device, thereby enabling convenient, effective inspiratory muscle training in the context of sports performance.

The historical evolution of pressure threshold devices is described here, accompanied by a critical evaluation of each technology. Having highlighted the limitations of current devices, proposed design modifications are outlined. The subsequent narrative describes how theoretically desirable features were implemented in practice. The remainder of the paper presents a technical evaluation of the final product design.

An evaluation of existing 'threshold' IMT devices

Nickerson & Keens (1982) devised a method for measuring ventilatory muscle endurance, which was subsequently utilised as a training device. It involved the user exerting a negative pressure, in an attempt to lift a weighted plunger which acted as an inspiratory valve. This simple concept provided a means of implementing a quantifiable resistive load to inspiration without the need to regulate inspiratory flow profiles. The range of loading was extensive, being directly proportional to the mass of the plunger. Typically, loads up to −150 cm H_2O were used. Unfortunately, the weighted plunger arrangement did not yield truly threshold loading as small flows (less than 0.05 L s^{-1}) were observed below desired threshold pressures.

Whilst the Nickerson and Keens device was portable, the necessity to suspend it in an absolutely vertical plane meant unsupervised use was impractical. Furthermore, the device needed to be dismantled to alter the loading. Several similar devices, based on the same principle, were subsequently implemented in IMT studies. Clanton *et al.* (1985) modified Nickerson & Keens' (1982) device so that the weight could be added to the valve externally. As with the preceding model, the authors reported that a linear relationship existed between the mass of the container and the negative inspiratory pressure required to open the valve. The authors refer to the technical specification supplied by Nickerson & Keens (1982) when describing the device's loading characteristics. However, unlike Nickerson and Keens, they quantify the degree of flow dependency. An increase in inspiratory flow rate of 0.2 L s^{-1} increased resistance by approximately −2 cm H_2O. Ostensibly, the limitations of this device are the same as those discussed with respect to that of Nickerson and Keens.

Flynn *et al.* (1989) made further modifications to the original Nickerson & Keens (1982) design, electing to house the loading weights within the internal architecture of the device. This configuration was such that a weighted plastic plunger was seated over an inspiratory port at the base of a cylindrical sleeve. This arrangement removed the criticality of suspending the device, and permitted a smaller dead-space; however, aside from these features, its functionality remained much the same as that of the original model upon which it was based.

A radical perspective on IMT apparatus was introduced in 1988 (Larson *et al.* 1988) who constructed a pressure threshold breathing device using a spring-loaded poppet valve. To train with this device, users were required to generate a predetermined negative pressure to open the valve thus permitting airflow; a nonreturn expiratory valve allowed unloaded expiratory flow. The resistance could be adjusted, by compressing the spring-loaded valve to produce a range of inspiratory pressure loads from −5 cm H_2O to −50 cm H_2O. This device facilitated wide-scale implementation of clinical IMT studies as it provided a portable intervention that could be used with minimal preparation or maintenance.

Gosselink *et al.* (1996) examined the reliability of The Threshold trainer in both healthy and chronic obstructive pulmonary disease groups. During 5 min bouts of use, at different load settings, the healthy subjects showed mean coefficients of variation for pressure and flow of 0.8% and 20.5%, respectively; the mean coefficients of variation for the patients were 0.6% and 14.5%, respectively. Thus, in both groups the change in pressure due to variations in flow were small. However, the maximum flow examined was 1.66 L s^{-1}. Thus, whilst the authors conclude that The Threshold is flow independent, this statement needs to be qualified.