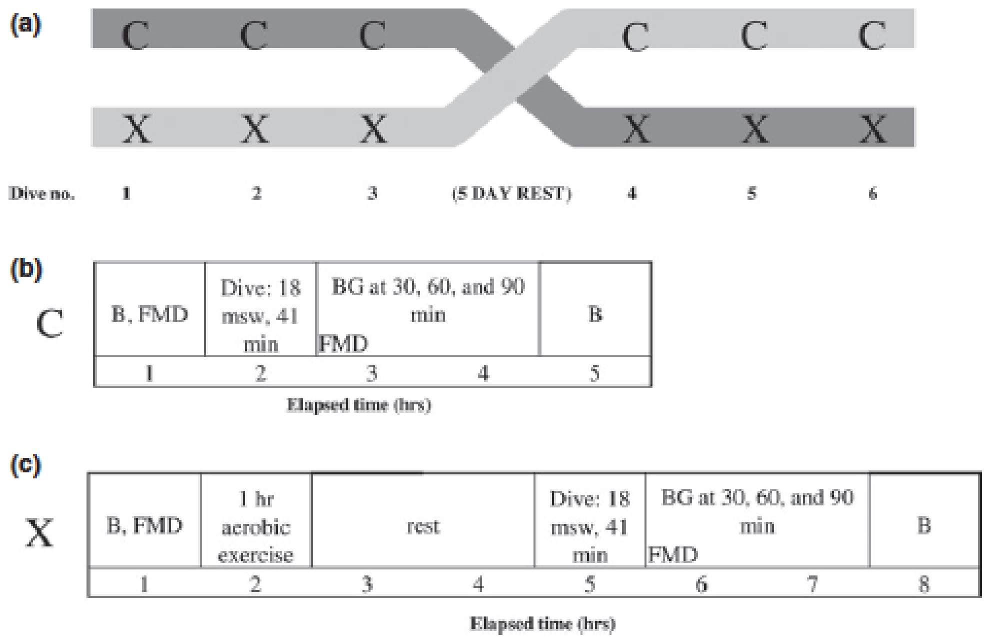


Figure 1 Study protocol. (a) Study protocol for G1 (dark-shaded track) and G2 (light-grey track). Numbers along x-axis represent dive no. C = control protocol, detailed in 1b and X = exercise protocol, detailed in 1c. Numbers along x-axis in (1b) and (c) represent elapsed time in hours.

Methods

The impact of predive exercise on repetitive SCUBA diving. Madden et al.

- 16 divers (9 males, 7 females)
- Total of 6 dives, two sessions of three dives
- Same dive profiles as previous study
- 20 min of jogging warm up, followed by 40 min of running intervals
- Added measurement of flow mediated dilation of brachial artery to assess endothelial function

