12:15 12:30 Giovanni **Calcagnini** ISS — Tecnologie per il monitoraggio cardiovascolare ed autonomico in ambiente iperbarico

Dipartimento di malattie Cardiovascolari, endocrino-metaboliche e Invecchiamento – Istituto Superiore di Sanità

G. Calcagnini, G. DE Angelis, E. Mattei, F. Ricci, C. Vivarelli,

Monitoraggio del Sistema Cardiovascolare e del Sistema Nervoso Autonomo quali segnali misurare….. in ambiente iperbarico?

- Monitoraggio del sistema cardiovascolare:
  - Elettrocardiogramma (ECG),
  - Pressione Arteriosa (PA),
  - Saturazione periferica di ossigeno (Sp02),
  - Attività Respiratoria,
  - Impedenza Cardiaca (ICG) -> Gittata Cardiaca

- Monitoraggio del Sistema Nervoso Autonomo:
  - Variabilità della frequenza cardiaca (HRV),
  - Impedenza Cardiaca -> Left-ventricular Ejection Time – LVET, Pre Ejection Period – PEP.

Review della letteratura

(JMIR Mhealth Uhealth 2022;10(9):e35727) doi: 10.2196/35727

Review

Wearable Devices in Diving: Scoping Review

Benjamin Bube[1,2], BSc, MSc; Bruno Baruque Zanón[2], PhD; Ana María Lara Palma[3], PhD; Heinrich Klocke[1], Prof Dr

Review della letteratura

(JMIR Mhealth Uhealth 2022;10(9):e35727) doi: 10.2196/35727

Table 1. Studies covering vital signs.

	Authors	Study topic	Maximum depth (construction depth), m	Sensors and actuators	Results
ECG, ICG	Tocco et al [27]	HR[a], SV[b], and CO[c] during DA[d]	3 (90)	Miniaturized impedance cardiograph	No changes in HR, SV, and CO when compared with surface breathing and when immersed at the surface and at a 4-m depth
ECG, ICG	Tocco et al [28]	HR, SV, and CO	3 (90)	Impedance and ECG[e] recorder	Bradycardia and decrements in SV and CO
ECG	Schuster et al [29]	Measuring body temperature (core and skin) and ECG monitoring	30 (N/A[f])	ECG, temperature sensor, and Bluetooth sensor	Weak housing and problematic cables
ECG	Cibis et al [30]	Underwater monitoring of a diver's ECG signal, including an alert system that warns the diver of predefined medical emergency situations	2.7 (N/A)	ECG sensor	Showed the good accuracy of the analysis system as well as the alert system
ECG, Sp02	Kuch et al [31]	Wrist-mounted apnea dive computer for the continuous plethysmography monitoring of oxygen saturation and HR	11 (200)	Transcutaneous oxygen saturation, HR, plethysmography pulse waveform, depth, time, and temperature sensors	Continuous measurement of oxygen, HR, and plethysmography pulse waves for water temperature and depth was successful
PA	Sieber et al [32]	Measurement of blood pressure underwater	10.5 (200)	Pressure sensor and sphygmomanometer	Accurate noninvasive measurement of blood pressure underwater
Sp02	Di Pumpo et al [33]	Detecting peripheral oxygen saturation for an electronic closed-circuit rebreather diver	14 (N/A)	Pulse oximeter	Detecting pulse oximetry during an immersion makes diving with a rebreather safer

Waterproof taping vs sealing compound

F. Ricci, C. Vivarelli, E. Marchetti, L. Fattorini, C. Costanzo, F. Sacco, E. Mattei, and G. Calcagnini. Heart rate variability in professional SCUBA divers. GNB2025, June 16th-18th 2025, Palermo, Italy

Sieber A., Bedini R., Yong X., Navarri A., Dalle Luche M., L'Abbate A. and Dario P. (2008). High Resolution Ecg And Depth Data Logger - A Novel Device to Study Breath Hold Diving Induced Variations of the PQ Interval . In *Proceedings of the First International Conference on Biomedical Electronics and Devices - Volume 1: BIODEVICES, (BIOSTEC 2008)* ISBN 978-989-8111- 17-3, pages 269-275. DOI: 10.5220/0001052102690275

ECG/ICG – metodi alternativi

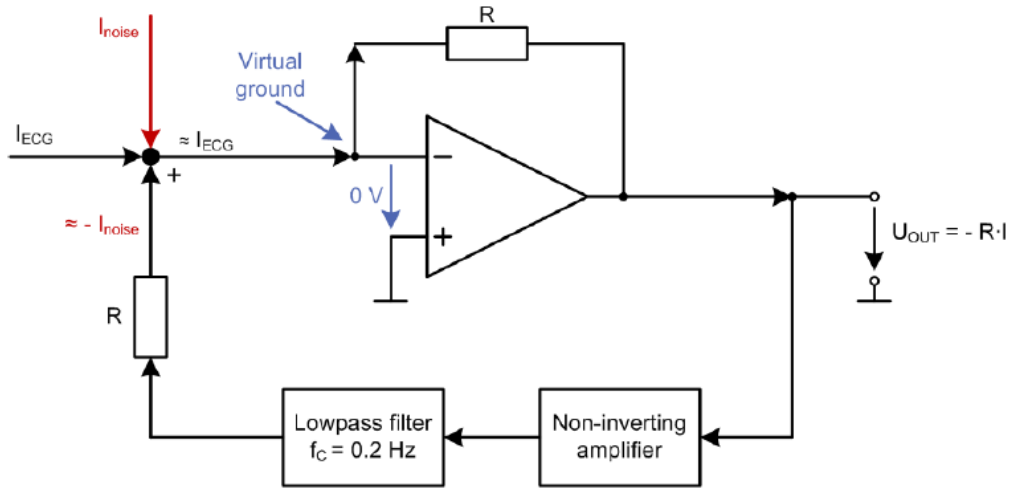
applied sciences

MDPI

Article

Wearable Current-Based ECG Monitoring System with Non-Insulated Electrodes for Underwater Application

