A TARGET FEEDBACK DEVICE FOR VENTILATORY MUSCLE TRAINING

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ABSTRACT. In a previous study, we successfully used a target feedback device, together with an external resistor, to train the ventilatory muscles of patients with chronic obstructive pulmonary disease. In this article, we describe the details of the design and function of the target feedback device. When used in conjunction with an external resistance, the target feedback device provides timing and pressure targets, together with feedback information, on whether these targets are achieved The target feedback device consists of readily available electronic components and is relatively simple to construct. Adjustment of an external pressure knob permits setting of pressure targets. Adjustment of internal components is possible and allows control of breathing frequency, inspiratory time, and breathing waveform.

KEY WORDS. Equipment Muscle: ventilatory.

The improved ability of patients with chronic obstructive pulmonary disease (COPD) to breathe through small inspiratory orifices after resistive ventilatory muscle training has been construed as evidence of improved ventilatory muscle function [1–5]. However, a reduction in breathing frequency and inspiratory flow rates reduces the work of breathing and the perception of effort [6]. Because breathing strategy was not monitored or controlled in previous studies, it cannot be determined if the improved performance of the patients was due to increased ventilatory muscle endurance or to changes in breathing strategy.

We recently reported the results of a study in patients with COPD that used a resistive breathing trainer (RBT) together with a target feedback device (TFD). This system provided timing and pressure information to the patients so that they were able to control their breathing strategy [7]. After a 6-week training program with this system, the patients showed increases in ventilatory muscle strength and improved endurance for both loaded and unloaded breathing. The purpose of this communication is to provide details on the design and function of the TFD. Details on the use of this device are provided in the previous publication [7].

METHODS

Theory of Operation

The TFD is a battery-operated portable device that provides timing and pressure feedback information to the patient (Fig 1). This TFD is linked to the RBT via a small tube that transmits mouth pressure to a small

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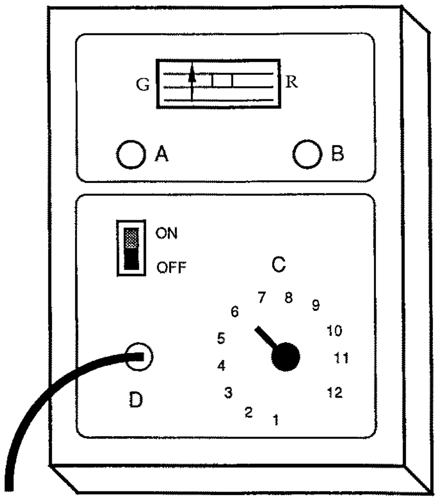

Fig 1. Illustration of the target feedback device. Analog scale is in the top portion; G *and* R *represent green and red zones, respectively.* A *is the green light, which signals the onset of inspiration;* B *is the red light, which lights when the maximal effort is reached. Light B comes on when the needle reaches the R zone of the analog scale.* C *is the knob that sets the pressures, while* D *is the tube connecting the target feedback device to the resistive breathing trainer. (See text for further details.)*

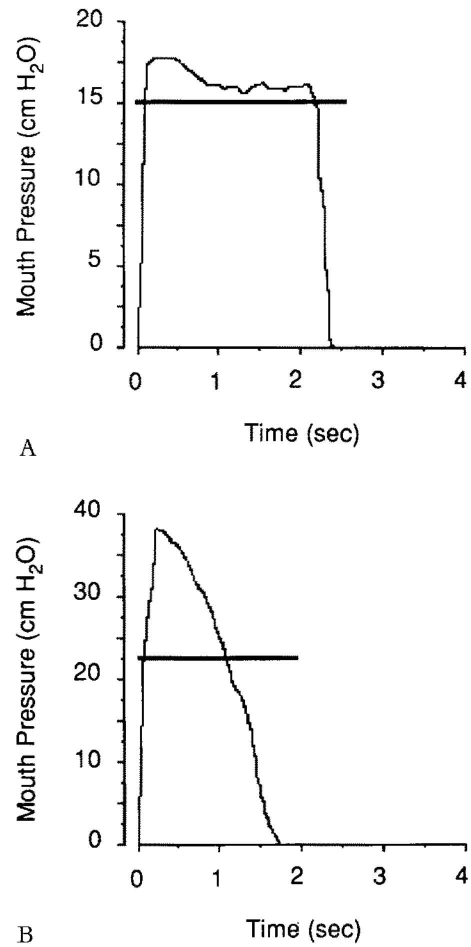

Fig 2. Illustration of the square-wave (A) and saw-toothed (B) breathing patterns. The thick dark horizontal line represents the threshold pressure below which the buzzer sounds. The time that this threshold is in effect can be adjusted.

solid-state pressure transducer in the TFD. The output of this transducer deflects the needle on the feedback meter, which is divided into three regions: left (yellow), mid (green), and right (red). As the pressure acting on the transducer increases, the needle is deflected rightward toward the red region. Knob C (see Fig 1) sets the target pressure ranges so that when the target pressure is reached, the needle just enters the green zone. When the target pressure is exceeded, the needle moves into the red zone. At pressure levels of approximately 80% above the threshold, the red light is on.

Respiratory timing is regulated by a green light-emitting diode (LED, labeled A in Fig 1). The onset of the green LED is the patient's cue to begin inspiration. The LED remains lit for the entire duration of the inspiratory time. Empirically, the timing of this device for the purpose of our study was set at a total breath time of 4.8 seconds, with an inspiratory time of 2.1 seconds. Two forms of breathing pattern are possible with this device (Fig 2) [7]. In the first, the square-wave breathing pattern (see Fig 2A), the patient reaches the target pressure indicated by the needle in the midrange (green) and holds this for the entire duration of the inspiratory time. Failure to reach this target causes a buzzer that sounds because the mouth pressure achieved is below threshold. The patient is allowed a grace period of 0.4 seconds from the onset of the green light to reach the target pressure. For the saw-toothed wave breathing pattern (see Fig 2B), the patient's objective is to reach as high a target pressure as possible with each breath. In this case, the patient is instructed to light the red light and/or to bring the needle to the right-most end of the pressure scale. As this maximal pressure cannot be sustained for the entire inspiratory time, the buzzer time can be shortened.

In this device, unlike the threshold-loading device [8,9], inspiratory flow rates are directly proportional to mouth pressure. With a given inspiratory orifice and target mouth pressure, the inspiratory flow rate required to sustain the target mouth pressure is readily predicted from the pressure flow properties of each orifice. With each orifice, therefore, there is a unique inspiratory flow rate that will allow achievement of the target mouth pressure. In our previous study we used an orifice 0.46 cm in diameter throughout the training period [7]. When smaller or larger orifices were used, the