SUPPLEMENTARY METHODS ANS RESULTS

Low-cost, easy-to-build non-invasive pressure support ventilator for under-resourced regions: open source hardware description, performance and feasibility testing

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METHODS

Active patient simulator.

To implement an active breathing model, the passive R-C system simulating the lungs was enclosed in a cylindrical box (20 cm diameter, 30 cm height), leaving the R-C inlet (airway opening) outside the box (Figure 2). The air in this box simulated the pleural compartment. The cylindrical box was connected to a negative pressure source based on a controlled blower (WM7040, Ning Bo Feng Hua Wei Cheng Motor Factory, Zhejiang, China). A pressure transducer (XGZP6847005KPG, CFSensor, Wuhu, Anhui, China) connected to the box chamber measured the air pressure, which played the role of pleural pressure in the model. The cylindrical box had a resistance orifice open to the room air to allow setting the level of simulated pleural pressure in combination with the amplitude of the flow generate by the blower. A half-cycle sinusoidal voltage signal driving the blower allowed to generate simulated pleural pressures realistically mimicking those induced by inspiratory muscles in terms of amplitude, frequency and time course.

Ventilator testing in healthy volunteers.

The volunteers were naïve to the pathophysiology of respiratory diseases and had never received mechanical ventilation. They were provided with detailed explanations of the procedure in a specific meeting, and signed a written consent to participate in the protocol. Each volunteer was told, in lay language, that: a) his/her respiration would be partially hindered to simulate the breathing difficulty perceived during a heavy physical work or sport practice, b) that a device to facilitate his/her breathing would then be connected through a nasal mask and c) that he/she would be

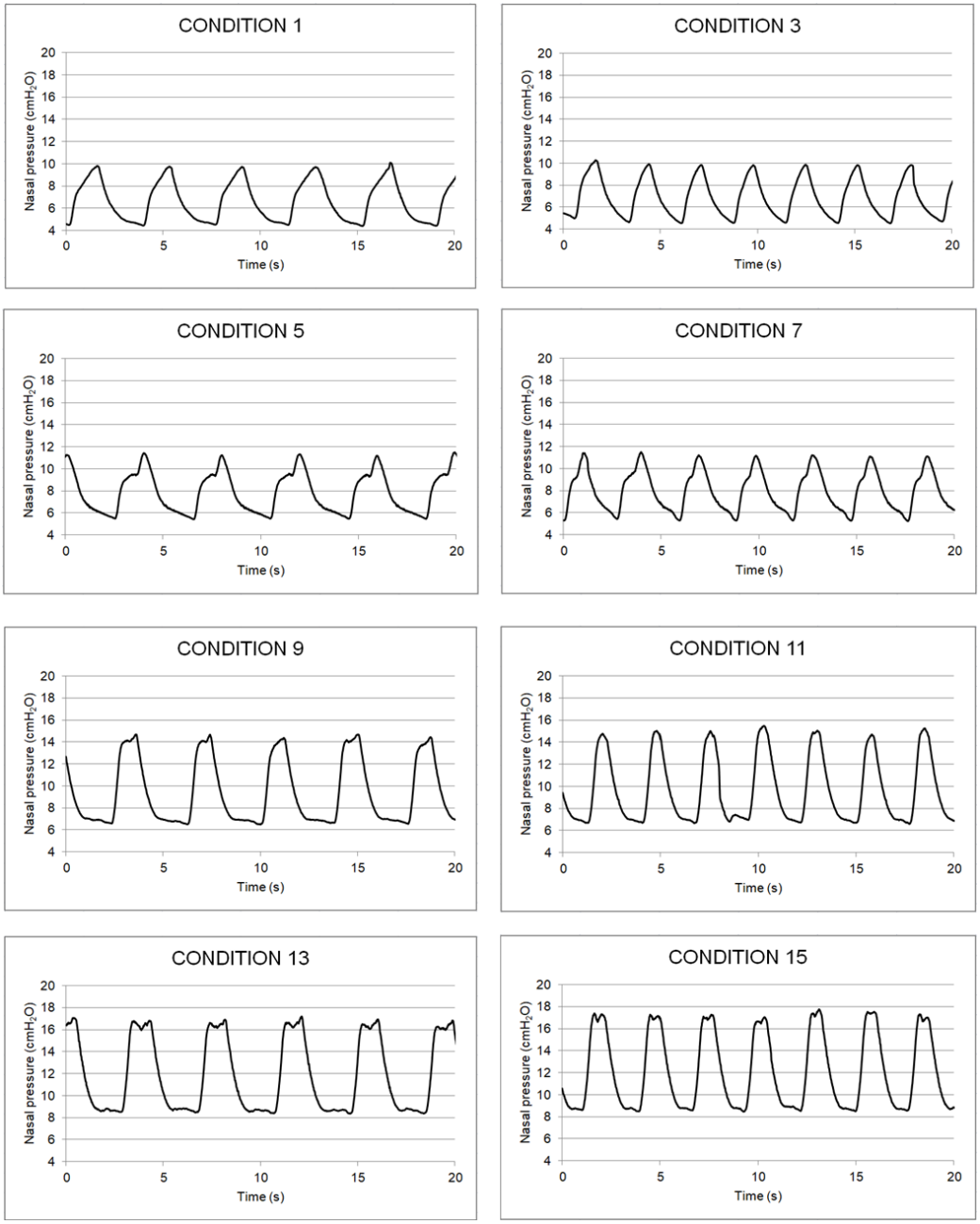
asked to score the level of comfort/discomfort experienced with/without the breathing support.