Stefan Gradl [1,*,†], Tobias Cibis [1,†], Jasmine Lauber [1], Robert Richer [1], Ruslan Rybalko [2], Norman Pfeiffer [2], Heike Leutheuser [1], Markus Wirth [1], Vinzenz von Tscharner [3] and Bjoern M. Eskofier [1]



Annals of Biomedical Engineering, Vol. 44, No. 8, August 2016 (© 2016) pp. 2464–2479
DOI: 10.1007/s10439-015-1528-8

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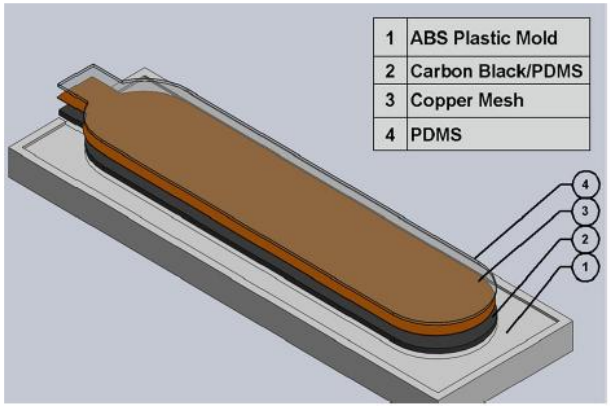
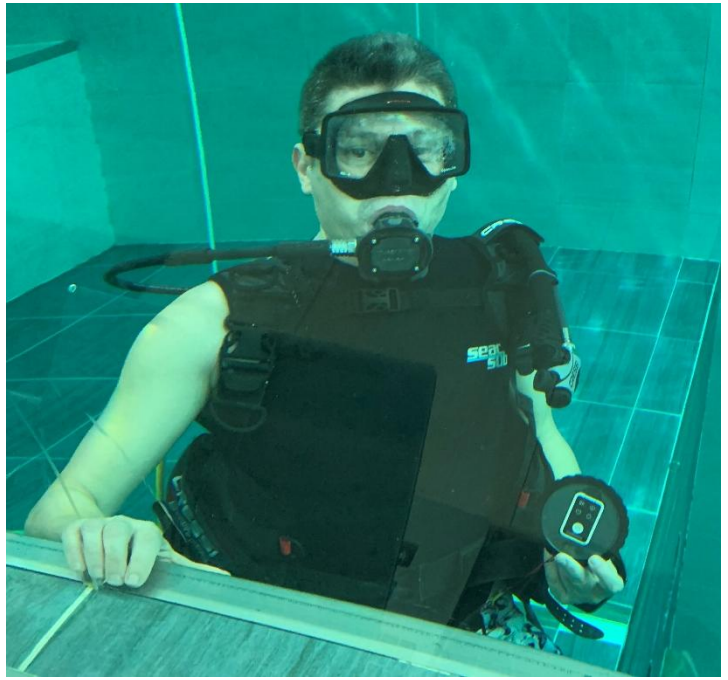
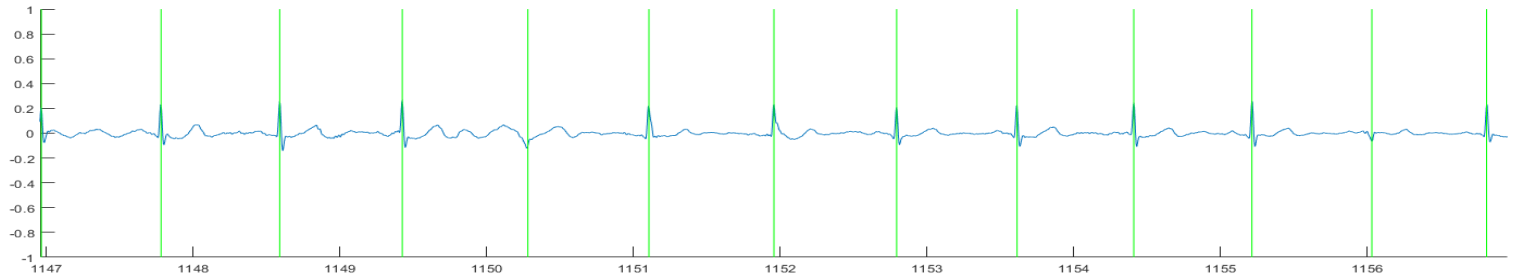
Novel Conductive Carbon Black and Polydimethlysiloxane ECG Electrode: A Comparison with Commercial Electrodes in Fresh, Chlorinated, and Salt Water