Methods

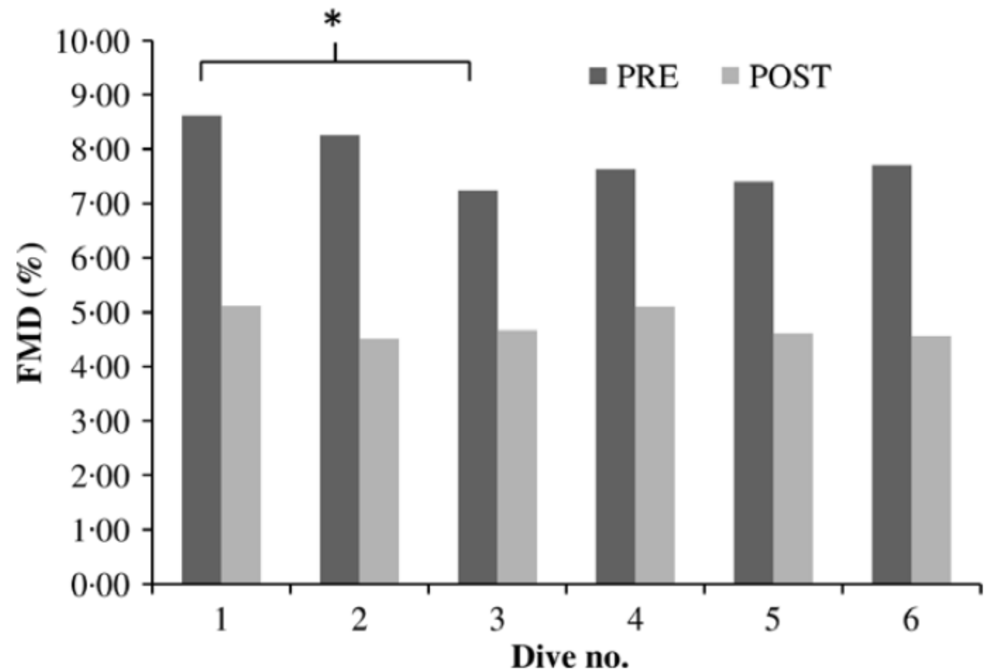


Figure 2 Flow-mediated dilation. Data show pre (dark-shaded bars)- and post (light-grey bars)-ΔFMD % for all divers in chronological order. *P<0·05 between dives 1 and 3 for all divers.

Results

The impact of predive exercise on repetitive SCUBA diving. Madden et al.

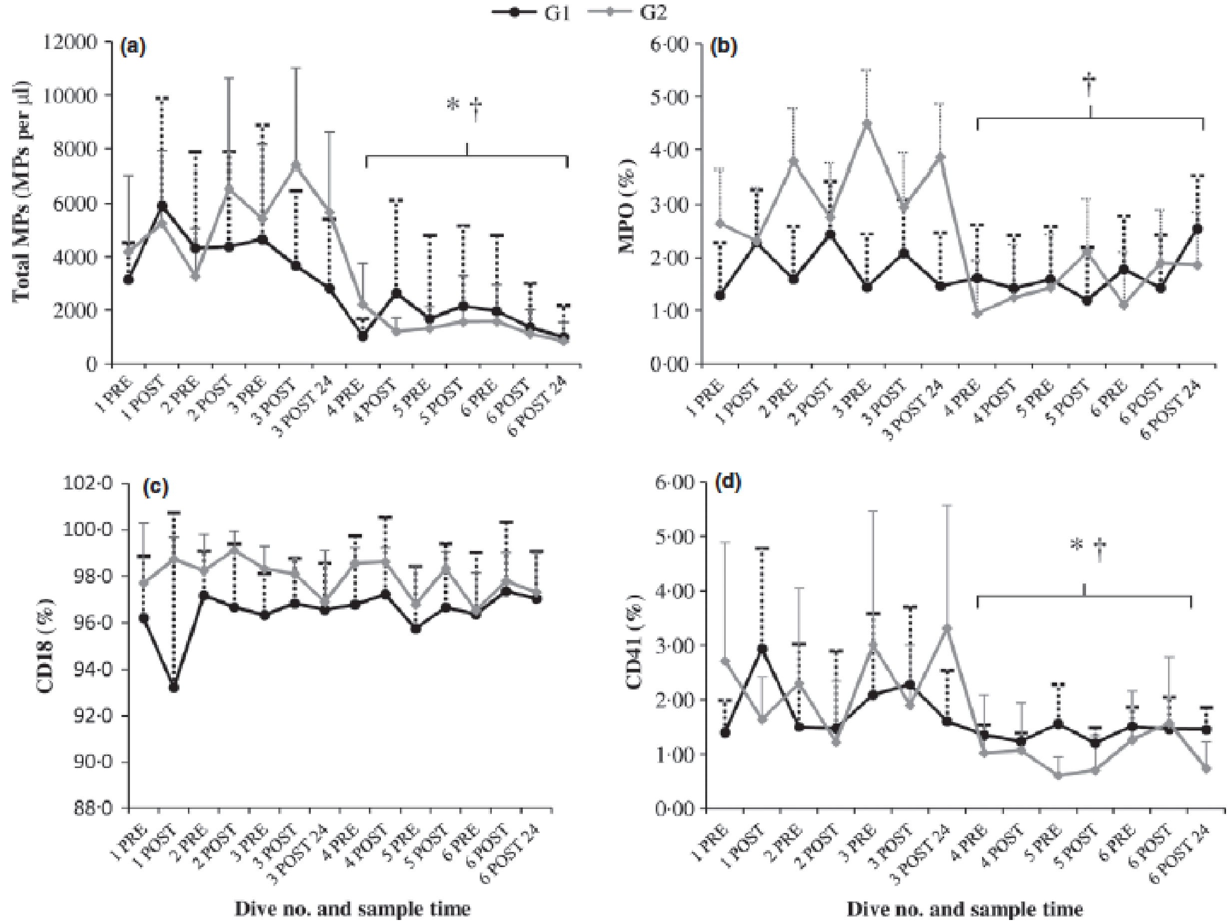


Figure 3 Microparticle counts, neutrophil activation and platelet interaction. Data show mean of circulating (a) MPs (0·3–1·0 µm) μl^{-1} and neutrophil activation identified by CD66b staining and per cent coexpression of (b) MPO, (c) CD18 and (d) CD41. * and †$P<0{\cdot}05$ in G1 and G2 for second series compared to the first series.