To mimic the respiratory load corresponding to an obstructive patient, a mesh-wire screen resistance (9.5 $cmH_2O/L/s$) was placed at the inlet of a conventional nasal mask for non-invasive ventilation. The built-in intended leak of the mask was sealed, and a 5 mm orifice intended leak open to the room air was placed between the end of the flexible tube connecting the ventilator to the mask and the 9.5 $cmH_2O/L/s$ added resistance which hence played the role of an actual increase in patient's airway resistance. To also load the volunteer with a restrictive component, a nonflexible belt (9 cm width) was tightly fit around the abdomen and a spring-based flexible belt (9 cm width) was adjusted around the thorax at the level of the manubrium sterni.

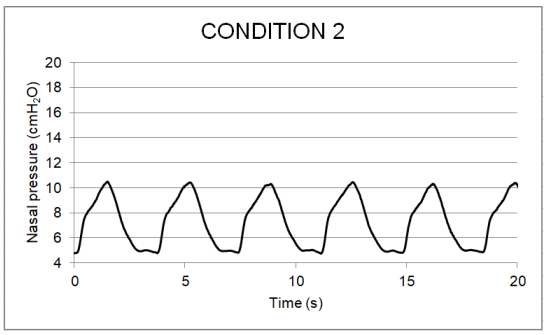
RESULTS

Figure 1. Suppl. Pressure generated by the prototype ventilator when connected to simulated patients under different conditions without (A) and with (B) unintended air leaks. (C) and (D) are the flow signals corresponding to the pressures in (A) and (B), respectively. See Table 1 in the main manuscript for conditions definition.

(A)



