Physiotherapy 100 (2014) 128–133

Reference chart of inspiratory muscle strength: a new tool to monitor the effect of pre-operative training

S. van Buuren [a,b,*], E.H.J. Hulzebos [c], K. Valkenet [d], E. Lindeman [d,1], N.L.U. van Meeteren [a]

[a] Netherlands Organisation for Applied Scientific Research TNO, Leiden, The Netherlands
[b] University of Utrecht, Utrecht, The Netherlands
[c] Child Development and Exercise Centre, Division of Paediatrics, University Children's Hospital Utrecht, Utrecht, The Netherlands
[d] Department of Rehabilitation, Nursing Science and Sport, Rudolf Magnus Institute of Neurosciences, University Medical Centre Utrecht, Utrecht, The Netherlands

Abstract

Objectives To develop a reference chart to monitor inspiratory muscle strength during pre-operative inspiratory muscle training for patients at high risk of developing postoperative pulmonary complications awaiting coronary artery bypass graft (CABG) surgery.
Design Secondary data analysis using patients from the intervention arm of a randomised clinical trial.
Setting University medical centre.
Participants Patients at high risk of developing postoperative pulmonary complications awaiting CABG surgery.
Interventions Patients performed inspiratory muscle training seven times per week for at least 2 weeks before surgery.
Main outcome measures Maximal inspiratory muscle strength.
Results A new reference chart was produced using a non-linear time trend model with a normal error structure.
Conclusions The chart is a novel tool for monitoring the progress of inspiratory muscle training for physiotherapy practice. Wider use of this chart is recommended.

Keywords: Randomised controlled trial; CABG; Pre-operative inspiratory muscle training; Postoperative pulmonary complications

Introduction

Pre-operative inspiratory muscle training (IMT) has positive effects for patients at high risk of developing postoperative pulmonary complications (PPCs) awaiting coronary artery bypass graft (CABG) surgery. In particular, IMT has been found to reduce the incidence of PPCs and length of hospital stay [1–4]. Hulzebos *et al.* provided a recent overview of the effectiveness of pre-operative IMT [5].

Maximal inspiratory muscle strength ($P_{i\text{–}max}$, cmH_2O) is a widely used, clinically relevant indicator of respiratory fitness. IMT before surgery can increase $P_{i\text{–}max}$, and thus improve the pre-operative respiratory condition of patients.

A present, no tools exist to monitor $P_{i\text{–}max}$ over time for patients awaiting CABG surgery. Such a tool would be useful to determine IMT performance prior to surgery. A pre-operative screening tool could assist the clinician in evaluating whether the patient has advanced sufficiently to be considered fit for surgery. Also, the tool could be used to show patients the effects of training in terms of increased inspiratory muscle strength. Visual feedback on progress could enhance patient motivation, and thus enhance training adherence and success.

The aim of this study was to develop a reference chart to monitor $P_{i\text{–}max}$ during pre-operative IMT for patients at high risk of developing PPCs awaiting CABG surgery.

* Corresponding author at: Netherlands Organisation for Applied Scientific Research TNO, P.O. Box 2215, 2301 CE Leiden, The Netherlands.
E-mail address: stef.vanbuuren@tno.nl (S. van Buuren).
[1] co-author Lindeman died some months ago, so this is a publication post-mortem. I suggest to make the reader aware of this.

0031-9406/$ – see front matter © 2013 Chartered Society of Physiotherapy. Published by Elsevier Ltd. All rights reserved.
http://dx.doi.org/10.1016/j.physio.2013.08.007

Methods

Design

This study analysed data collected in a randomised clinical trial at the Department of Cardiothoracic Surgery, University Medical Centre Utrecht, Utrecht, The Netherlands [1]. In total, 279 patients were eligible for randomisation and were assigned to either the intervention group (IMT, $n = 140$) or the control group (usual care, $n = 139$). The main results of the trial have been reported elsewhere [1]. The present study used data from a subset of the intervention group.

