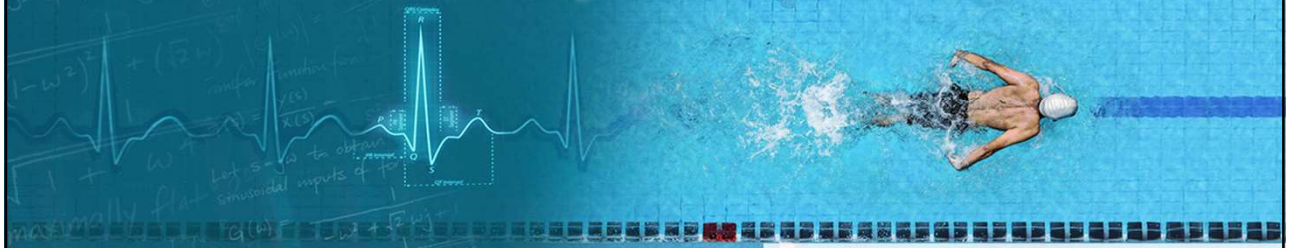
# XLII Annual School 2023
# The Bioengineering of Sport

## Cardiovascular Self Monitoring in Sport



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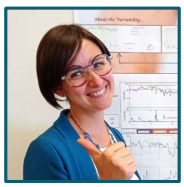
## Who and where?

Prof. Laura Burattini

Micaela Morettini, PhD

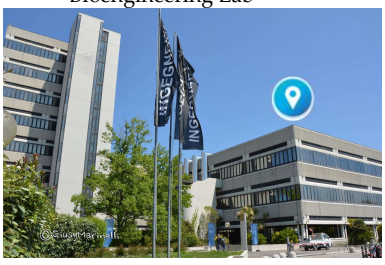


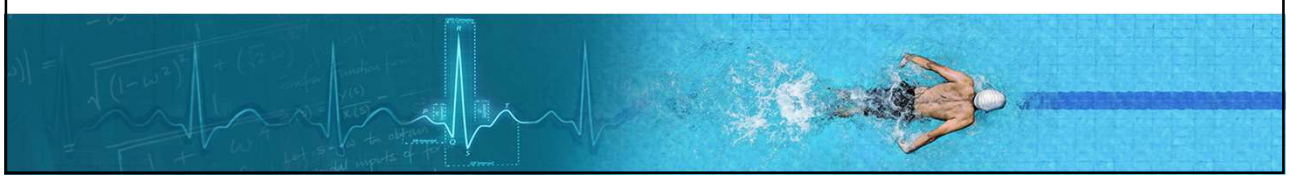
Agnese Sbrollini, PhD

Sofia Romagnoli

BR3IN
https://br3in.dii.univpm.it/

Cardiovascular
Bioengineering Lab





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# Why Self Monitoring?

Piermario Morosini
26 y

Vigor Bovolenta
38 y

Marc-Vivien Foé
28 y

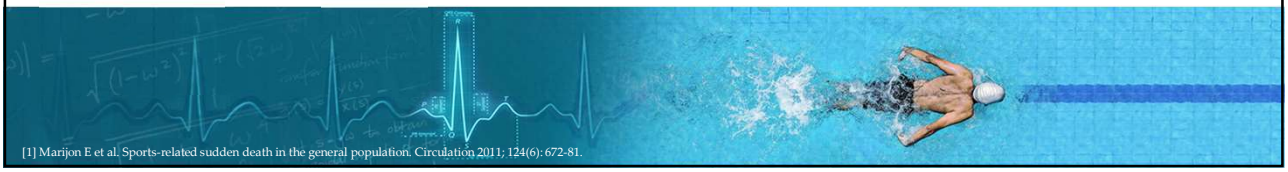
Alexander Dale Oen
27 y

***Sport-related sudden cardiac death (SrSCD):***

a death occurring during sport or within one hour of cessation of sport activity[1]

"Every year 1000 'under 35' lose their lives and one out of 100 teenagers is at risk"

Sic 2015 - Prof. Francesco Fedele



[1] Marijon E et al. Sports-related sudden death in the general population. Circulation 2011; 124(6): 672-81.