Results

The impact of predive exercise on repetitive SCUBA diving. Madden et al.

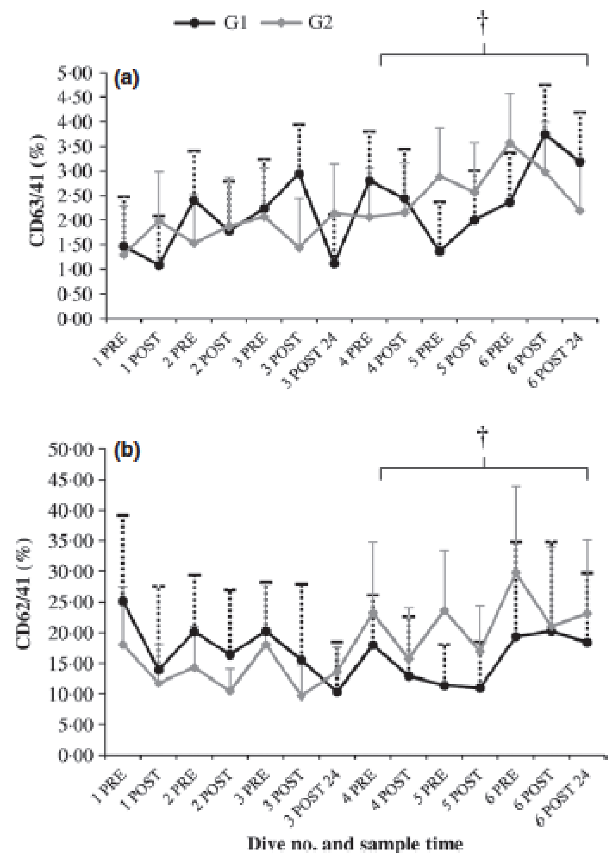


Figure 4 Platelet activation as per cent and mean fluorescence. Platelet activation shown as (a) Per cent CD41-positive MPs coexpressing the CD63 and (b) CD62 activation-associated surface proteins. †$P<0{\cdot}05$ in G2 for second series compared to the first series.

Results

The impact of predive exercise on repetitive SCUBA diving. Madden et al.

- One person got DCS-symptoms began 30 min after surfacing
  - Fatigue, numbness and tingling in lower extremities, and rash along torso
- Had bubble grade 4c (no arterialization)
- Treated for 120 min with HBO and had complete resolution

Results

- Different results than expected
- Diving reduced FMD
- Total MPs dropped in the second series in both arms

Discussion and Conclusions

- Were the men and the women in this study equal?

Limitations

Table 1 Anthropometric data for male and female divers.

	Male $n = 9$	Female $n = 7$	Combined $n = 16$
Age (year)	40·1 ± 7·8	33·4 ± 7·4	36·7 ± 8·1
Dive exp. (year)	19·4 ± 7·8	8·0 ± 3·9*	13·3 ± 8·7
Ht (cm)	182·3 ± 1·8	166·1 ± 5·8*	175·2 ± 9·2
Wt (kg)	89·9 ± 10·3	62·2 ± 7·9*	77·8 ± 16·9
Body fat (%)	15·1 ± 3·2	16·5 ± 1·2	15·7 ± 2·7
VO_{2max} (ml kg^{-1} min^{-1})	37·1 ± 3·8	37·9 ± 6·9	37·5 ± 5·3
FVC (% pred)	111·9 ± 14·4	116·8 ± 12·0	114·1 ± 13·2
FEV_1 (% pred)	112·3 ± 13·3	112·9 ± 9·5	112·6 ± 11·4
FEV_1/FVC (% pred)	102·7 ± 5·4	102·9 ± 6·0	102·8 ± 5·5

Values are means ± SD; n, no. of subjects.
Pulmonary function parameters are expressed as a percentage of the predicted values (% pred) FVC, forced vital capacity; FEV_1, forced expiratory volume in 1 s; VO_{2max}, maximal O_2 uptake, determined through graded maximal treadmill test. Body fat estimated from 3-site skinfold measurements.
*P<0·01 compared to male subjects.

