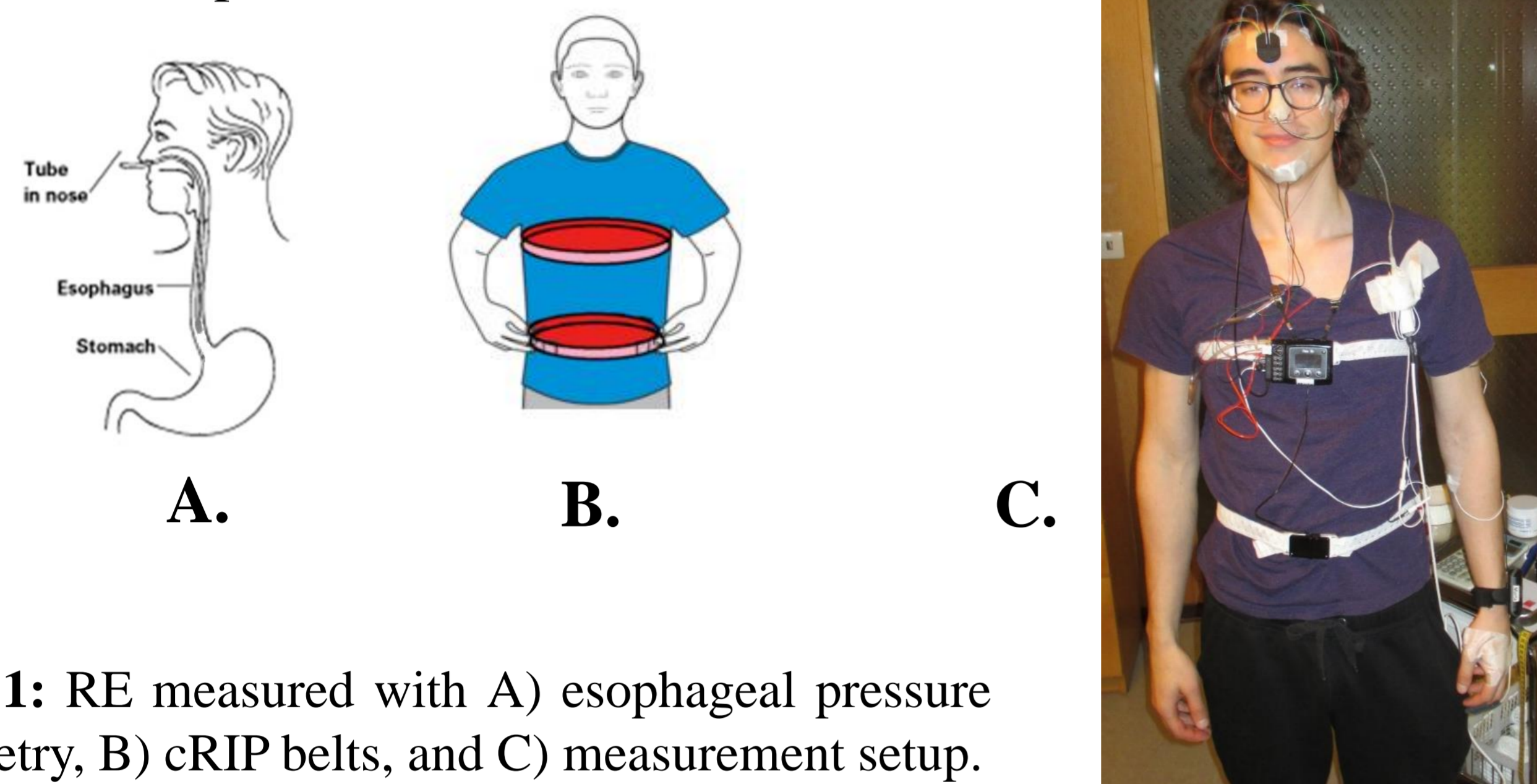


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## Introduction and Purpose

Esophageal pressure manometry (Pes) is the gold standard method to measure respiratory effort (RE) during sleep. Due to the discomfort of the Pes measurement, a novel non-invasive method to assess RE was evaluated. The breathing movements of thorax and abdomen were measured with calibrated respiratory inductance plethysmography (cRIP) belts. The measured movements were divided into breathing and non-breathing components. By analyzing the movement components the RE was estimated.



**Figure 1:** RE measured with A) esophageal pressure manometry, B) cRIP belts, and C) measurement setup.

## Methods

**Procedure:** Thirty subjects underwent nocturnal home polysomnography (A1 device, Nox Medical ehf., Iceland) with simultaneous Pes (Catheter Tip Transducer, Gaeltec Devices Ltd, Scotland) measurement. All measurements were scored according to AASM rules version 2.1.