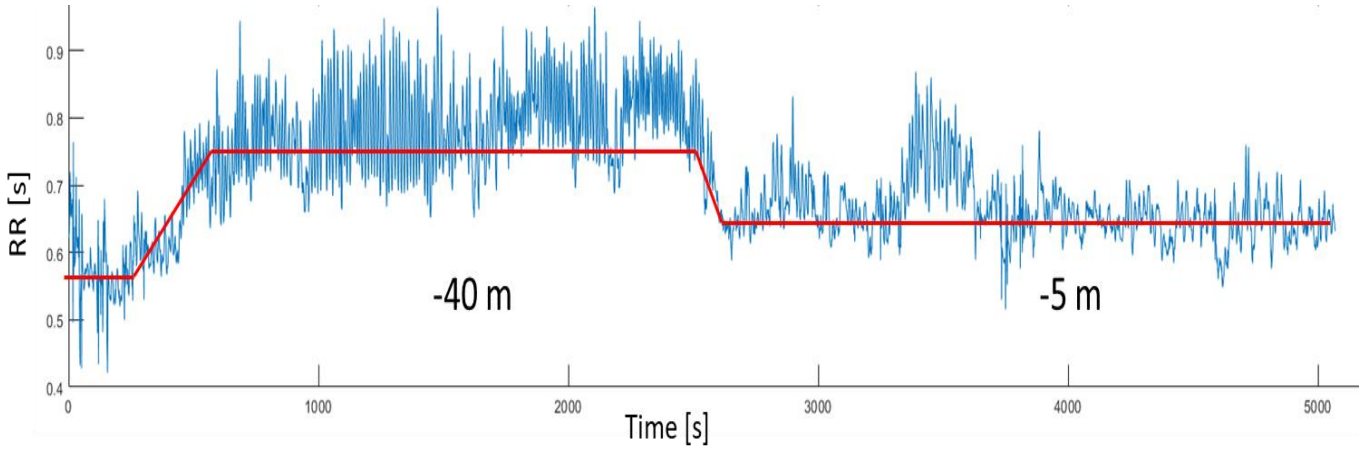
YEONSIK NOH,[1] JUSTIN R. BALES,[1] BERSAIN A. REYES,[1] JENNIFER MOLIGNANO,[2] AMANDA L. CLEMENT,[2] GEORGE D. PINS,[2] JOHN P. FLORIAN,[3] and KI H. CHON[1]



Montegrotto – aprile 2024







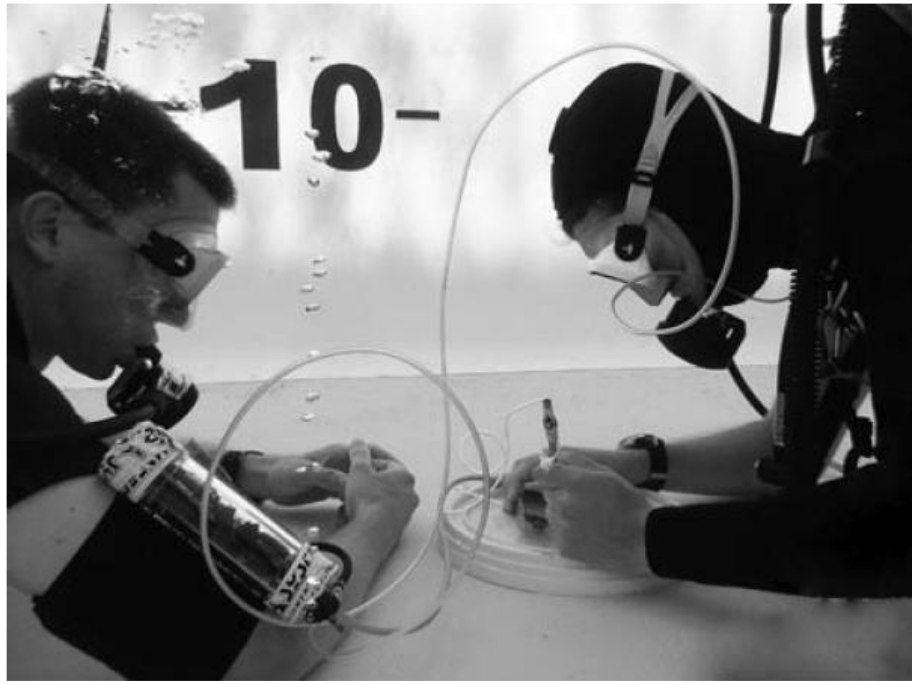
	Heart Rate [bpm] (% respect surface)		
	Surface	-30m	-40m
Sub 1	91.7	86.8 (-5.3%)	72.6 (-20.9%)
Sub 2	93.4	84.4 (-9.6%)	75.7 (-18.9%)
Sub 3	75.8	67.5 (-11.0%)	62.3 (-17.9%)

Misura della Pressione Arteriosa

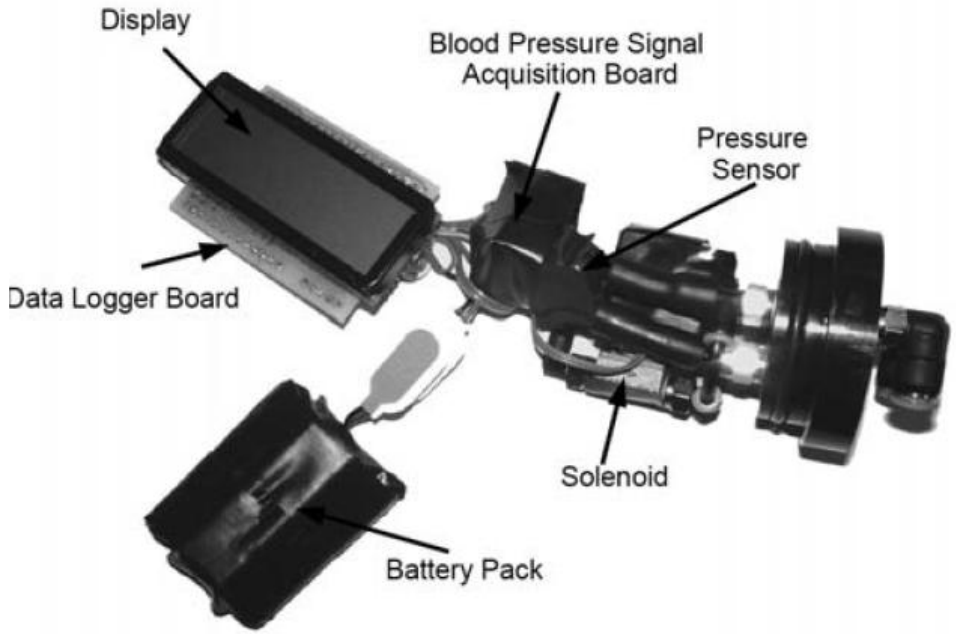
128 Diving and Hyperbaric Medicine Volume 38 No. 3 September 2008