Limitations

The impact of predive exercise on repetitive SCUBA diving. Madden et al.

Table 2 Median bubble grade at rest 30, 60 and 90 min after surfacing.

	Control dives			Exercise dives		
Dive	**1**	**2**	**3**	**1**	**2**	**3**
30 min						
Male	3	3	3	4A	3	3
Female	1*	2*	1*	1*	2*	1*
60 min						
Male	3	3	3	4A	3	3
Female	2	3	2*	2*	2	0*
90 min						
Male	3	2	2	3	2	2
Female	1*	1*	0*	1*	1*	0*

Values represent median BG on Brubakk scale. Male and female subjects are compared within each dive, separately from assigned groups. *P≤0·05 compared to male subjects.

Limitations

The impact of predive exercise on repetitive SCUBA diving. Madden et al.

Limitations

- Gender differences
- Did not look at enlarged MPs in this study

- The exact role of microparticles in DCS is still not fully understood
- The role of exercise, SCUBA, and microparticles is complex
- Stay tuned…

Take Home Points

High intensity cycling before SCUBA diving reduces post-decompression microparticle production and neutrophil activation. Madden et al.

Serum Albumin as a Biomarker of Capillary Leak in Scuba Divers with Neurological Decompression Sickness

Emmanuel Gempp, Sebastien De Maistre,
Pierre Louge

Aviation, Space and Environmental Medicine. Vol 85, No. 10, October 2014

- Mechanism of damage in neurologic DCS thought to partially be due to systemic inflammatory response
- Animal models display increased permeability of blood brain barrier
- Anecdotal experience of hypotension in DCS requiring volume resuscitation
- Albumin is the chief contributor of intravascular oncotic pressure

Background

Serum Albumin as a Biomarker of Capillary Leak in Scuba Divers with Neurological Decompression Sickness. Gempp et al

- Hypothesize that lower serum albumin levels are associated with the development of neurological DCS
- Examine albumin as a diagnostic biomarker

Hypothesis and Goals of Study

Serum Albumin as a Biomarker of Capillary Leak in Scuba Divers with Neurological Decompression Sickness. Gempp et al

- Prospective, observational, case-control study of recreational divers
- 52 cases of neurologic DCS, 52 controls
- Exclusion Criteria: suspected CAGE, "ambiguous presentation," admission >6 hours after start of sxs, hx of liver or renal failure or acute sepsis
- Blood drawn immediately after presentation
- Compared serum albumin levels between groups

Methods

Serum Albumin as a Biomarker of Capillary Leak in Scuba Divers with Neurological Decompression Sickness. Gempp et al

TABLE I. DISTRIBUTION OF DCS DIVERS WITH CNS SYMPTOMS AT INITIAL PRESENTATION.

Initial Presentation	*N*
Subjective sensory abnormalities only	17
Objective sensory loss and/or mild motor impairment	6
Severe presentation with sensory, motor, and sphincter dysfunction	7
Cerebral involvement (speech, visual, or cognitive function alterations)	3

TABLE II. CHARACTERISTICS OF THE DIVERS ENROLLED IN THE STUDY.

Variables	DCS Divers (*N* = 52)	Controls (*N* = 52)	*P*-Value
Age (yr)	48 ± 9	45 ± 13	0.14
Male sex	21%	11%	0.39
Diving depth (msw)	42 ± 10	42 ± 13	0.99
Total dive time (min)	36 ± 8	33 ± 12	0.14
Repetitive dive	19%	10%	0.9
Delay for blood collection (min)	120 [60–300]	150 [60–270]	0.18
Fluid loading after diving (ml)	500 [0–3000]	300 [0–1500]	0.31
Hematocrit (%)	44.5 ± 4.4	43.6 ± 2.2	0.22

Data are presented as means ± SD, or median [range], or percentages of presented cases. Note that all divers were rehydrated orally except for two DCS divers in whom fluid loading was administered with normal saline infusion.

