Electrocardiography (ECG) during Exercise

Technical Note

TN 04102018

PHYSICAL ACTIVITY | TASK DESCRIPTION

One of the applications of the ECG sensor is to measure the activity of the heart during physical activity. In this experiment the subject performed an intensive exercise on an ergometer during a 10 minutes acquisition.

During the first minute, the subject was in a resting state. After this period, the subject has progressively increased his effort until he reached the maximum effort between minutes 4 and 5, resting during the last 2 minutes and half.

SIGNAL CHARACTERISTICS

Typical Frequency Band:

- 0.5 to 100 Hz [Recommended]

SENSOR AND HARDWARE DESCRIPTION

There were used gelled self-adhesive disposable Ag/AgCl electrodes together with a single-lead local differential bipolar ECG sensor (*Fig. 1*).

SUBJECT DESCRIPTION

A 26-year-old male subject with no reported heart conditions (height: 1.81 m; weight: 71 kg - *Fig. 2*).

PROTOCOL OF ACQUISITION

Steps enumeration:

1. Prepare the skin:
   a. Use a razor to remove any hair from the skin where the electrodes will be placed;
   b. Afterwards, rub the surface of the skin with an abrasive material;
   c. Remove any dirtiness and fat from the skin surface with alcohol.

2. Place the electrodes in the V2 configuration of the 12-Lead ECG scheme (*Fig. 3* and *Fig. 4*):
   a. Positive electrode under the left nipple, near the interception of the 4th rib with the sternum;
   b. Negative electrode over the left nipple, near the interception of the 4th rib with the sternum.

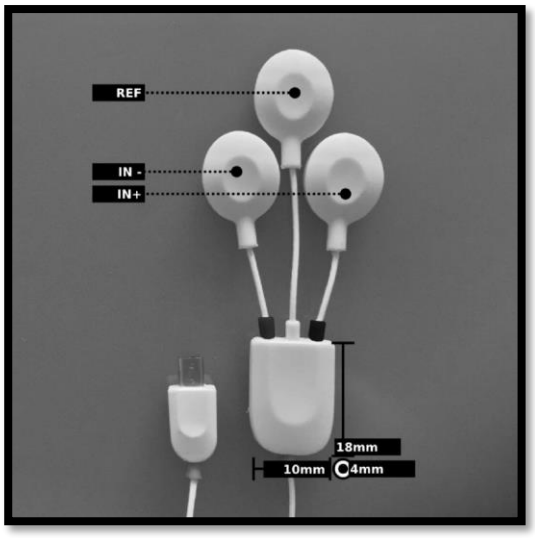

Fig. 1. Sensor Overview

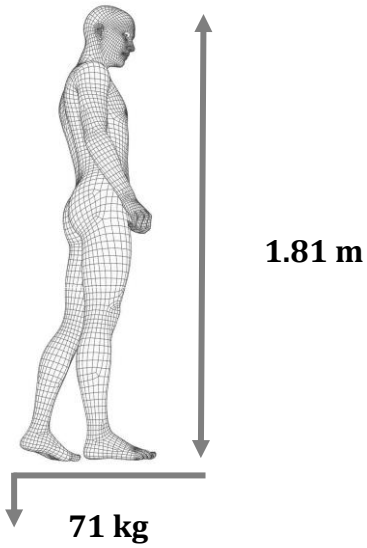

Fig. 2. Anthropometric Measures

PLUX – Wireless Biosignals, S.A.
Av. 5 de Outubro, n. 70 – 8.
1050-059 Lisbon, Portugal
plux@plux.info
http://biosignalsplux.com/

REV A

3. Place the ground in a surface bone, like the ankle, the clavicle, or the sternum (*Fig. 4*);
4. Sit the subject on the ergometer and let him rest for around 1 minute and half;
5. Ask the subject to simulate cycling, increasing the effort every minute and half;
6. After minute 6 the cycling effort should decrease gradually;
7. The volunteer should stop the exercise near 7m30s instant;
8. Start the recovery phase (while in rest) during the remaining time.