**Data analysis:** The first four subjects (2 males and 2 females, mean  $\pm$  standard deviation; BMI =  $34.1 \pm 10.8$ , age =  $37.8 \pm 8.7$ , AHI =  $7.5 \pm 7.1$ ) were scored for Pes and cRIP events.

**Pes signal** Pes events were manually scored applying the following criteria: Pes crescendo (Pesces)  $\leq 60$ sec and Pes sustained (Pessus)  $> 60$ sec. [1]  
**cRIP parameters** The breathing movement can be divided into two components, i.e. a breathing component and a non-breathing component. The non-breathing component is caused by the patient overcoming an obstruction in the airway, i.e. paradoxical breathing. The novel parameters are defined as

- cRIP-1: The breathing and non-breathing components represent the patients drive to breath.
- cRIP-2: The ratio between the non-breathing component and the breathing movement. This represents the ratio of the movement lost to overcome an obstruction.

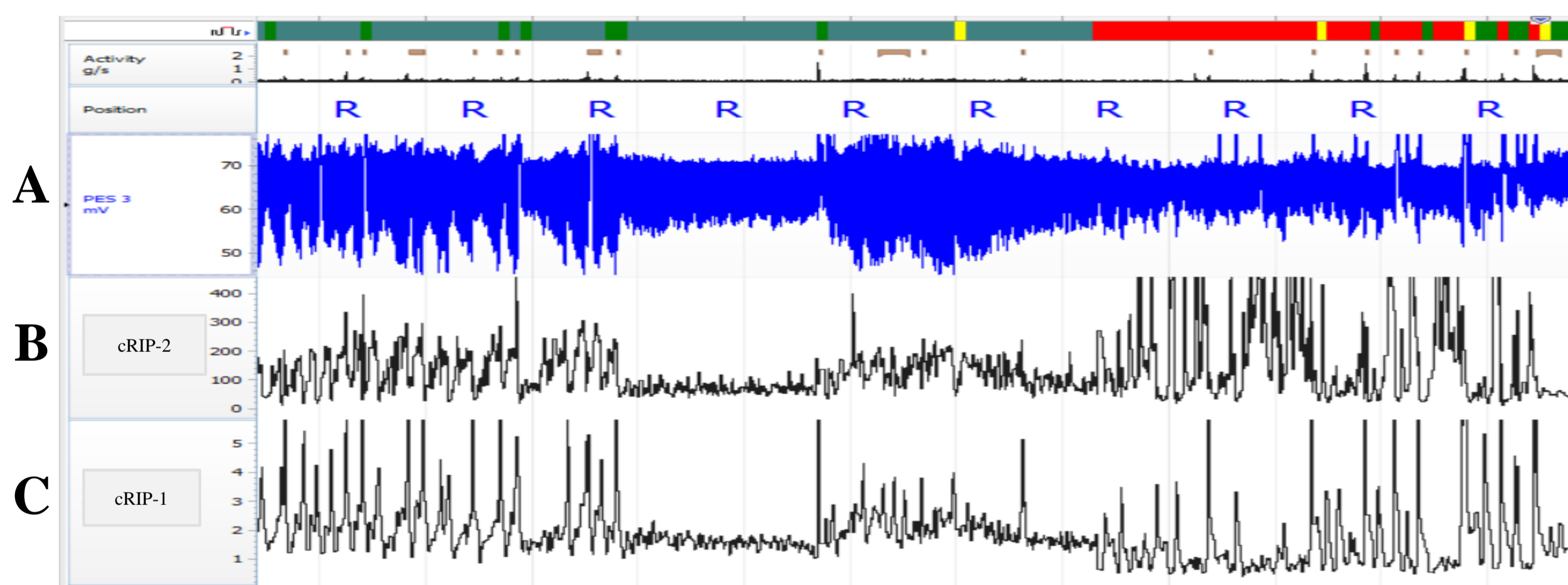
Scored events in the cRIP parameters were compared to scored events in the Pes signal. Peristimulus time histograms were constructed, for each subject, with Pesces and Pessus serving as triggers for cRIP-1 and cRIP-2.

Furthermore, it was investigated if events scored in the cRIP-1, cRIP-2, or Pes precede arousals. Significance was assessed using two-tailed one-sample z-test for proportions, at  $\alpha = 0.05$  level.