Results

Serum Albumin as a Biomarker of Capillary Leak in Scuba Divers with Neurological Decompression Sickness. Gempp et al

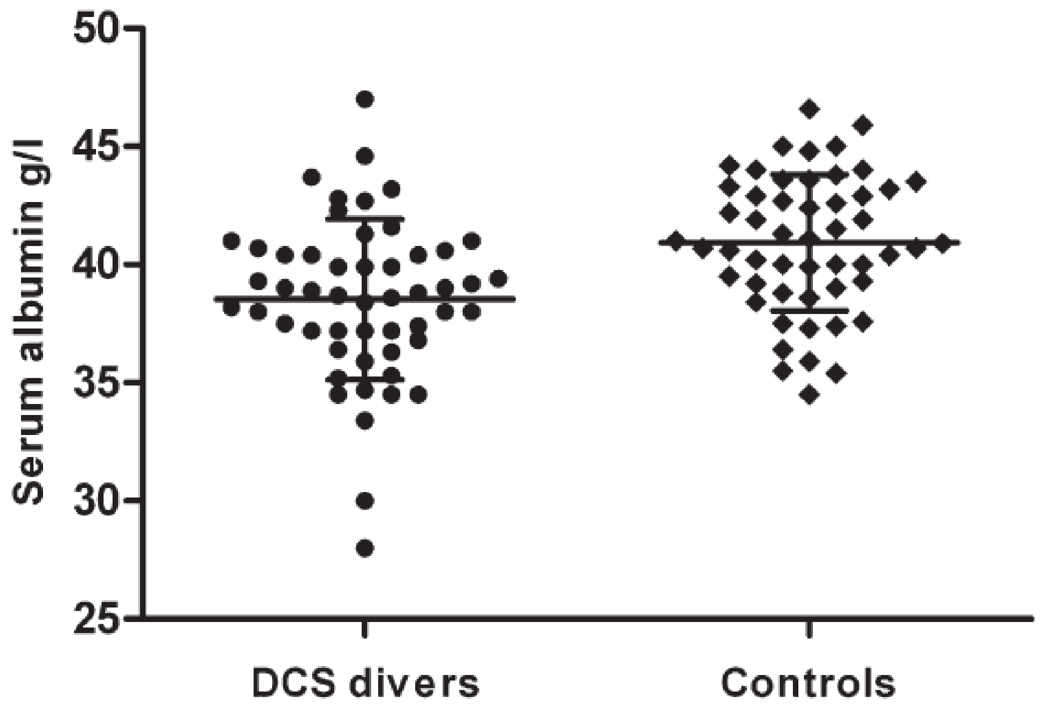


Fig. 1. Distribution of individual values of serum albumin between the two groups of divers. Bars are mean ± SEM.

38.7 +/-3 g/L DCS Divers vs. 41 +/- 2.9 g/L Controls (p=0.0002)

Results

Serum Albumin as a Biomarker of Capillary Leak in Scuba Divers with Neurological Decompression Sickness. Gempp et al

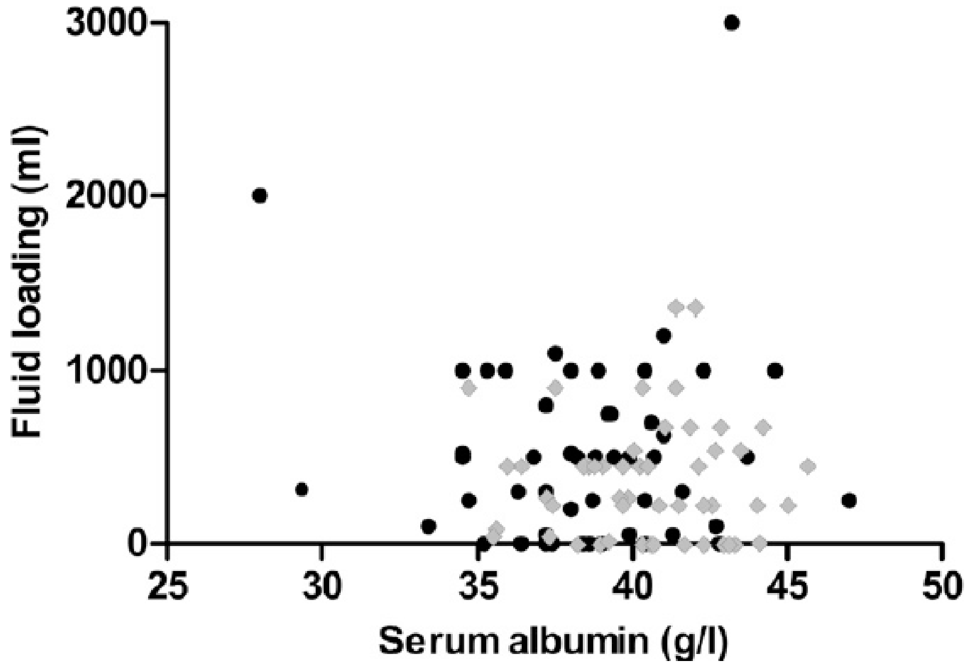


Fig. 2. Distribution of individual values of serum albumin vs. volume of fluid loading after diving for DCS divers (black symbols) and controls (gray symbols).