An underwater blood pressure measuring device

Arne Sieber, Benjamin Kuch, Antonio L'Abbate, Matthias Wagner, Paolo Dario and Remo Bedini

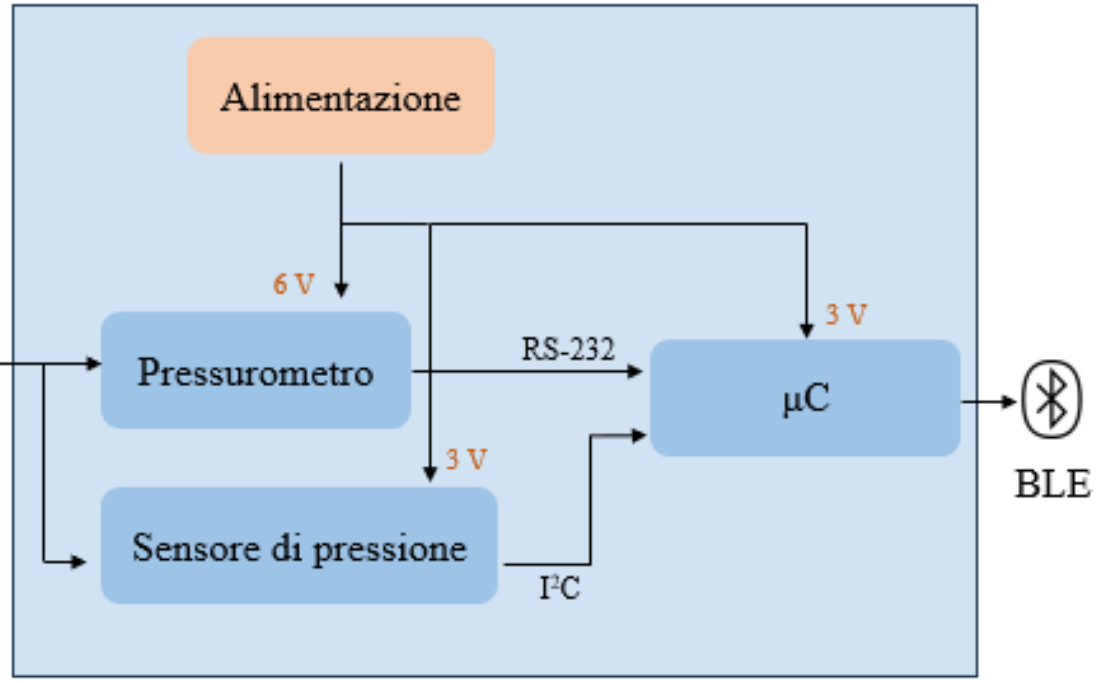


Prototype BP monitor dismantled to display its component parts



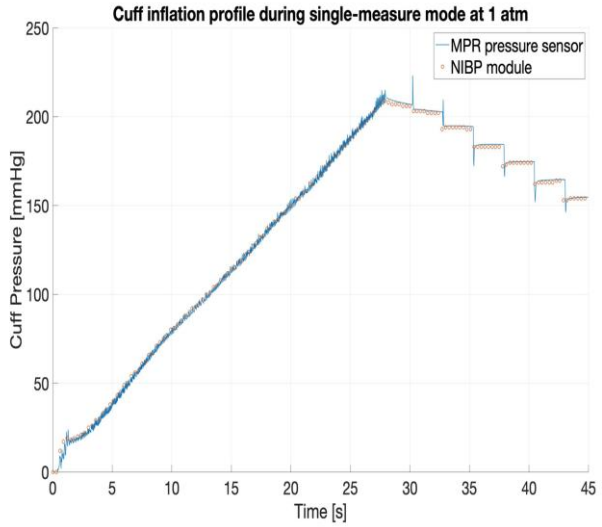
Misura della Pressione Arteriosa

Muta stagna

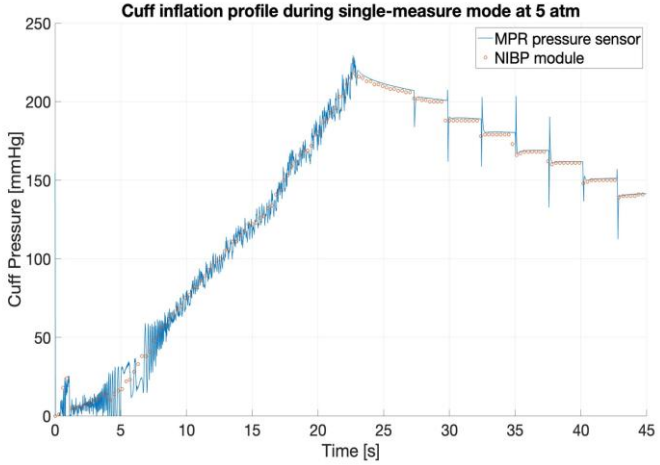


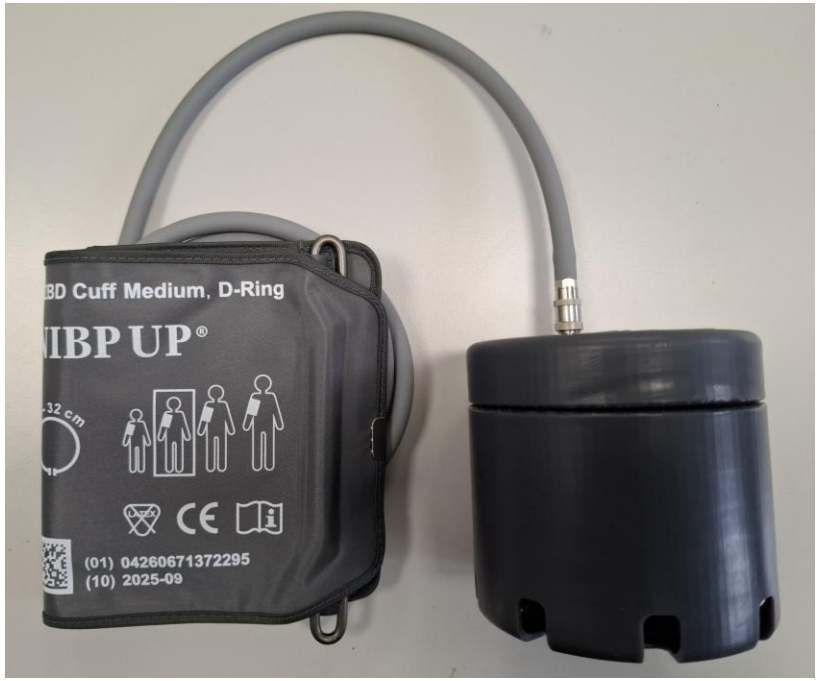
Misura della Pressione Arteriosa