## Results

### cRIP-1 and cRIP-2 events occur with Pes events

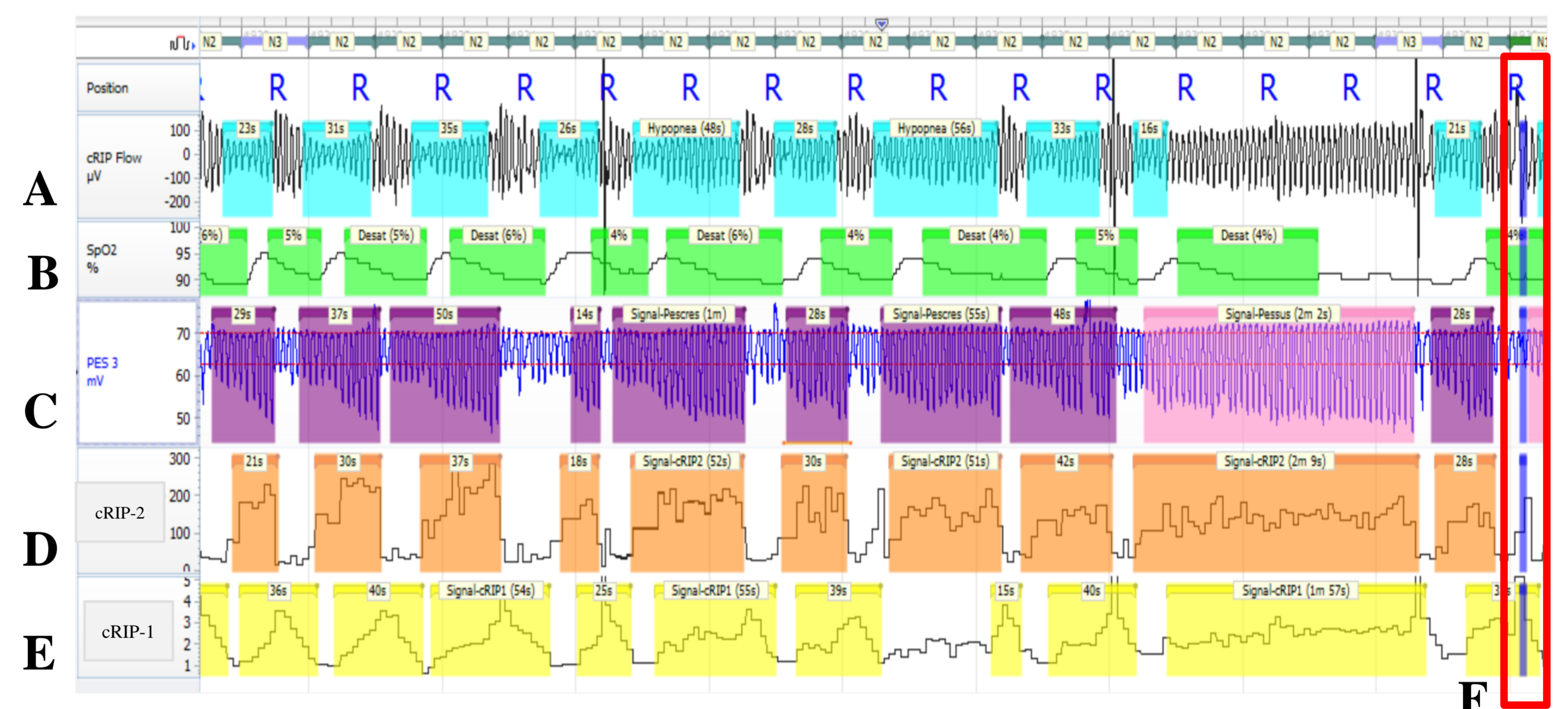
Onset of cRIP-1 events followed onset of Pes events within 10 sec in 52% of all Pes event. Figure 3 shows that cRIP-1 followed Pes by up to 27 sec. Onset of cRIP-2 followed onset of Pes events within 10 sec in 80% of all Pes events.



**Figure 2:** A) Pes sensor, B) cRIP-2, and C) cRIP-1.

### Pes, cRIP-1 and cRIP-2 precede arousals

cRIP-1 preceded 70% of all respiratory arousals, cRIP-2 preceded 65% of all respiratory arousals and Pes events preceded 60% of all respiratory arousals.