Results

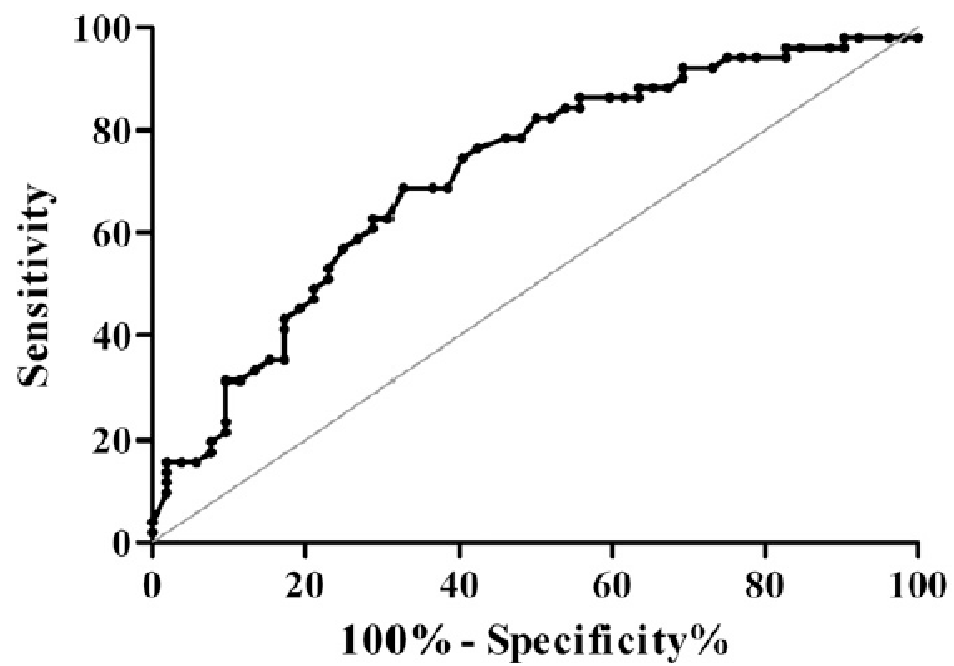


Fig. 3. Receiver operating curve of serum albumin in predicting neurological decompression sickness in scuba divers. The area under the curve is 71% ($P < 0.0002$). The grey diagonal line represents the line of no discrimination.

Highest Specificity and Sensitivity -> **40 g/L (69%, 67%)**

Cut-off of 35.2 g/L was 98% specific and **16% sensitive for DCS**

Results

Serum Albumin as a Biomarker of Capillary Leak in Scuba Divers with Neurological Decompression Sickness. Gempp et al

- Significant decrease in albumin in patients presenting with neurologic DCS
- DCS may be responsible for capillary leak and albumin loss
- Hematocrit changes may be more delayed
- Can “rule-in” neurologic DCS when albumin less than 35.2 g/L

Discussion/Conclusions

Serum Albumin as a Biomarker of Capillary Leak in Scuba Divers with Neurological Decompression Sickness. Gempp et al

Limitations

- How clinically relevant is this information?
  - Normal value does not rule out DCS
  - But may show potential as treatment modality
- The mean for both groups was still within normal limits
- Wide range of clinical condition of neurologic DCS
- Potentially confounding cases of inner ear barotrauma

- At this point, albumin probably does not have great utility in diagnosis of neurologic DCS
- May further our understanding of the mechanism of disease
- Future areas of research may include prognostic significant of low albumin, other treatment modalities

Take Home Points

Flying After Diving: In-Flight Echocardiography After a Scuba Diving Week

Danilo Cialoni, Massimo Pieri, Costantino Balestro, Allessandro Marroni

Aviation, Space and Environmental Medicine. Vol 85, No. 10, October 2014

Background

- Flying after diving may increase risk of DCS, but lack evidence for guidelines for minimum preflight surface interval (PFSI) between diving and high altitude exposure
- Current guidelines for recreational divers
  - 12 hours after single no-deco dive
  - 18 hours after multiple dives
  - >18 hours after decompression dives