validazione preliminare

1 atm (0 m)



5 atm (-40 m)





Credits: Giorgia Mangano, ISS - Univ. Campus Biomedico, 2025

Saturazione periferica do Ossigeno - Sp02

UHM 2019, VOL. 46 NO. 1 - PULSE OXIMETRY IN REBREATHER DIVING

RESEARCH ARTICLE

Pulse oximeter to detect peripheral oxygen saturation in underwater rebreather ECCR diver: a preliminary study

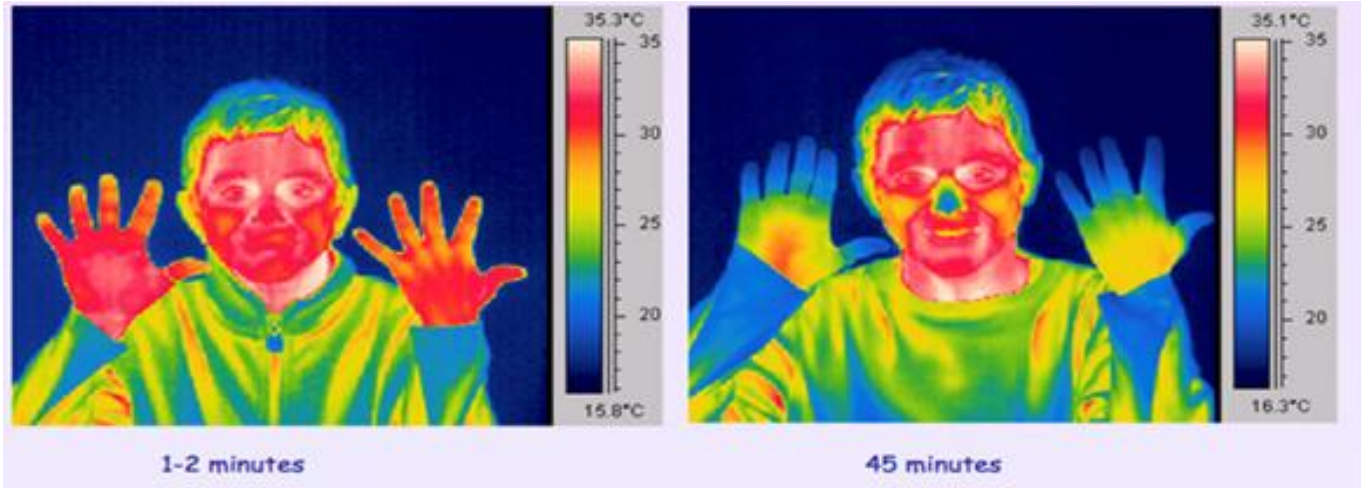
Fabio Di Pumpo, MD [1]; Giovanni Ruffino, MD [2]; Paolo Malacarne, MD [3]