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# Why Self Monitoring?

**Prevention** remains the only weapon to contrast SrSCD.

The need to implement screening for athletes[1] is widely debated.

Pre-participation screening includes[2]:

- clinical history
- family history
- physical examination
- rest 12-lead electrocardiographic test
- stress 12-lead electrocardiographic test

Athletes screening includes[3]:

- clinical history
- family history
- physical examination
- rest 12-lead electrocardiographic test
- stress 12-lead electrocardiographic test
- specific tests


[1] Sharma S et al. Clinical decisions. Cardiac screening before participation in sports. N Engl. J. Med., vol. 369, no. 21, pp. 2049-2053, 2013.
[2] De Innocentiis C et al. Athlete's heart: Diagnostic challenges and future perspectives, Sports Med., vol. 48, no. 11, pp. 2463-2477, 2018.
[3] Sen-Chowdhry S et al. Sudden cardiac death in the young: a strategy for prevention by targeted evaluation, Cardiology, vol. 105, no. 4, pp. 196-206, 2006.

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# Why Self Monitoring?

**Prevention** remains the only weapon to contrast SrSCD.

YOUNG ATHLETES & HEART HEALTH

Unfortunately:

- ✓ Some causes are not detectable by ECG
- ✓ Screening is mandatory only for competitive athletes
- ✓ Clinics cannot manage a massive screening
- ✓ Athletes should be screened INTO THE FIELD

↓

SUPPORT THE SELF-MONITORING

[1] Sharma S et al. Clinical decisions. Cardiac screening before participation in sports. N Engl. J. Med., vol. 369, no. 21, pp. 2049-2053, 2013.
[2] De Innocentiis C et al. Athlete's heart: Diagnostic challenges and future perspectives, Sports Med., vol. 48, no. 11, pp. 2463-2477, 2018.
[3] Sen-Chowdhry S et al. Sudden cardiac death in the young: a strategy for prevention by targeted evaluation, Cardiology, vol. 105, no. 4, pp. 196-206, 2006.

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# But athletes are strange animals!

**Athletes do not like to be monitored:**

**1 - Sport is synonymous of health!**

**2 - Athletes look at performance**

**3 - Resting… is never resting!**

**4 – Athletes or not athletes?**

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# We have wearable sensors





Wearable devices for cardiac monitoring have become increasingly popular[1]!!!

Wearable devices are designed to be worn on different body locations for noninvasive sensing of an individual's parameters without interrupting or restricting the user's movements.

Electrocardiography (ECG) and heart rate (HR) are the main signals used to evaluate cardiac status during sport[2].

Wearable devices were the top trend in an electronic survey of health and fitness trends by ACSM's Health & Fitness Journal for 2022, and they have been estimated to be a $100 billion industry in the US[3].

[1] Romagnoli S at al. Wearable and Portable Devices for Acquisition of Cardiac Signals while Practicing Sport: A Scoping Review. Sensors 2023, 23, 3350.
[2] Sun, W. et al A review of recent advances in vital signals monitoring of sports and health via flexible wearable sensors. Sensors 2022, 22, 7784.
[3] Thompson W.R. Worldwide survey of fitness trends for 2022. ACSM'S Health Fit. J., 2022, 26, 11–20.

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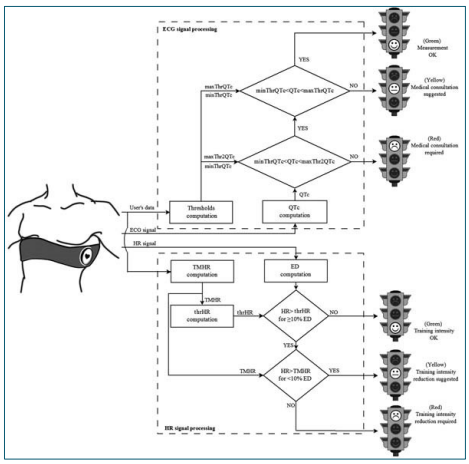
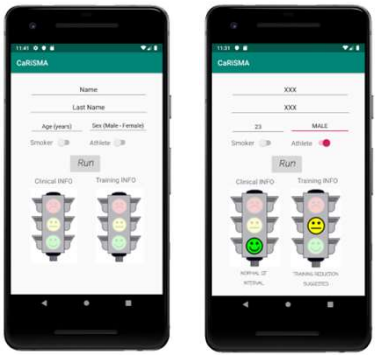
# CaRiSMA 1.0: Cardiac Risk Self-Monitoring Assessment