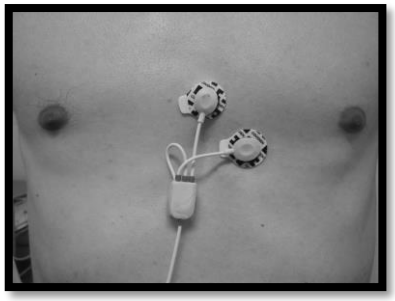

Fig. 3. Sensor Placement (V2 configuration)

Fig. 4. Ground Electrode Placement (ankle)

NOISE EVALUATION PROCEDURE

Signal to Noise Ratio (SNR) is an important metric that classifies objectively the quality of the acquisition, and like the name suggests the relation between the intensity of the signal and the undesired noise in the acquired data ($acquired$), which is defined by:

$$SNR = \frac{V_{pp}^{signal}}{V_{pp}^{noise}} \quad \textbf{(1)}$$

being V_{pp}^{signal} and V_{pp}^{noise} the peak-to-peak amplitude of the $signal$ and $noise$ component, respectively.

SNR Estimate [Complete Acquisition]

To infer noise presence on the ECG signal, the signal-to-noise ratio (SNR) should be calculated with the following approach:

1) Measure the Peak to Peak Amplitude of the signal (V_{pp}^{signal});

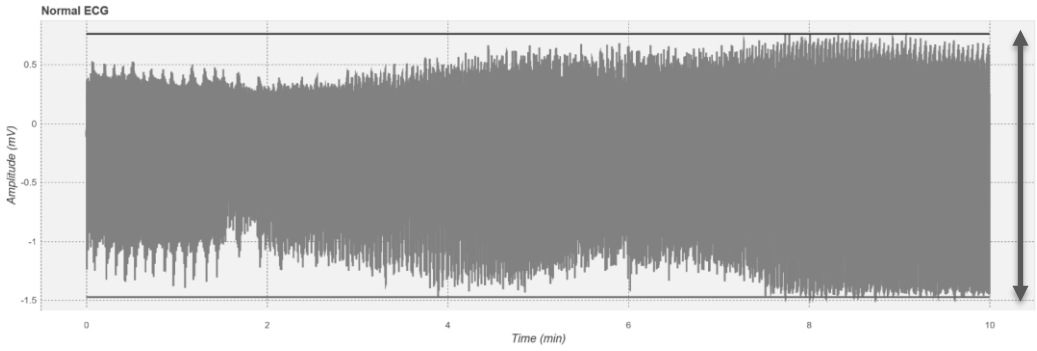

Fig. 5. ECG signal defining graphically the peak to peak amplitude (V_{pp}^{signal})

2) Measure the average peak-to-peak amplitude (V_{pp}^{noise}) from all the areas where there is no presence of ECG signal (*Fig. 6*);