[1] Italian Navy Medical Service Naval Academy, Livorno, Italy

[2] Italian Navy Medical Service COMSUBIN Varignano, Le Grazie, La Spezia, Italy

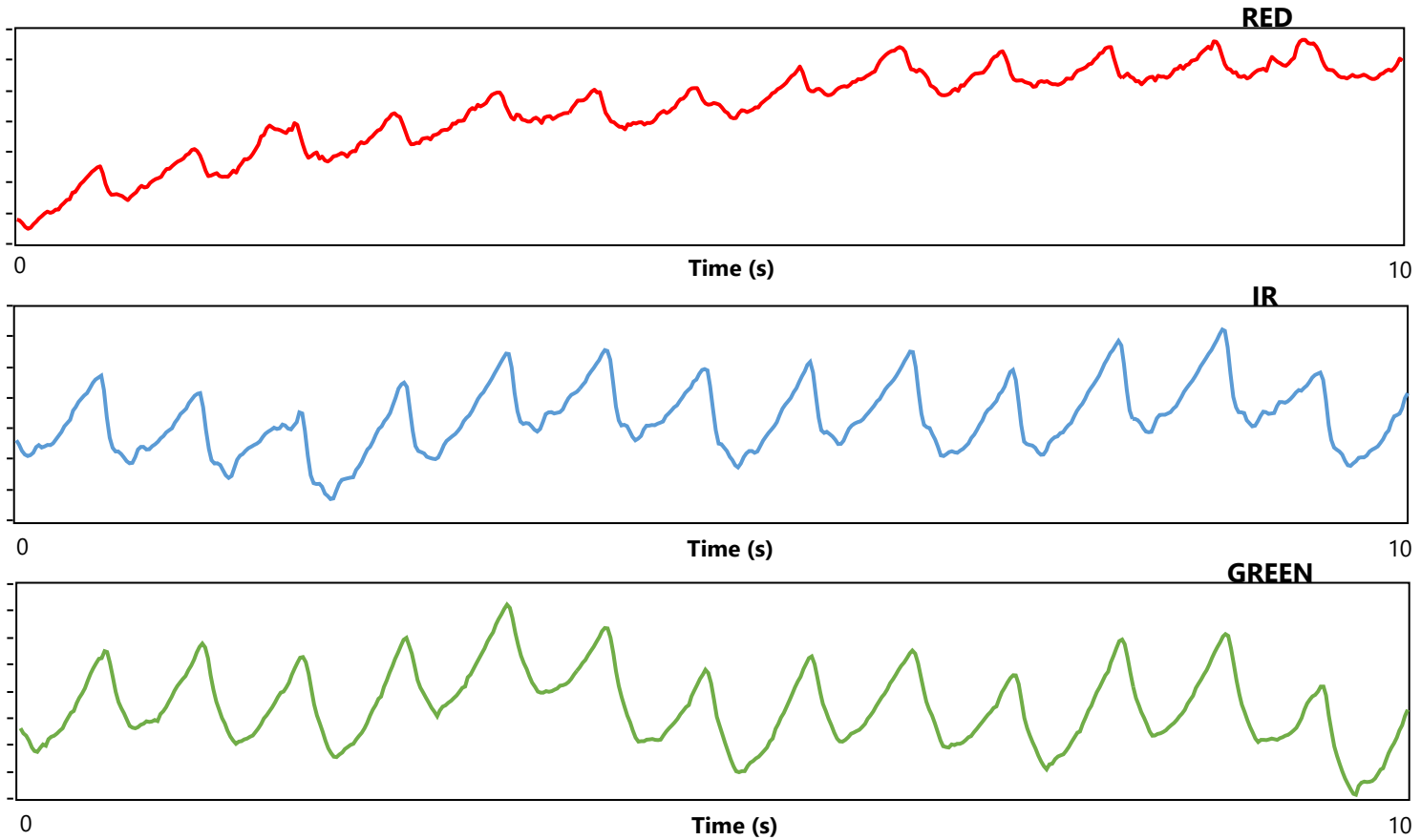
[3] Unit of Anesthesia and Resuscitation, Azienda Ospedaliero-Universitaria Pisana, Pisa, Italy

CORRESPONDING AUTHOR: Fabio Di Pumpo – *fabiodipumpo@gmail.com*



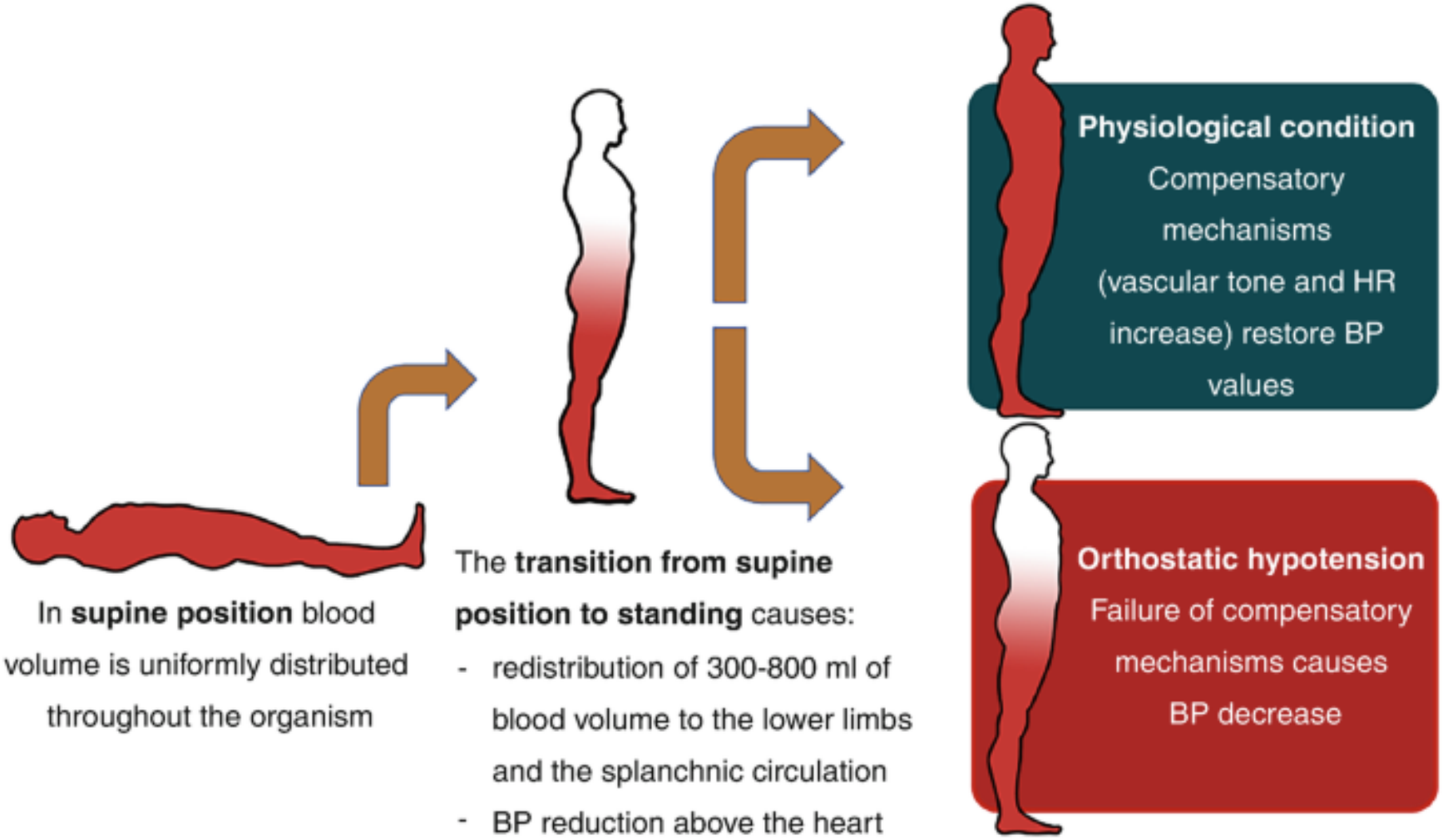
Bebout DE, Bednarski WL. Physiologic considerations in detection of hypoxemia during vasoconstriction: radial artery compared to various pulse oximeter sensor sites. *J Lung Pulm Respir Res.* 2017;4(4):124–128. DOI: 10.15406/jlprr.2017.04.00137