CaRiSMA 1.0 is an application for self-monitoring of cardiac health. While training, the user wears a sensor able to record the ECG signal and, eventually, the HR signal.

[1] Agostinelli A. et al. "CaRiSMA 1.0: cardiac risk self-monitoring assessment", Open Sports Sci. J., vol. 10, pp. 179-190, 2017.

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# CaRiSMA: Measurement Protocol

To use CaRiSMA 1.0, cardiac data should be acquired according to the following protocol:

**Step 1**: Position and start the wearable sensor.

**Step 2**: Remain in resting conditions (sitting or lying) for at least 5 minutes.

**Step 3**: Exercise; exercise duration (ED) is free.

**Step 4**: Acquire cardiac data while recovering for at least 5 minutes.

**Step 5**: Take off the sensor and download data.

**Step 6**: Run CaRiSMA 1.0.

[1] Agostinelli A. et al. "CaRiSMA 1.0: cardiac risk self-monitoring assessment", Open Sports Sci. J., vol. 10, pp. 179-190, 2017.

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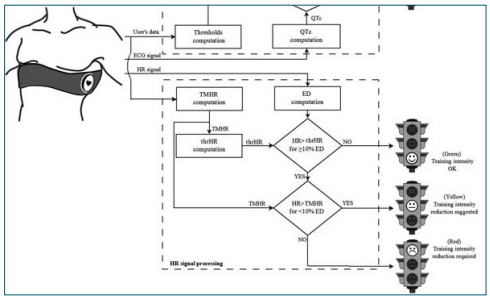
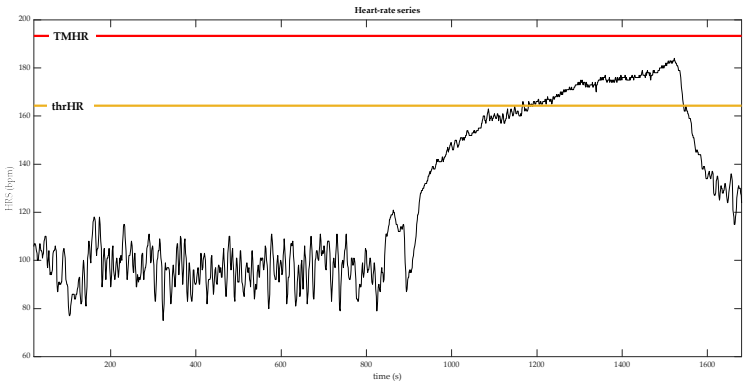
# CaRiSMA: Heart-Rate Traffic Light




$$\begin{cases} TMHR = 208 - 0.7 \cdot age & \text{if not smoker} \\ TMHR = 208 - 0.7 \cdot age - 7 & \text{if smoker} \end{cases}$$

$$thrHR = 0.85 \cdot TMHR$$

[1] Agostinelli A. et al. "CaRiSMA 1.0: cardiac risk self-monitoring assessment", Open Sports Sci. J., vol. 10, pp. 179-190, 2017.
[2] Papathanasiou G et al. Effects of smoking on heart rate at rest and during exercise and on heart rate recovery, in young adults. Hellenic J Cardiol 2013; 54(3): 168-77.
[3] Atwal S et al. Cardiovascular effects of strenuous exercise in adult recreational hockey: the Hockey Heart Study. CMAJ 2002; 166(3): 303-7.
[4] Sperlich B, Holmberg HC. Wearable, yes, but able, but able? It is time for evidence-based marketing claims Br J Sports Med 2017; 51(16): 1240.