Intervention

The intervention group received pre-operative exercises, namely IMT, incentive spirometry, education in active cycle of breathing techniques and forced expiration techniques. Patients performed IMT seven times per week for at least 2 weeks before surgery [6]. Each session consisted of 20 minutes of IMT, which was performed six times per week without supervision, and once a week with supervision by a physical therapist, who measured P_{i-max} and endurance of the inspiratory muscles after each week of training.

P_{i-max} at residual volume was measured with a hand-held pressure gauge (Micro Medical MPM; PT Medical, Leek, The Netherlands). All measurements were taken by the same physical therapist. The inspiratory load of the threshold IMT (http://www.respironics.com/) is calibrated in cmH_2O and can be increased by removing the mouthpiece and tightening the spring. The patients started breathing at an inspiratory resistance equal to 30% of baseline P_{i-max} for 20 minutes. Resistance was increased incrementally based on the rate of perceived exertion scored on the Borg scale [7]. If the rate of perceived exertion was less than 5, the resistance of the inspiratory threshold trainer was increased incrementally by 5%. Additional detail on the measurement procedure can be found elsewhere [1].

Training duration was bounded by the period between the date at baseline and the date of surgery. The date of surgery was determined in advance at baseline, and did not depend on the condition or IMT of the patient.

Participants

Patients scheduled for elective CABG surgery who were able to provide informed consent were eligible for inclusion in the main study. A pulmonary risk score was calculated for each patient based on age, productive cough, diabetes mellitus, smoking history, chronic obstructive pulmonary disease (COPD), body mass index and pulmonary function tests. Only patients with an elevated risk score were eligible for inclusion in the present study. The inclusion criteria were very similar to those described by Agostini *et al.* [8], but ordinate grades 2, 3 and 4 alone were used in the present study [5,9]. Exclusion criteria were: surgery scheduled within 2 weeks of initial contact; history of cerebrovascular accident; use of immunosuppressive medication in 30 days preceding surgery; and presence of a neuromuscular disorder, cardiovascular instability or an aneurysm.

The duration of training varied between 1 and 10 weeks, but only data observed between Weeks 1 to 8 were analysed. The data set for analysis contains 413 weekly P_{i-max} measurements from 89 patients (out of 140 randomised to IMT) for whom we had at least two preoperative inspiratory muscle function measurements.

Data analysis

The statistical model describes the variation of P_{i-max} as a normal distribution where the mean and spread vary with training week (i.e. weeks since baseline). GAMLSS 4.1-5 in R Version 2.15.0 (R Foundation for Statistical Computing, Vienna, Austria) was used to obtain estimates of the mean and standard deviation (SD) that are smooth functions of training week [10]. The degrees of freedom of the smoothers were determined by the Worm plot [11] and by Q-statistics [12].

Results

Preliminary analysis

At baseline, the mean age of the 89 selected patients (70 males, 19 females) was 66.2 (SD 9.0) years. Mean body mass index was 28.7 (SD 6.3) kg/m^2, mean forced expiratory volume in 1 second (FEV_1) was 84 (SD 20)% predicted [20], mean forced vital capacity (FVC) was 91 (SD 17)% predicted, mean FEV_1/FVC was 95 (SD 15)%, mean P_{i-max} was 83 (SD 29) cmH_2O and mean P_{m-peak}/P_{i-max} was 43 (SD 20)%, where P_{m-peak} is maximal peak pressure. In terms of New York Heart Association class, five patients were Class I, 16 patients were Class II, 66 patients were Class III and two patients were Class IV.

Reference values and chart

Fig. 1 shows the reference chart developed for clinical use. It portrays the distribution of P_{i-max} as a function of training week. The distribution is described by centile lines at −2 SD, −1 SD, 0 SD, +1 SD and +2SD, corresponding to 2%, 16%, 50%, 84% and 98% of the reference population, respectively.

All centiles rise with training duration. Training during the first few weeks leads to the greatest gains in inspiratory muscle strength. The effect of IMT tapers off after approximately 5 to 6 weeks. Interestingly, patients with lower scores at Week 0 have steeper curves, so the gain in inspiratory muscle strength in patients that start off in the lower centiles is generally larger. Overall, the increase in inspiratory muscle strength from Week 0 to Week 6 is approximately 1 SD. Table 1 shows the corresponding reference data.