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# Weaned but weary: One third of adult intensive care patients mechanically ventilated for 7 days or more have impaired inspiratory muscle endurance after successful weaning

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ABSTRACT

*Objectives:* The purpose of this study was to establish whether intensive care unit (ICU) patients have impaired inspiratory muscle (IM) endurance immediately following weaning from prolonged mechanical ventilation (MV), and whether IM weakness is related to function or perceived exertion.
*Background:* Impaired IM endurance may hinder recovery from MV, however it is unknown whether this affects patients' function or perceived exertion.
*Methods:* Prospective observational study of 43 adult ICU patients following weaning from MV (>7 days duration). IM endurance was measured using the fatigue resistance index (FRI).
*Results:* IM endurance was impaired (FRI = mean 0.90, SD 0.31), with 37% scoring below 0.80. IM strength did not significantly correlate with function ($r = 0.24$, $p = 0.12$) or perceived exertion during exercise ($r = -0.146$, $p = 0.37$).
*Conclusions:* IM endurance is reduced in one third of patients, while IM weakness does not appear closely associated with function or perceived exertion immediately following successful weaning.


## Introduction

Intensive care unit (ICU) patients frequently experience peripheral muscle wasting and these changes are detectable very early in the admission. Early rapid proteolysis occurs in the diaphragm muscles of ventilated patients.[1] Inspiratory muscle weakness, manifesting as a reduction in maximum inspiratory pressure (MIP), is also associated with limb muscle weakness in ICU patients.[2] Thus proteolysis of both the skeletal muscles and diaphragm are likely to complicate illness and affect the recovery trajectory for many ICU patients.

The resulting diaphragmatic weakness is a potential contributor to difficulty in weaning from mechanical ventilation.[3] However, few studies to date have measured functional endurance of the diaphragm in this patient group. This is surprising, as diaphragmatic endurance, rather than force, is required to achieve breathing independently of the mechanical ventilator.

In 2005 Chang and colleagues[4] demonstrated that respiratory muscle endurance is impaired for some time after successful

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weaning from mechanical ventilation. In addition, impaired endurance is negatively associated with duration of mechanical ventilation ($r = -0.65$, $p = 0.007$).

To our knowledge, the relationship between respiratory muscle weakness (impaired strength or endurance) and global functional measures in ICU patients (e.g., Barthel Index, Acute Care Index of Function) has not been explored. Functional status (i.e. the ability to transfer and mobilize independently) is important for longer term outcomes and quality of life. It is plausible that difficulty breathing, secondary to residual respiratory muscle weakness, may impact on the functional status of ICU survivors. It is therefore important to establish the relationship between respiratory muscle weakness and physical function in ICU patients.

Perceived exertion may also impact on functional status, but remains uninvestigated. In the context of mobilizing intensive care patients, patient dyspnea or perceived exertion during exercise is likely related to inspiratory muscle weakness. In athletes, perception of dyspnea may be the limiting factor during high-intensity endurance exercise.[5] Whether this contributes to functional limitation in mobilizing intensive care patients warrants investigation.

Thus the aim of this study was to answer the following questions:

1. In adult intensive care patients who have been recently weaned from 7 days or more of mechanical ventilation, is inspiratory muscle endurance impaired?
2. Is there a relationship between inspiratory muscle weakness, functional status and perceived exertion following successful ventilator weaning in this group?

## Methods

### Design

This prospective observational study is a sub-study of a larger trial[6] of outcomes in ICU patients ventilated for 7 days or longer. The present study analyses the baseline data collected for 43 subjects eligible for inclusion in the post-weaning study between February 2011 and December 2013. The study was approved by the Australian Capital Territory Health Human Research Ethics Committee and patients provided their own written informed consent.

### Setting

This prospective study occurred in a single tertiary 22 bed mixed medical/surgical ICU in Canberra, Australia. This unit practices minimal sedation and early rehabilitation as the standard of care, whereby both nursing and physiotherapy staff facilitate sitting out of bed and mobilization of patients as early as possible (in the absence of established contraindications).[7]

### Participants

All patients ventilated for 7 days or longer were screened for inclusion in this study once successfully extubated for 48 h. Patients were included if they were able to provide informed consent, were alert (Riker Sedation and Agitation Scale = 4)[8] and able to participate actively in inspiratory muscle training, and rate their dyspnea via a modified Borg scale.[9] Patients were excluded if they were $<16$ years of age, pregnant, had heart rates, respiratory rates, blood pressure or oxygen saturation outside stated limits, had active infection[6] or were likely to be palliated imminently. Patients were also excluded from the study if they had participated in specific inspiratory muscle strengthening while ventilated. Fig. 1 illustrates the flow of patients through the study. The most frequent reason for exclusion was impaired neurological status with an inability to follow commands ($n = 62$).

### Variables and measures

The primary measure was inspiratory muscle endurance, measured as the Fatigue Resistance Index (FRI). Using the same protocol described previously by Chang and colleagues,[4] this test compares Maximum Inspiratory Pressures (MIP) before and after a 2 minute loading challenge, where patients breathe through a resistance of 30% of MIP. MIP is measured from residual volume using a handheld device (MicroRPM Respiratory Pressure Meter), in accordance with the protocol recommended by the American Thoracic Society and European Respiratory Society.[10] This requires patients to inhale maximally from residual volume, sustaining the effort for at least 1 second. Efforts are repeated three times to ensure less than 20% variability between measurements. This method of measuring MIP is both reliable and valid using portable handheld devices.[11] FRI is calculated as the post–challenge MIP divided by the pre-challenge MIP (scores $<1.00$ indicate the presence of fatigue).

The secondary measures include patients' rate of perceived exertion (RPE) using a modified Borg scale (0–10)[9] which has acceptable reliability and validity in ICU patients.[12] Patients self-reported their RPE both at rest and during peak exercise. As peak exercise varied between patients (e.g., from sitting on the edge of the bed, to mobilizing around the ICU) depending on ability, patients were asked to report the highest exertion they experienced during any form of exercise on the day of measurement. All MIP, FRI and RPE measures were completed by specifically trained research staff.

Global function was measured by the treating physiotherapist using the Acute Care Index of Function (ACIF) tool[13] which has good inter-rater reliability[14] and construct validity[15] in acute neurological patients.

### Data analysis

Based on a previous study,[4] we estimated that a sample size of 16 patients would be required to detect a change in 10% of MIP when measuring FRI (correlation co-efficient of $>0.6$). Normalized values for MIP scores were calculated using the method outlined by Evans and colleagues.[16] Parametric correlations were performed between variables, with statistical significance considered

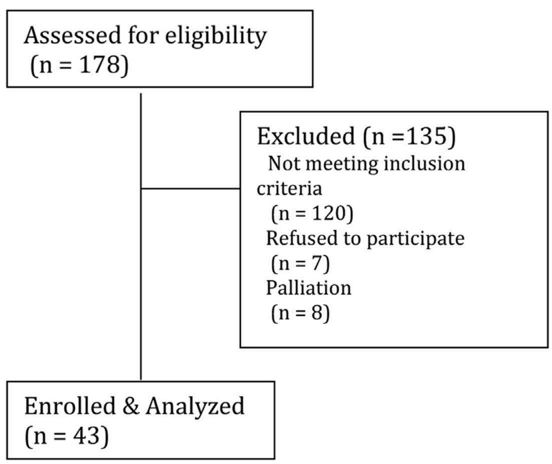


**Fig. 1.** Flow of participants through study.