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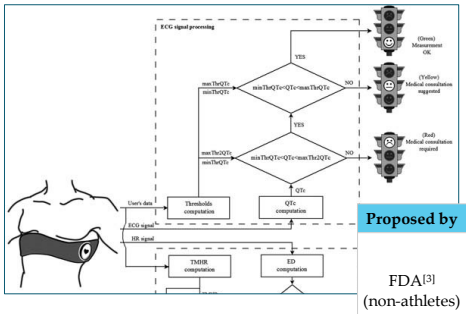
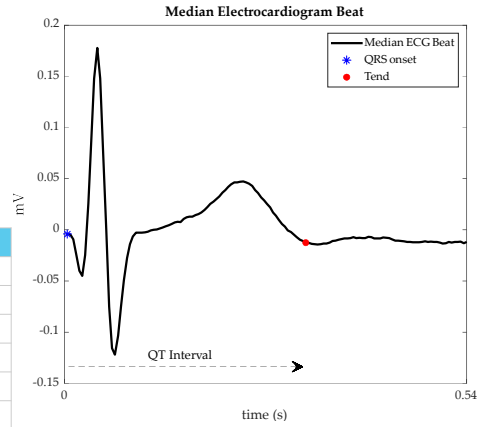
# CaRiSMA: QTc Traffic Light




$$QTc = \frac{QT}{\sqrt{RR}}$$

| Proposed by | QTc (ms) | Male | Female |
|---|---|---|---|
| FDA[3] (non-athletes) | Long QT | >450 | >460 |
| | Possible Long QT | 431-450 | 451-460 |
| | Normal | 390-430 | 390-450 |
| | Short QT | <390 | <390 |
| Seattle Criteria[4] (athletes) | Long QT | >499 | >499 |
| | Possible Long QT | 470-499 | 480-499 |
| | Normal | 321-469 | 321-479 |
| | Short QT | <321 | <321 |




[1] Agostinelli A. et al. "CaRiSMA 1.0: cardiac risk self-monitoring assessment", Open Sports Sci. J., vol. 10, pp. 179-190, 2017.
[2] Bazett HC. An analysis of time relations of the electrocardiogram. Heart 1920; 7: 353-70.
[3] Rautaharju PM et al. AHA/ACCF/HRS recommendations for the standardization and interpretation of the electrocardiogram: part IV: the ST segment, T and U waves, and the QT interval: a scientific statement from the American Heart Association Electrocardiography and Arrhythmias Committee, Council on Clinical Cardiology; the American College of Cardiology Foundation; and the Heart Rhythm Society. J Am Coll Cardiol 2009; 53(11): 982-91.
[4] Drezner JA, Ackerman MJ, Anderson J, et al. Electrocardiographic interpretation in athletes: the 'Seattle criteria'. Br J Sports Med 2013; 47(3): 122-4.

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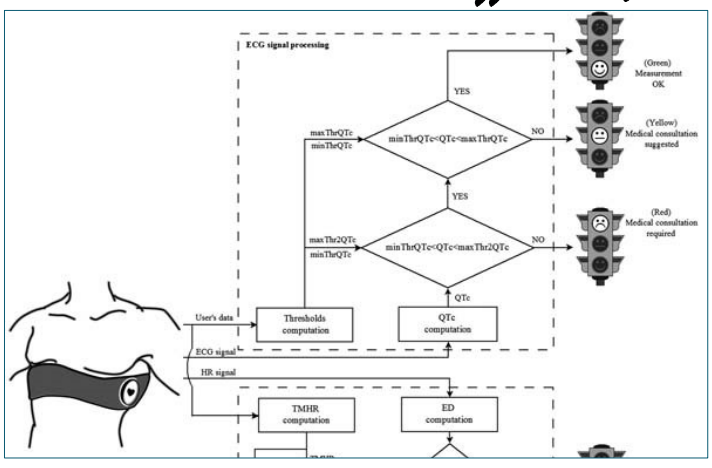
# CaRiSMA: QTc Traffic Light




