

was not accomplished, the degree of flow dependency achieved was substantially lower than that reported for previous devices. Furthermore, the degree of flow dependency observed at anything other than low loads was of limited functional relevance.

It is important to note that variable loading is possible even when the threshold load remains fixed. However, this requires development of markedly different inspiratory manoeuvres. Given that load is largely independent of flow it is evident that inspiratory duration is most important in establishing the effective work done. In this regard, if variability in training stimulus is to be minimised, it is desirable to standardise the inspiratory manoeuvre being performed, especially with respect to duty cycle (inspiratory duration relative to expiratory duration).

The current device has been used in several studies examining lung function and exercise tolerance; it has been demonstrated to improve inspiratory muscle strength and endurance substantially and to engender both warm-up and ergogenic benefits to a range of users.

The present device is registered with the Medical Devices Agency as a class I medical device. In complying with the Medical Devices Regulations 1994 the product is authorised to carry the CE mark. It is covered by an active patent no. 2278545 and is trademarked Powerbreathe (IMT Technologies Ltd, Birmingham, UK).

Conclusions

This paper describes the development and evaluation of a pressure threshold inspiratory muscle trainer for use in the context of sports performance. The device described provides true threshold, near flow-independent loading across the range of physiologically relevant intensities. Load selection is continuous with the degree of flow dependency observed being of limited functional relevance. The device is both comfortable and practical to use and maintain. Thus, in respect of the desirable characteristics outlined previously, the present device fulfils all defined criteria. This does not signify that this device cannot be improved upon but rather that it overcomes previously existing functional limitations.

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References

- Anderson, J.B., Dragsted, L., Kann, T., Johansen, S.H., Nielsen, K.B., Karbo, E. & Bentzen, L. (1979) Resistive breathing training in severe chronic obstructive pulmonary disease. *Scandinavian Journal of Respiratory Disease*, **60**, 151–156.
- Belman, M.J. & Shadmehr, R. (1988) Targeted resistive ventilatory muscle training in chronic obstructive pulmonary disease. *Journal of Applied Physiology*, **65**, 2726–2735.
- Boutellier, U., Büchel, R., Kundert, A. & Spengler, C. (1992) The respiratory system as an exercise limiting factor in normal trained subjects. *European Journal of Applied Physiology*, **65**, 347–353.
- Boutellier, U. & Piwko, P. (1992) The respiratory system as an exercise limiting factor in normal sedentary subjects. *European Journal of Applied Physiology*, **64**, 145–152.
- Caine, M.P. & McConnell, A.K. (1998) Pressure threshold inspiratory muscle training improves submaximal cycling performance. In: *Proceedings of the 3rd Annual Congress of the European College of Sport Science* (eds Sargent, A.J. & Siddons, H.), pp. 101. The Centre for Health Care Developments, Liverpool, UK.
- Clanton, T.L., Dixon, G.F., Drake, J. & Gadek, J.E. (1985) Inspiratory muscle conditioning using a threshold loading device. *Chest*, **87**, 62–66.
- Copstake, A.J. (1995) The influence of inspiratory muscle training upon exertional breathlessness in healthy elderly men and women. PhD Thesis, Loughborough University of Technology, Loughborough, Leicestershire, UK.
- Delhez, L., Bottin, R., Thonon, A. & Vierset, J. (1966) Modifications du diagramme pression-Volume maximum de l'appareil thoraco-pulmonaire après entraînement des muscles respiratoires par des exercices statiques. *Arch. Internat. De Physiol. Et de Biochimie.*, **74**, 335–336.
- Dempsey, J.A., Hanson, P., Pegelow, D., Claremont, A. & Rankin, J. (1982) Limitations to exercise capacity and endurance: pulmonary system. *Canadian Journal of Applied Sport Science*, **7**, 4–13.
- Flynn, M.G., Barter, C.D., Nosworthy, J.C., Pretto, J.J., Rochford, P.D. & Pierce, R.J. (1989) Threshold