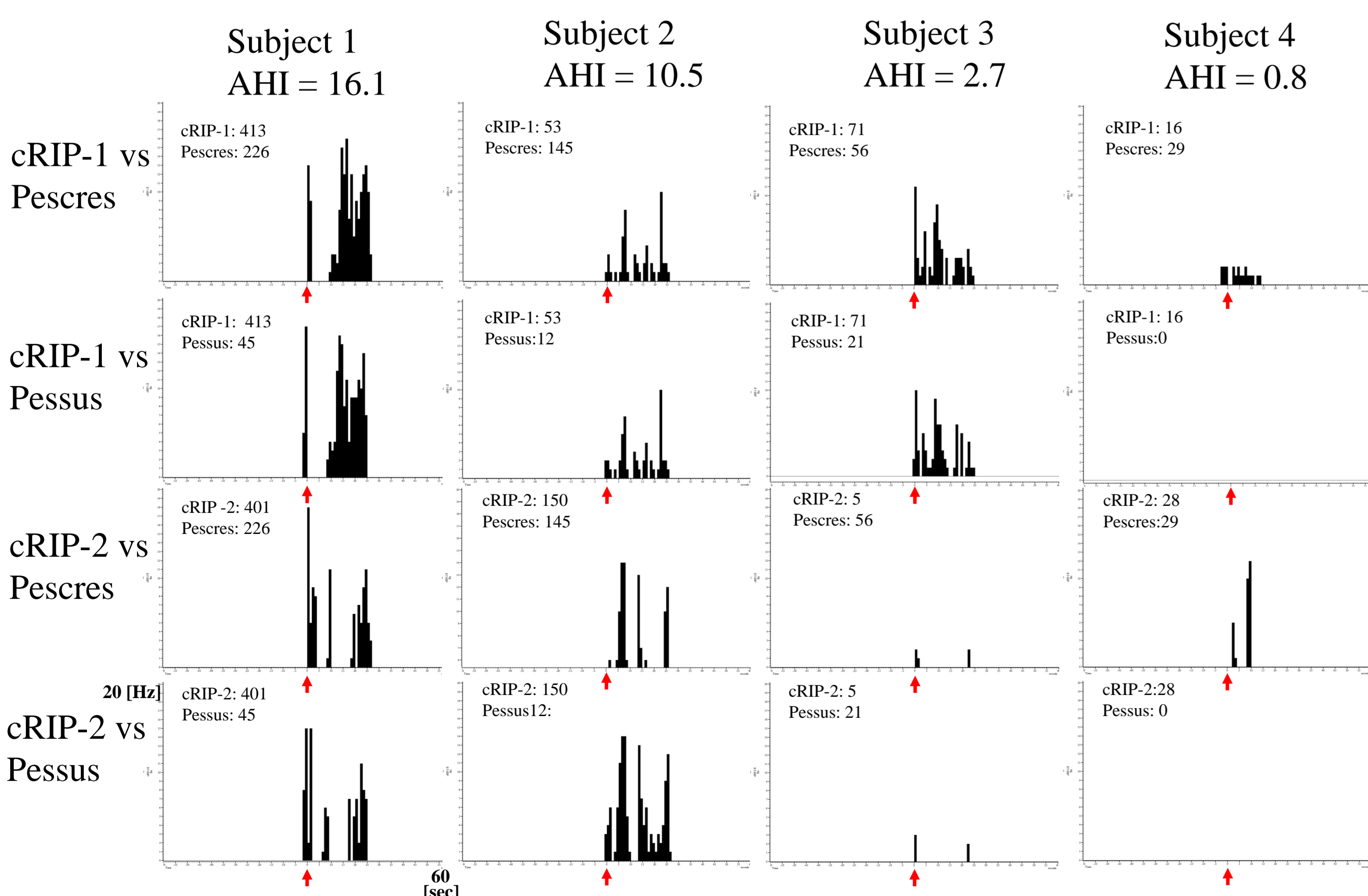
**Figure 4:** A) cRIP flow signal with scored hypopneas. B) Oxygen saturation. The green color indicate desaturation events. C) Pes signal. Two types of events were scored: Pesces, purple color, and Pessus, pink color. D) cRIP-2 signal with scored events are shown. E) cRIP-1 signal with scored events. The relationship between hypopneas, Pes, cRIP-1 and cRIP-2 events is shown. During an hypopnea the pressure in esophagus decreases, oxygen saturation decreases, the cRIP-2 increases and shortly after the cRIP-1 increases. The drive in the respiratory system increases as a response to oxygen desaturation. The figure shows an arousal preceded by an hypopnea, Pes, cRIP-1, and cRIP-2 events (F).

## Conclusions

- cRIP-1 and cRIP-2 are a new promising signals for evaluating respiratory effort.
- cRIP-2 events co-occur with Pes events.
- cRIP-1 events follow Pes events.
- cRIP-1 and cRIP-2 events are a useful measure for respiratory related arousals.
- cRIP-1 and cRIP-2 precede arousals significantly more often than Pes.
- The cRIP method could potentially replace the highly invasive Pes method but needs further validation.

### Acknowledgements

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**Figure 3:** Peristimulus time histograms showing data from the first 4 subjects. Red arrows indicate the onset of Pes events. The plots show the delay in onset in cRIP-1 and cRIP-2 events compared to Pes events.