## QTc[2] traffic light is a measure of cardiac risk!

$$minThrQTc = \begin{cases} 390\ ms & \text{for non - athlete males} \\ 390\ ms & \text{for non - athlete females} \\ 321\ ms & \text{for athlete males} \\ 321\ ms & \text{for athlete females} \end{cases}$$

$$maxThrQTc = \begin{cases} 430\ ms & \text{for non - athlete male} \\ 450\ ms & \text{for non - athlete females} \\ 469\ ms & \text{for athlete males} \\ 479\ ms & \text{for non - athlete males} \end{cases}$$

$$maxThr2QTc = \begin{cases} 450\ ms & \text{for non - athelete males} \\ 460\ ms & \text{for non - athelete females} \\ 499\ ms & \text{for athelete males} \\ 499\ ms & \text{for athelete females} \end{cases}$$

[1] Agostinelli A. et al. "CaRiSMA 1.0: cardiac risk self-monitoring assessment", Open Sports Sci. J., vol. 10, pp. 179-190, 2017.
[2] Bazett HC. An analysis of time relations of the electrocardiogram. Heart 1920; 7: 353-70.
[3] Rautaharju PM et al. AHA/ACCF/HRS recommendations for the standardization and interpretation of the electrocardiogram: part IV: the ST segment, T and U waves, and the QT interval: a scientific statement from the American Heart Association Electrocardiography and Arrhythmias Committee, Council on Clinical Cardiology; the American College of Cardiology Foundation; and the Heart Rhythm Society. J Am Coll Cardiol 2009; 53(11): 982-91.
[4] Drezner JA, Ackerman MJ, Anderson J, et al. Electrocardiographic interpretation in athletes: the 'Seattle criteria'. Br J Sports Med 2013; 47(3): 122-4.

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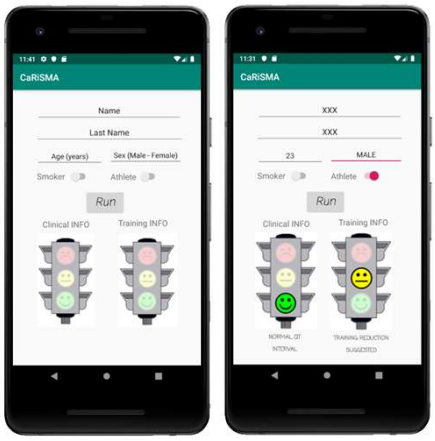
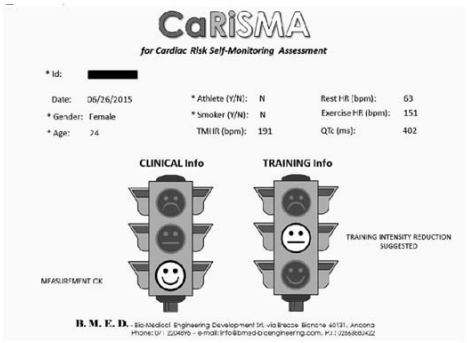
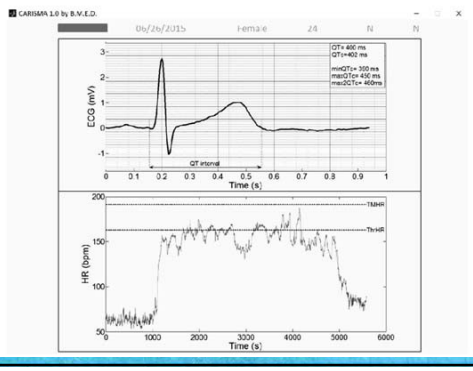
# CaRiSMA Output



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# From CaRiSMA...