- “inert gas accumulated during exposure to increased hyperbaric pressure may remain in the tissues for longer than the so-far estimated safe interval of 24 h after multiple multiday recreational diving”
- “a rapid decrease of the ambient pressure may generate a further tissue super saturation that, in predisposed subjects, may in turn generate the formation of bubbles”
- Perform echocardiography on commercial flights on divers returning home after 7 days of repetitive diving after 24 PFSI

Hypothesis and Goals of Study

- Prospective, observational, nonblinded study
- 32 healthy divers (23 m, 9 w) dove every day for 1 week in the Maldives (total 448 dives)
- All dives were no-decompression dives, not exceeding 45 min or 30 m, with average ascent of 9-10 m/min and 5 min safety stop at 5 m
- Transthoracic echocardiogram and doppler done on each diver
- All tests performed on board Boeing 767-300ER, pressurized to 8000 ft (2400 m)

Methods

Flying after Diving: In-Flight Echocardiography After a Scuba Diving Week. Cialoni et al.

TABLE I. MEASUREMENT PROTOCOL.

	Test Procedure	Timing Test
Control 1	During the flight to the Maldives (no previous diving exposure)	30, 60, & 90 min after takeoff
Control 2	During the diving week: before and after every dive	30, 60, & 90 min after surfacing
Control 3	Before boarding the return flight: after a 24-h preflight surface interval	90, 60, & 30 min before takeoff
Test in flight	During the return flight	30, 60, & 90 min after takeoff

The subjects were studied by transthoracic echocardiography and with precordial Doppler ultrasound four different times: three controls and during the return flight.

Methods

- For analysis, divided divers into three groups
  - Bubblers
    - Developed bubbles every day and after every dive
  - Occasional Bubblers
    - Developed bubbles occasionally
  - Non-Bubblers
    - Did not develop bubbles

Methods

- No Divers had bubbles on flight over
- During the week, 6 developed bubbles every day, 10 occasional bubblers, and 16 had no bubbles
- After 24 hour PFSI, no one had bubbles prior to flying

Results

Grade	Definition
0	No observable bubbles
1	Occasional bubbles
2	At least 1 bubble every 4 heart cycles
3	At least 1 bubble every heart cycle
4	At least 1 bubble per cm^2 in every image
5	"White-out", single bubbles cannot be discriminated