(B)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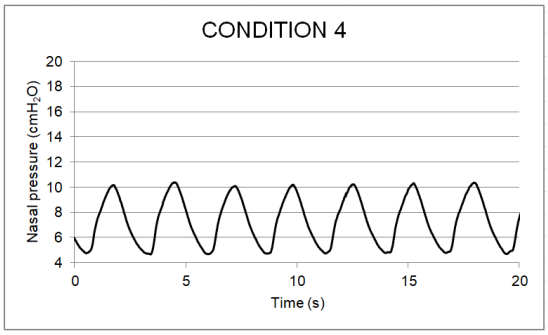
Nasal pressure (cmH2O)
Time (s)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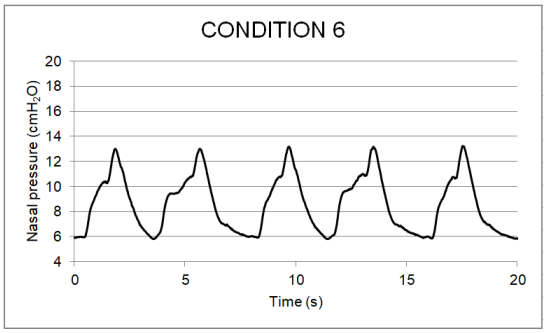
Nasal pressure (cmH2O)
Time (s)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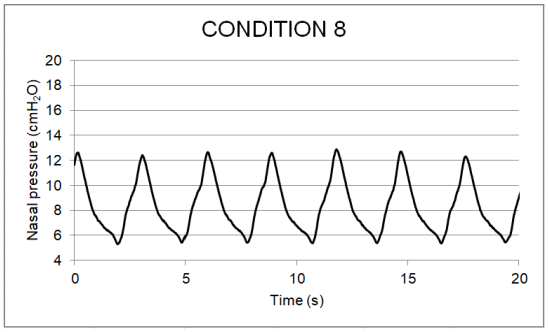
Nasal pressure (cmH2O)
Time (s)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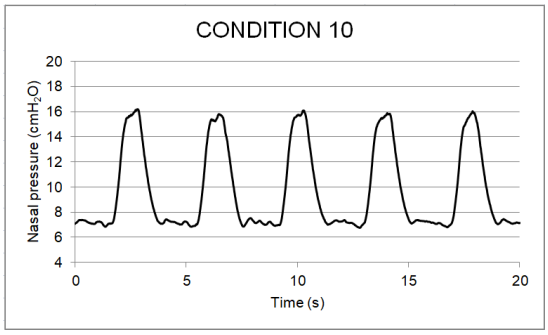
Nasal pressure (cmH2O)
Time (s)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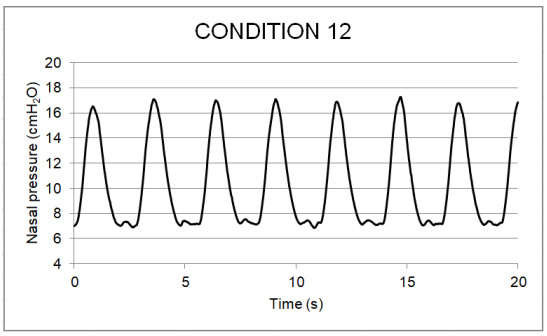
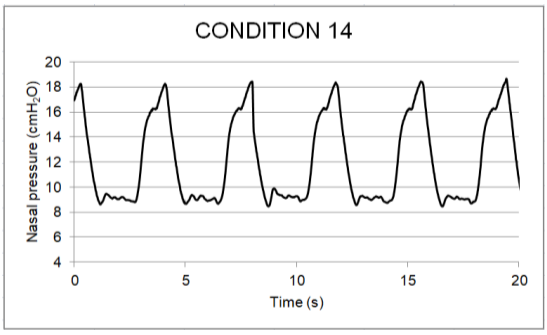
Nasal pressure (cmH2O)
Time (s)