Data in brief 27 (2019) 104793

Contents lists available at ScienceDirect

Data in brief

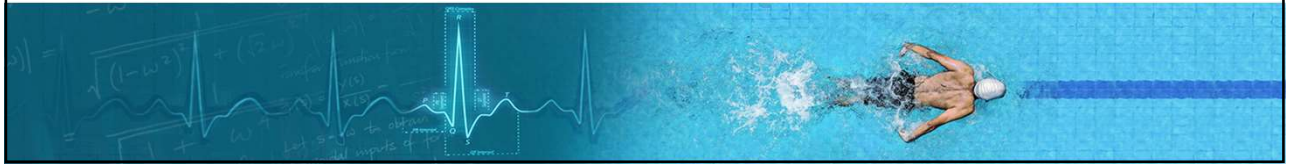
journal homepage: www.elsevier.com/locate/dib

Data Article

Sport Database: Cardiorespiratory data acquired through wearable sensors while practicing sports

Agnese Sbrollini [a], Micaela Morettini [a], Elvira Maranesi [b], Ilaria Marcantoni [a], Amnah Nasim [a], Roberta Bevilacqua [c], Giovanni R. Riccardi [b], Laura Burattini [a,*]

Sport Database includes 126 cardiorespiratory datasets from 81 subjects while performing 10 different sports!



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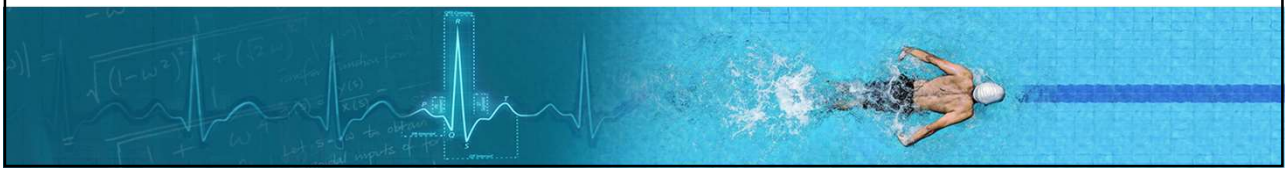
Sport Database includes 126 cardiorespiratory datasets from 81 subjects while performing 10 different sports!

- 1/81 of Atrial Fibrillation!
- 1/81 of Short QT interval!



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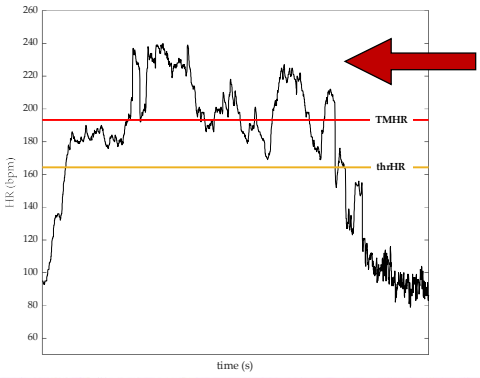


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Sport Database includes 126 cardiorespiratory datasets from 81 subjects while performing 10 different sports!

**Sport DB 2.0: a New Database of Data Acquired by Wearable and Portable Devices while Practicing Sport**

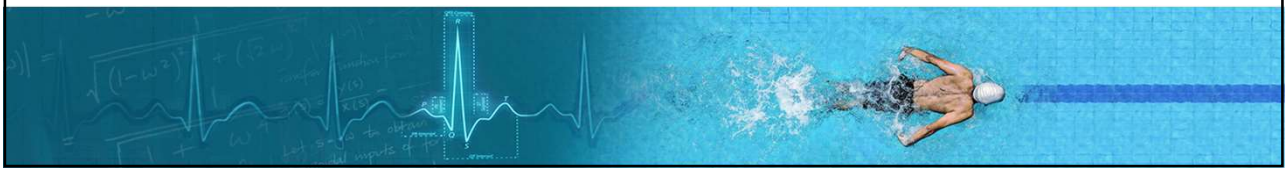
Sofia Romagnoli[1], Agnese Sbrollini[1], Antonio Nocera[1], Micaela Morettini[1], Ennio Gambi[1], Danilo Bondi[2], Tiziana Pietrangelo[2], Vittore Verratti[2], Laura Burattini[1, *]

[1]Università Politecnica delle Marche, Ancona, Italy
[2]Università degli studi 'G. d'Annunzio', Chieti-Pescara, Italy

**Abstract**

*Sport DB 2.0 is a collection of 156 cardiorespiratory datasets, acquired through wearable sensors and portable devices from 130 subjects while practicing 11 different sports during training and competition. Each dataset consists of demographic data (sex, age, weight, height,* and the breathing rate (BR) series. Consequently, research activity on data acquired by wearable and portable devices may provide some insights into athletes' health.

