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LETTERS TO THE EDITOR

Solenoid valve *v* weighted plunger in incremental inspiratory threshold loading

Dr P A Bardsley and others (April 1993;**48**:354–9) compared measurements of inspiratory muscle performance obtained with two threshold loading devices: one incorporating a solenoid valve, and the other a weighted inspiratory plunger.[1,2] We had two major problems with this paper. Firstly, the solenoid device does not provide a threshold load for the duration of inspiration and, secondly, there is a danger that readers of this paper could conclude that the weighted plunger principle is inadequate because of the manifest inadequacies of their particular device.

A "threshold" load requires a given pressure to be developed before air will flow. Once the threshold pressure (Pth) is exceeded, in the ideal device, flow is independent of pressure.[1,3] In the solenoid device described by Bardsley *et al*, once the Pth was exceeded the valve opened and the load disappeared for the remainder of inspiration. This device does not threshold load inspiration; it threshold loads initial inspiratory effort. In contrast, the weighted inspiratory plunger imposes a threshold load throughout inspiration: if Pth is not exceeded no inspiratory flow can occur. A consequence of this is that, at equivalent Pth, frequency, and timing, the work performed by the inspiratory muscles is greater when breathing against a weighted plunger than against a solenoid valve; inspiratory muscle performance using these two devices is not comparable.

The weighted plunger used in Bardsley's study behaved linearly up to a Pth of -75 cm H_2O, beyond which addition of further weights had little effect on Pth as shown in fig 4 of their paper. This alinearity at higher loads is most probably associated with the inspiratory plunger rocking on its seating and partially opening, thereby allowing subjects to generate inspiratory flow at a lower Pth than would normally be required. We have experienced similar problems in the past and have modified the weighted plunger using the diaphragm and valve seating from a threshold valve used to deliver positive end expiratory pressure (AMBU International, Denmark) to yield improved pressure-flow characteristics (figure). These data illustrate a linear relation between the weights on the plunger and threshold pressure, and the independence of pressure and inspiratory flow above threshold pressure at each weight. We have used our modified device extensively to study aspects of inspiratory muscle fatigue and endurance.[4] During these studies subjects have consistently achieved a maximum Pth during inspiratory threshold loading similar to previously reported values (87–95% of maximum),[2,5] and notably greater than those achieved by the subjects in Bardsley's study (60% of maximum).

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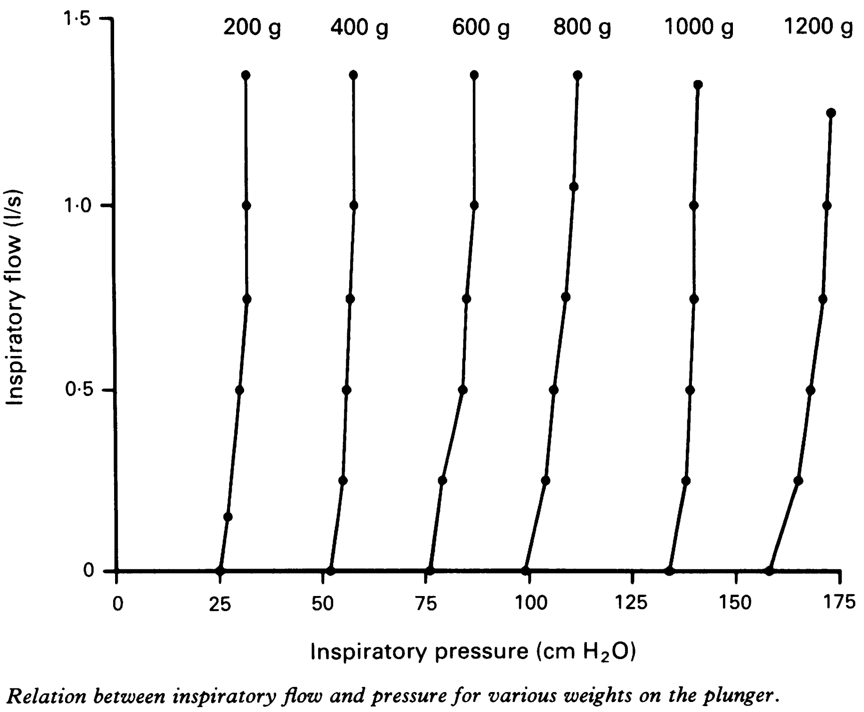

Relation between inspiratory flow and pressure for various weights on the plunger.

1 Nickerson BG, Keens TG. Measuring ventilatory muscle endurance in humans as sustainable inspiratory pressure. *J Appl Physiol: Respir Environ Exercise Physiol* 1982;**52**:768–72.
2 Martyn JB, Moreno RH, Pare PD, Pardy RL. Measurement of inspiratory muscle performance with incremental threshold loading. *Am Rev Respir Dis* 1987;**135**:919–23.
3 Campbell EJM, Dickinson CJ, Dinnick OP, Howell JBL. The immediate effects of threshold loads on the breathing of men and dogs. *Clin Sci* 1961;**21**:309–20.
4 Eastwood PR, Hillman DR, Finucane KE. Ventilatory responses to threshold loading and the role of muscle fatigue in task failure. *J Appl Physiol* (in press).
5 McElvaney G, Fairbarn MS, Wilcox PG, Pardy RL. Comparison of two-minute incremental threshold loading and maximal loading as measures of respiratory muscle endurance. *Chest* 1989;**96**:557–63.

AUTHORS' REPLY We are grateful for the opportunity to reply to this letter which raises two important issues. The main point highlighted is that the weighted plunger becomes unreliable at high inspiratory loads during incremental threshold loading. Drs Eastwood and Hillman acknowledge our observations and have had to modify their device because of this problem. The reference they quote refers to work published as an abstract in which their modification to the weighted plunger was not mentioned, so we can be forgiven for not being aware of it.

Whether the ideal threshold device should provide a threshold load for the duration of inspiration is an interesting point and merits wider debate. As we state in our paper we recognise that the solenoid valve and weighted plunger are different and threshold load the inspiratory muscles in different ways. However, the solenoid valve could be modified to provide a threshold load throughout inspiration. Our aim was not to develop the "ideal" threshold device but to develop an accurate, reproducible, progressive, and incremental test of inspiratory muscle performance. Incremental threshold loading with the solenoid valve generates an accurate mouth pressure response even at high loads, and at the end of the tests both external work and metabolic work performed by the inspiratory muscles are reproducible.

The weighted plunger is a very useful device but it does seem to have its limitations. We believe the solenoid valve overcomes the inaccuracies at high threshold loads and has several advantages over the weighted plunger. We look forward to seeing the full transcript of their modification when it is published. Meanwhile it is important to emphasise that both techniques may be capable of providing a stable platform for a test of incremental loading of the inspiratory muscles.

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