CONDITION 12
Nasal pressure (cmH2O)
Time (s)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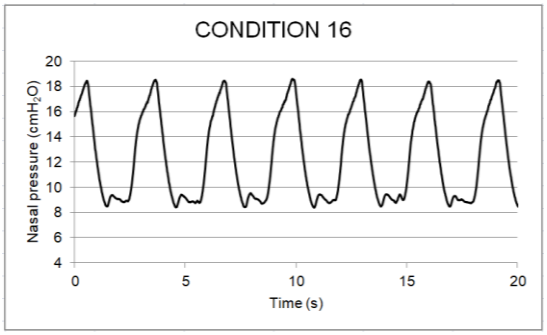
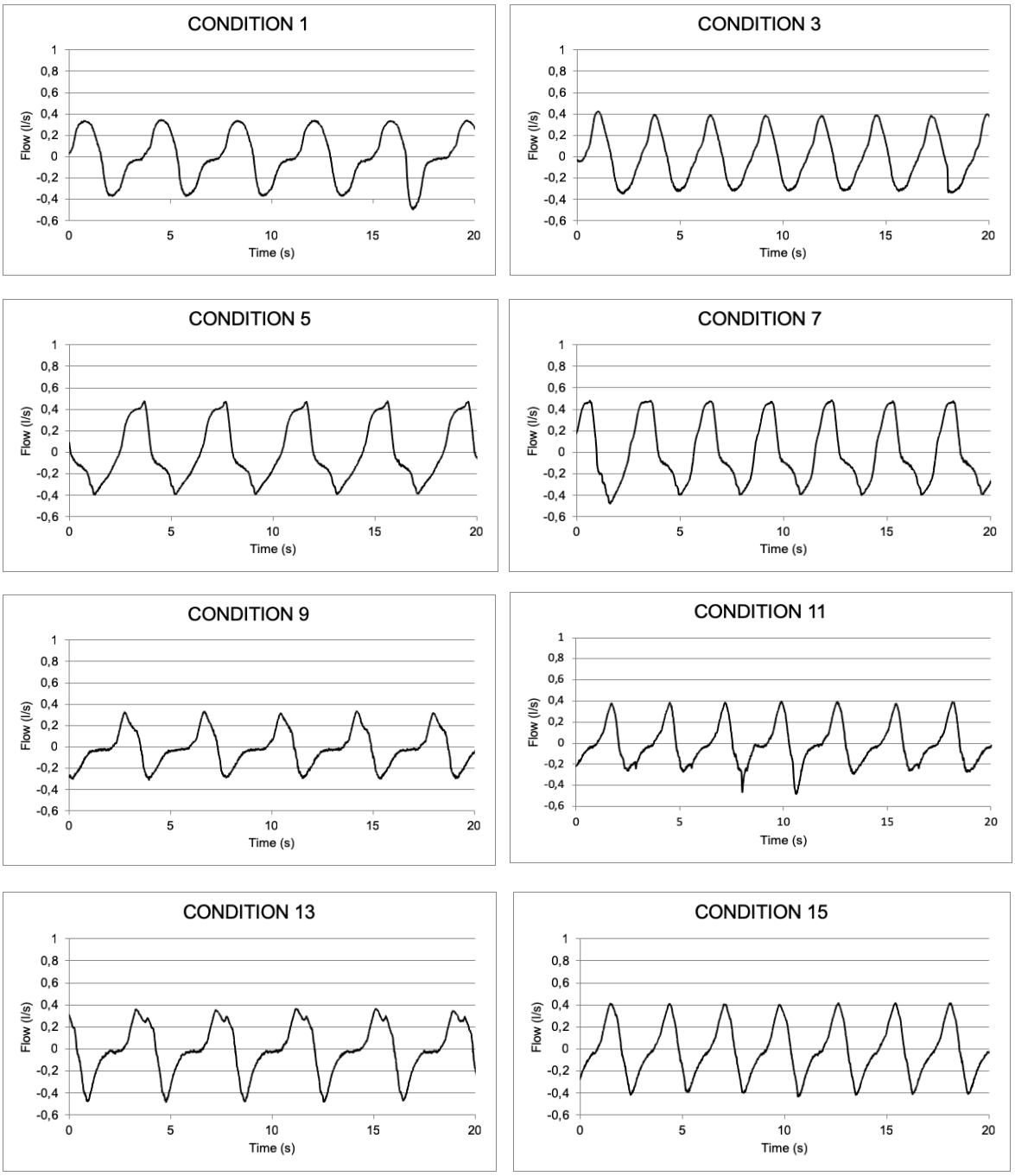
Time (s)


CONDITION 16
Nasal pressure (cmH2O)
Time (s)

(C)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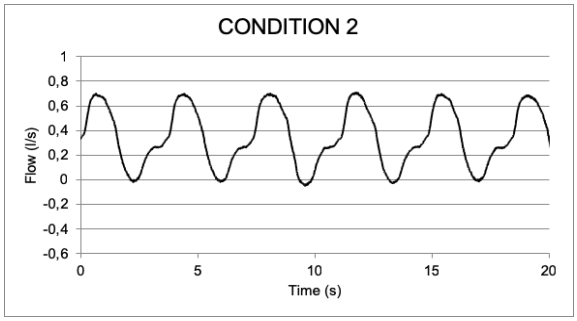
CONDITION 3
CONDITION 5
CONDITION 7
CONDITION 9
CONDITION 11
CONDITION 13
CONDITION 15
Flow (l/s)
Time (s)