In 2019, Sbrollini et al. [1] published Sport Database, a collection of cardiorespiratory data acquired through the chest band BioHarness 3.0 by Zephyr while practicing sports. Sport Database includes 126 cardiorespiratory



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# Hands-on on «Cardiovascular Self Monitoring in Sport»

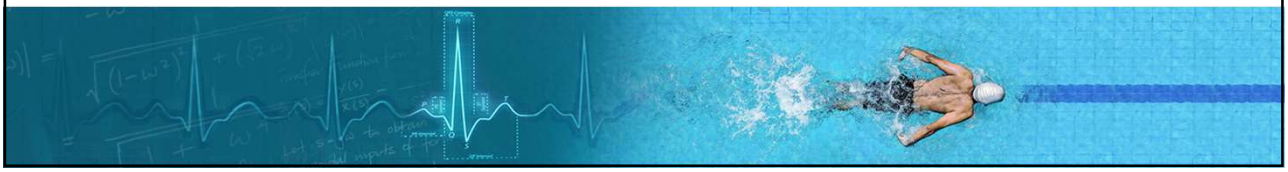
**Preamble**

The assignment consists of processing cardiac signals (heart-rate series and electrocardiogram) acquired by using wearable sensors. The aim is to characterize the cardiac status of the subjects, proving a cardiac risk assessment.
The group will provide the main indices for the assessment of cardiovascular risk.
The total score is 10.

Data were acquired from two subjects, which anamnestic and training info are reported in the following table:

| Subjects | Sport | Anamnestic Data | | | | Training Info | | |
|---|---|---|---|---|---|---|---|---|
| | | Age | Sex | Smoker | Athlete | Resting Duration | Exercise Duration | Recovery Duration |
| #1 | Basketball | 22 | Male | Yes | Yes | 5'53'' | 1h28'3'' | 0'' |
| #2 | Tennis | 56 | Male | No | No | 14'32'' | 46'58'' | 4'52'' |

Data consist of the simultaneously acquired cardiac signals by BioHarness 3.0 of Zephyr. Heart-rate series (sampling frequency of 1Hz, measured in bpm) and electrocardiogram (sampling frequency of 250Hz, measured in mV) are stored in a MATLAB structure. The file "**CardiovascularSelfMonitoringInSport**.m" represents a code template for analysis.



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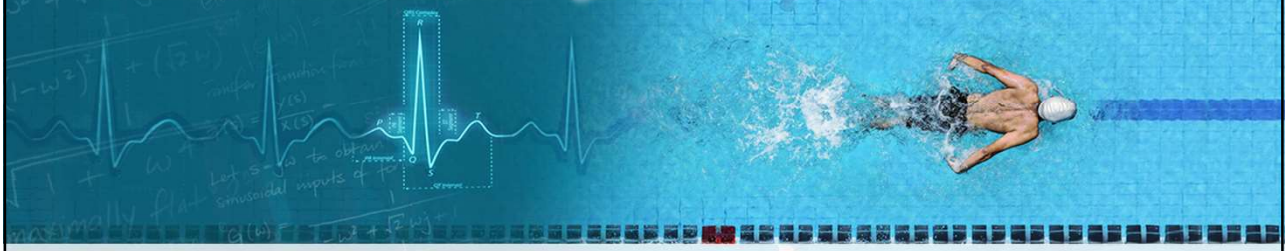
# Cardiovascular Self Monitoring in Sport



Thanks for the Attention!
Questions?

**Agnese Sbrollini**, PhD
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Department of Information Engineering,
Università Politecnica delle Marche

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