Eftedal and Brubakk Scoring System

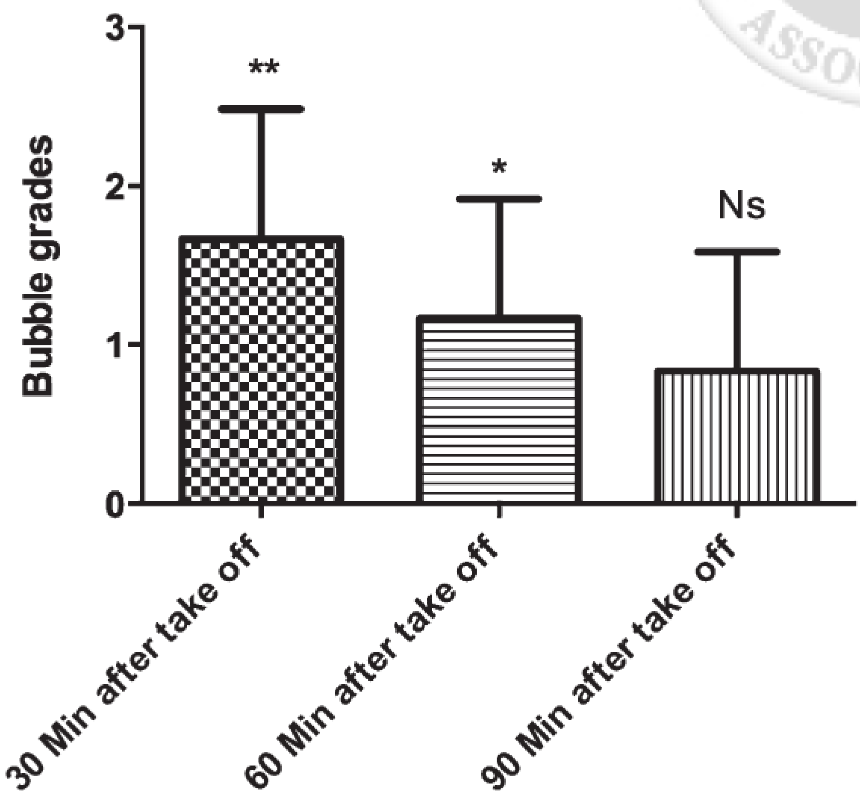


Fig. 1. Venous gas emboli evolution during flight in six divers. Difference in bubble grades between baseline (control 1 and control 3 – equal to zero) and the return flight (30, 60, and 90 min after takeoff). Ns = not significant; *$P < 0.05$; **$P < 0.01$. Note: 6 of the 32 divers developed bubbles during flight; these were the same subjects that developed bubbles every day after every dive.

Results

Flying after Diving: In-Flight Echocardiography After a Scuba Diving Week. Cialoni et al.

TABLE II. AVERAGE AND MEDIAN BUBBLE GRADES AFTER ALL 14 DIVES IN BUBBLERS, OCCASIONAL BUBBLERS, AND NON-BUBBLERS ON THE BOAT AND IN FLIGHT.

	Mean in Boat	Median in Boat	Mean in Flight	Median in Flight
Bubblers	2.52 ± 1.28	3.0	1.28 ± 0.83	1.0
Occasional Bubblers	0.50 ± 0.86	0.0	0.0	0.0
Non-Bubblers	0.0	0.0	0.0	0.0
Bubblers vs. Non-Bubblers	P-value < 0.0001		P-value < 0.0001	

Difference in bubble grades was statistically significant ($P < 0.0001$).

Results

Flying after Diving: In-Flight Echocardiography After a Scuba Diving Week. Cialoni et al.

- Only significant difference between Non-Bubblers, Occasional-Bubbler, and Bubblers was age ($p=0.0004$)
  - Older divers produced more bubbles
- No relationship between height, BMI, fitness, HR, BP, VC, max depth, bottom time, or surface intervals
- All divers boarded flight after 24 hours and their was no significant difference in the cabin pressure between the six flights

Results

- Majority of divers did not develop bubbles during altitude exposure after 24 hour PFSI
- A cohort of divers developed bubbles after every dive and during flight
- There may be a positive correlation between age and bubble formation
- The lack of correlation to depth, exposure, GF, etc suggests that some people may be predisposed to form bubbles, despite “low-risk” diving

Discussion and Conclusions

- What does this mean clinically?
  - Bubbles don’t necessarily equal DCS
  - Despite having bubbles, none of these divers developed symptoms of DCS
- Maybe bubbles were not present after 24 hours (pre-flight) or maybe they just weren’t detected
- Diving behavior may have changed because they were being observed (Hawthorne Effect)

Limitations

- 24 hours may not be a safe interval for certain people after multiple days of diving
- Some people appear to be predisposed to forming bubbles
  - Age may be a contributing factor

Take Home Points

Flying after Diving: In-Flight Echocardiography After a Scuba Diving Week. Cialoni et al.

Recap

- New experimental set up has been developed to observe the formation of bubbles in real time
- Pre-dive exercise *may* have some protective effect against elevated microparticle levels
- Neurologic DCS appears to be associated with low serum albumin levels
- 24 hours may not be safe PFSI for all divers
  - Particularly the subset of people who are prone to developing bubbles

1. **Decompression induced bubble dynamics on ex vivo fat and muscle tissue surfaces with a new experimental set up.** Papadopoulou et al. Colloids Surf B Biointerfaces. 2015 Mar 24;129:121-129. PMID: 25835147
2. **High intensity cycling before SCUBA diving reduces post-decompression microparticle production and neutrophil activation.** Madden et al. Eur J Appl Physiol. 2014 Sep;114(9):1955-61. PMID: 24917356
3. **The impact of predive exercise on repetitive SCUBA diving.** Madden et al. Clin Physiol Funct Imaging. 2014 Nov 4. PMID: 25371042
4. **Serum Albumin as a Biomarker of Capillary Leak In Scuba Divers with Neurological Decompression Sickness.** Gempp et al. Aviat Space Environ Med. 2014 Oct;85(10):1049-52. PMID: 25245905
5. **Flying After Diving: In-Flight Echocardiography After a Scuba Diving Week.** Cialoni et al. Aviat Space Environ Med. 2014 Oct;85(10):993-8. PMID: 25245898

Questions?