Sp02 – sensorized mouthpiece



Credits: Federica Ricci – ISS, Univ. di Roma 3.

Valutazione del Sistema Nervoso Autonomo

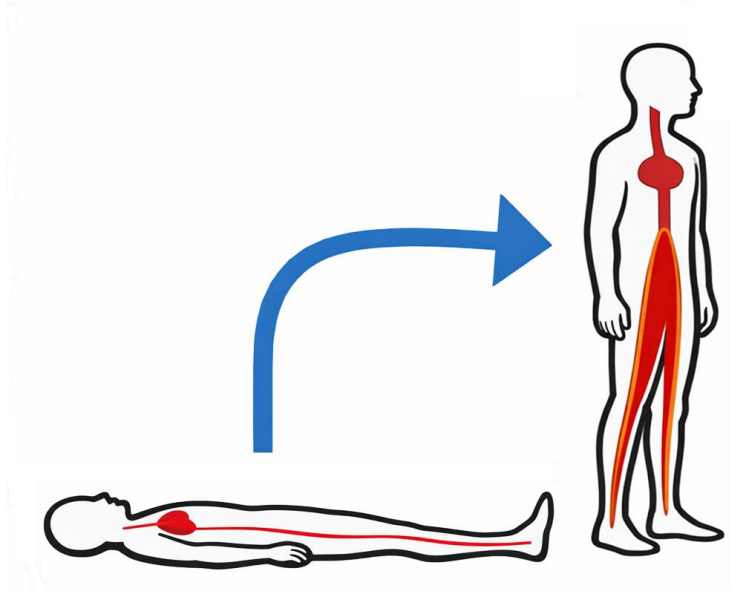


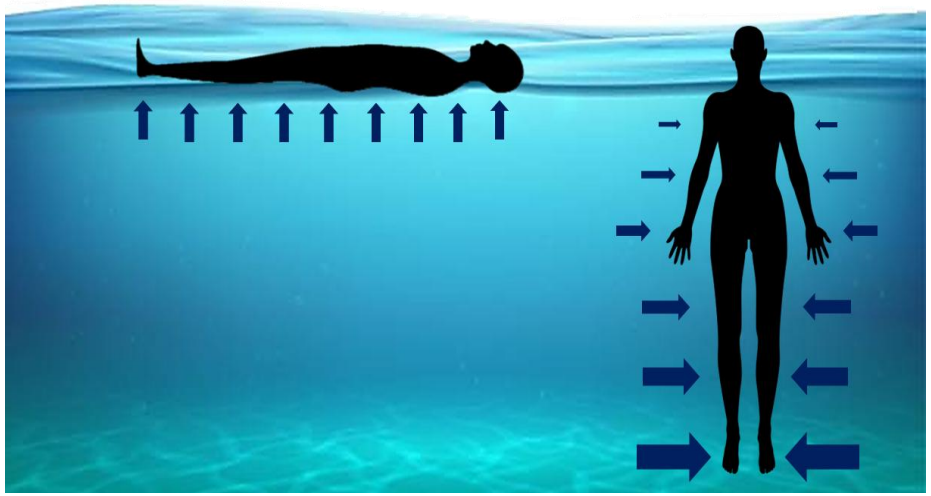
In **supine position** blood volume is uniformly distributed throughout the organism

The **transition from supine position to standing** causes:

- redistribution of 300-800 ml of blood volume to the lower limbs and the splanchnic circulation
- BP reduction above the heart

Valutazione del Sistema Nervoso Autonomo





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Gravitational venous pooling
500 – 1000 mL
splanchnic circulation >> lower limbs