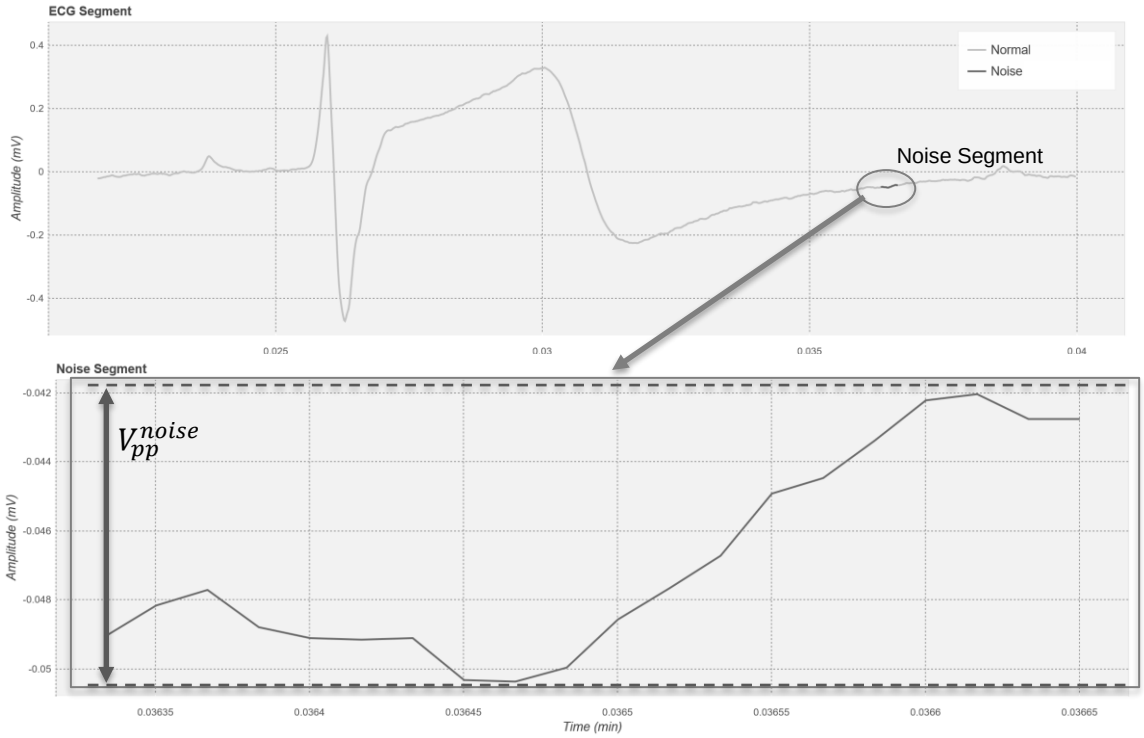

Fig. 6. An example of peak to peak amplitude (V_{pp}^{noise}) on a noise segment

3) Calculate an estimate of SNR using the following formula:

$$SNR_{dB} = 20\ log_{10}\left(\frac{V_{pp}^{signal}}{V_{pp}^{noise}}\right) \quad \textbf{(2)}$$

Rest Conditions

For a parallel acquisition (stage of rest before exercise), instead of being used all the available cardiac cycles we assumed that one of them are sufficiently representative to achieve a reasonable SNR estimate.

The determined value was approximately **41 *dB***.

Increased Effort Conditions

A similar approach was used to calculate the SNR during effort. In figure (*Fig. 5*) the whole recording is shown.

However, in this case, to assess the SNR during the exercise, three different representative moments were picked, right after the start, at the 5 minutes mark, and near the end of the 10 minutes (*Fig. 7*).

The formula describe before was applied to each segment, resulting in the following SNRs

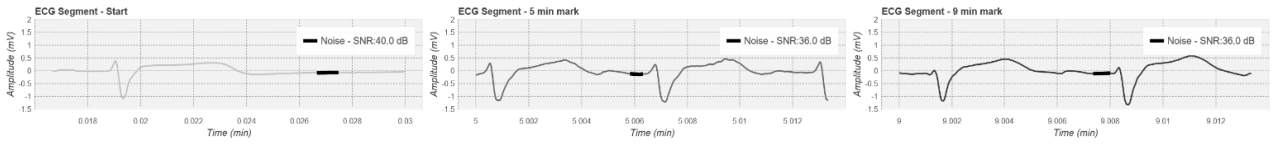

Fig. 7. ECG signal segments (800 ms) from each one of the three stages of the trial, highlining the noise region

Segment	*Start*	*5 min Mark*	*10 min Mark*
SNR	40 dB	36 dB	36 dB

Although there is a slight decrease in the ratio, it is still possible to collect the ECG, even in conditions where major movements occur.

HEART BEAT ANALYSIS

To get the heart rate, the Pan and Thompkins algorithm for R Peak detection was used.

Afterwards, a rolling mean of 40 points was performed to easily assess the influence of the test on the subject's heart rate (*Fig. 8*).

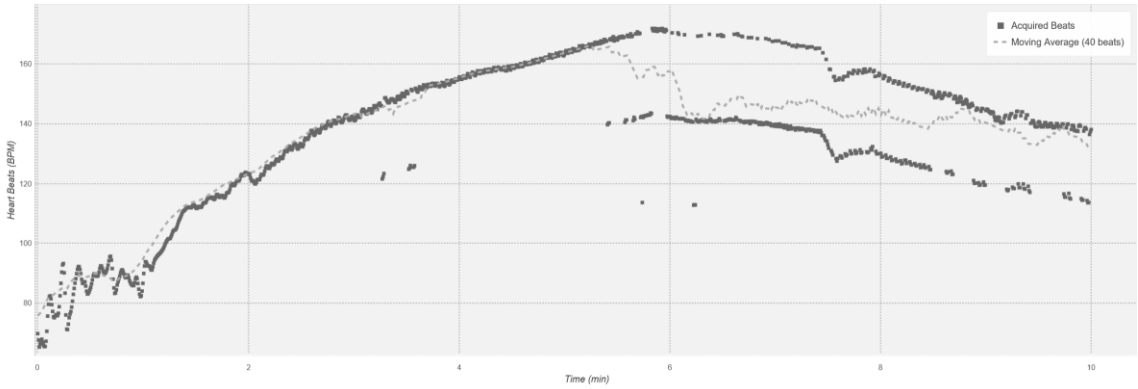

Fig. 8. Evolution of heart rate and representation of the average values during the cycling protocol

As expected, there is a progressive increase of the heart rate during the test.