(D)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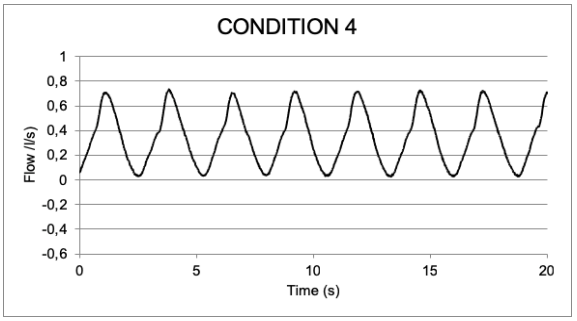
Flow (l/s)
Time (s)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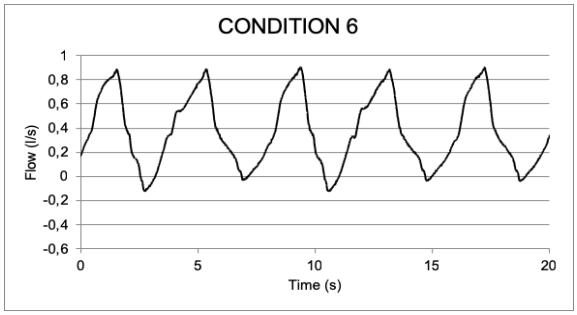
Flow (l/s)
Time (s)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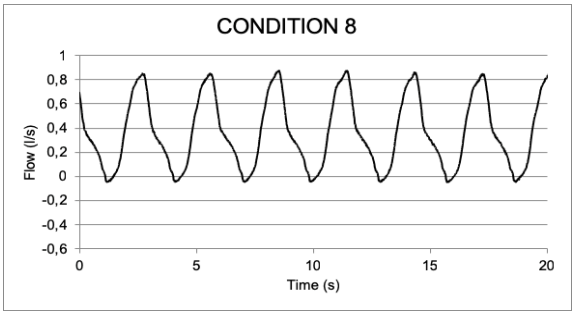
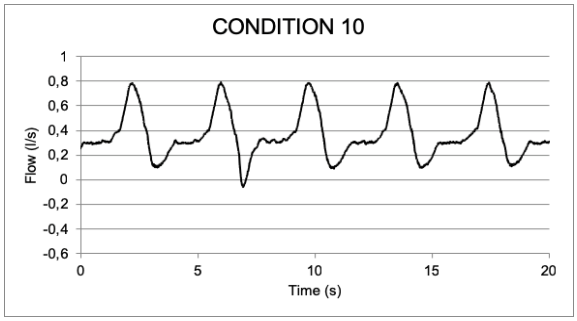
Flow (l/s)
Time (s)


CONDITION 8
Flow (l/s)
Time (s)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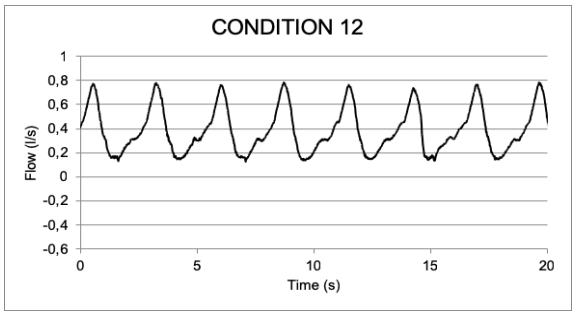
Flow (l/s)
Time (s)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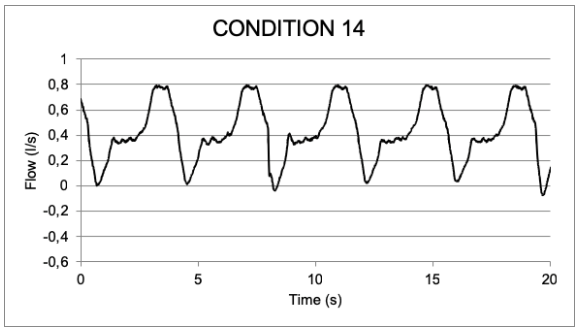
Flow (l/s)
Time (s)


CONDITION 14
Flow (l/s)
Time (s)

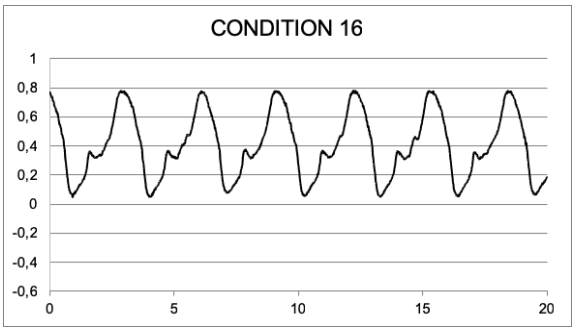

CONDITION 16

Figure 2. Suppl. Example of the nasal pressure and breathing flow signals recorded in a resistive-restrictive loaded breathing volunteer subjected to ventilatory support with the prototype ventilator. From second 12 to 30, the volunteer was asked to perform an end-inspiratoy apnea with glottis closure to observe that the ventilator automatically triggered mandatory inspirations at the 12 breath/min backup frequency. Both the pressure (in cmH_2O) and flow (uncalibrated arbitrary units (a.u.)) recording correspond to the unfiltered signals from the sensors within the ventilator. The flow observed during the apnea corresponds to the flow though the intended leak corresponding to the inspiratory and expiratory pressure.