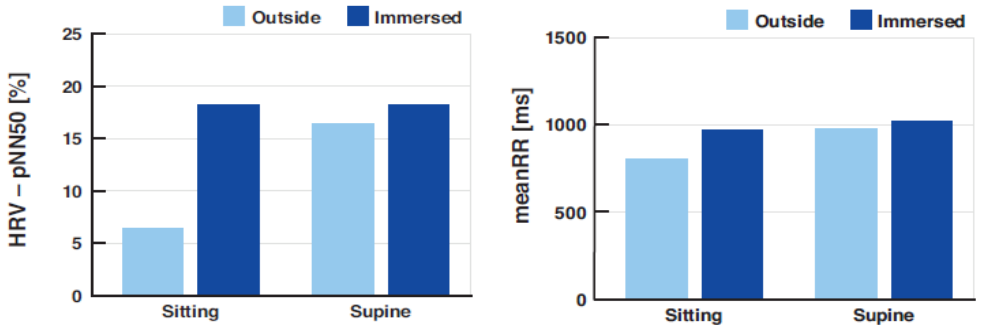
↓ Venous Return
↓ Cardiac Output

Baroreflex Response:
↑ Sympathetic tone
↓ Parasympathetic tone

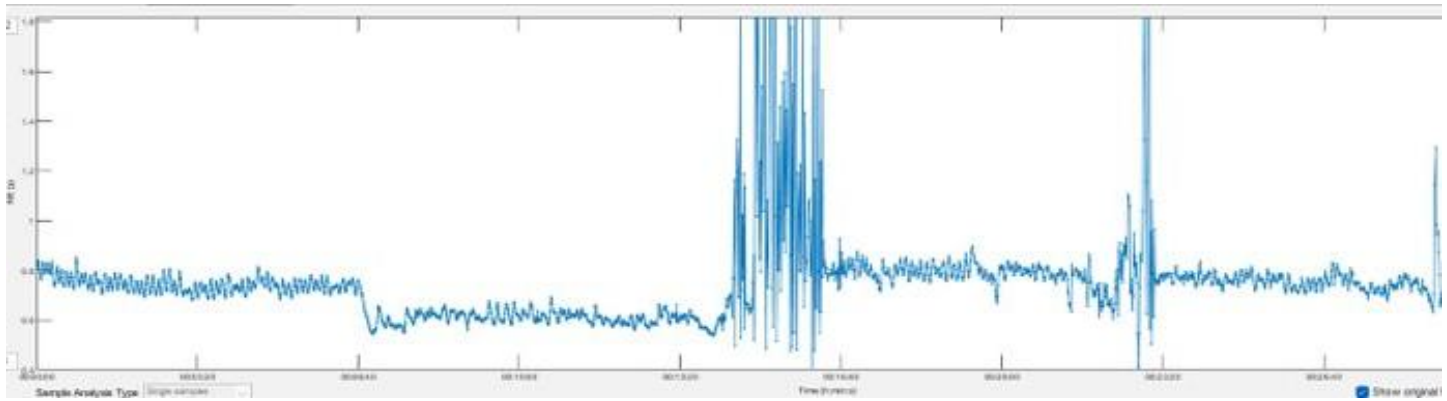
Cardiac output recovery
Vasoconstriction
Restoration of blood pressure

Valutazione del Sistema Nervoso Autonomo



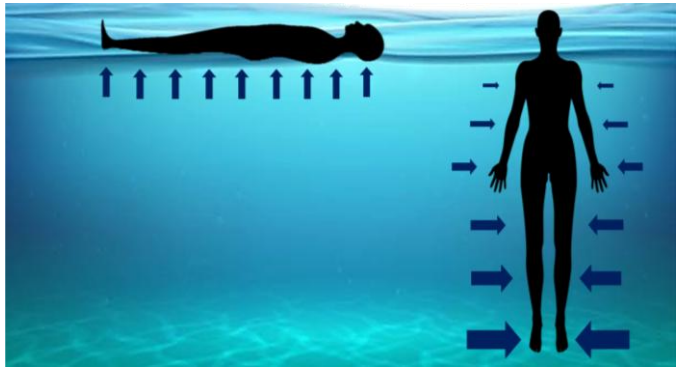
Gradl et al. Appl. Sci. **2017**



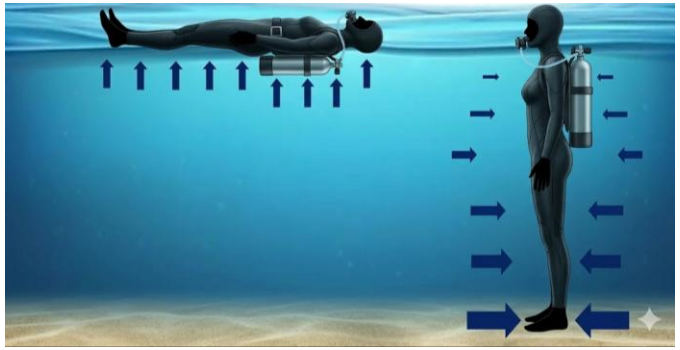
Supino (aria) in piedi (aria) supino (acqua) verticale (acqua)

F. Ricci, et al, GNB **2025**

Valutazione del Sistema Nervoso Autonomo



Muta umida



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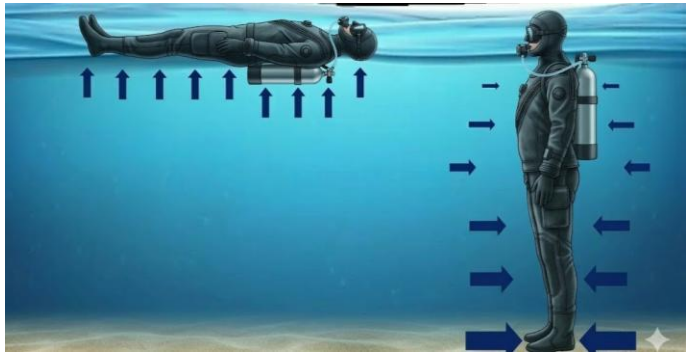
Muta stagna



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Grazie

Giovanni Calcagnini
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Eugenio Mattei
Federica Ricci
Cecilia Vivarelli