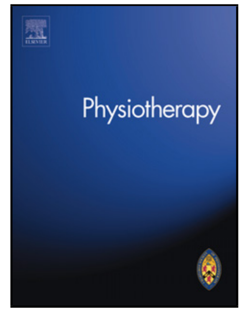
Accepted Manuscript



Title: Differences in selection and application of respiratory treatments by on-call physiotherapists in mechanically ventilated children: A randomised crossover trial

Author: Harriet Shannon Janet Stocks Rachael K. Gregson Sarah Hines Mark J. Peters Eleanor Main

PII: S0031-9406(15)00002-4
DOI: http://dx.doi.org/doi:10.1016/j.physio.2014.12.001
Reference: PHYST 797

To appear in: *Physiotherapy*

Received date: 9-6-2014
Accepted date: 27-12-2014

Please cite this article as: Shannon H, Stocks J, Gregson RK, Hines S, Peters MJ, Main E, Differences in selection and application of respiratory treatments by on-call physiotherapists in mechanically ventilated children: a randomised crossover trial, *Physiotherapy* (2015), http://dx.doi.org/10.1016/j.physio.2014.12.001

Title: Differences in selection and application of respiratory treatments by on-call physiotherapists in mechanically ventilated children: a randomised crossover trial

Authors and affiliations:

Harriet Shannon[a], Janet Stocks[a], Rachael K Gregson[a,b], Sarah Hines[b], Mark J Peters[a,c], Eleanor Main[a]

[a] Respiratory, Critical Care and Anaesthesia section in Infection, Immunity, Inflammation and Physiological Medicine. University College London Institute of Child Health, 30 Guilford Street, London WC1N 1EH, United Kingdom

[b] Physiotherapy Department, Great Ormond Street Hospital for Children NHS Foundation Trust, Great Ormond Street, London WC1N 3JH, United Kingdom

[c] Intensive Care Department, Great Ormond Street Hospital for Children NHS Foundation Trust, Great Ormond Street, London WC1N 3JH, United Kingdom

Correspondence (for review and publication):

Dr Harriet Shannon (PhD)

Respiratory, Critical Care and Anaesthesia section in Infection, Immunity, Inflammation and Physiological Medicine. University College London Institute of Child Health, 30 Guilford Street, London WC1N 1EH United Kingdom

Tel: +44 (0) 207 905 2689, Fax: +44 (0) 20 7829 8634

Email: h.shannon@ucl.ac.uk

Word Count: 3,444 words

Abstract

Objectives: To investigate differences, if any, in the delivery of respiratory treatments to mechanically ventilated children between non-respiratory on-call physiotherapists and specialist respiratory physiotherapists.

Setting: Paediatric, tertiary care hospital in the United Kingdom.

Participants: 93 children (aged between 3 days and 16 years), and 22 physiotherapists (10 specialist respiratory physiotherapists) were recruited to the study.

Interventions: Recruited children received two physiotherapy treatments during a single day, one delivered by a non-respiratory physiotherapist, the other by a specialist respiratory physiotherapist in a randomised order. Selection, delivery and effects of techniques were recorded for each treatment.

Outcome measures: Primary outcomes were selection and application of treatment components. Secondary outcomes included respiratory effects (in terms of changes in flow, volume and pressure) of selected treatment components.

Results: Both non-respiratory on-call physiotherapists and specialist respiratory physiotherapists used combinations of saline instillation, manual lung inflations, chest wall vibrations and endotracheal suction during treatments. However specialist respiratory physiotherapists used combinations of chest wall vibrations with suction, and recruitment manoeuvres, significantly more frequently than non-respiratory on-call physiotherapists (92% versus 52%, and 87% versus 46% of treatments respectively, $p<0.001$). Chest wall vibrations delivered by non-respiratory on-call physiotherapists were 15% less effective at increasing peak expiratory flow.

Conclusion: Clinically important differences between non-respiratory and specialist respiratory physiotherapists' treatment outcomes may be related to differences in the selection and application of techniques. This suggests an important training need for non-respiratory on-call physiotherapists, particularly in the effective delivery of physiotherapy techniques.

Trial registration: Clinicaltrials.gov NCT01999426

Key-words: After-hours care, Acute Respiratory, Pediatric Intensive Care Units, Physiotherapy Specialty

INTRODUCTION

Paediatric respiratory physiotherapy treatments during the day are generally administered by, or under the supervision of, physiotherapists who specialise in the treatment of children with respiratory conditions (often referred to as specialist respiratory physiotherapists in the UK). However, overnight and at weekends the on-call physiotherapy rota is likely to be populated by physiotherapists from other specialties within the hospital (e.g. musculoskeletal physiotherapy, orthopaedics or neurology). Significant fluctuations in cardiovascular stability, in critically ill patients, can contribute to organ failure or lung damage [1]. It is not uncommon for some ventilated patients to exhibit short-term deteriorations in lung function following physiotherapy treatments even when administered by specialist intensive care staff [2].

It is possible that the risk of significant deterioration is increased when inexperienced on-call staff perform such interventions. Differences in clinical outcomes have been described between ventilated children who were treated by non-respiratory on-call staff in comparison with specialist respiratory physiotherapists [3]. On a case-by-case level, there were significantly fewer clinically important improvements when patients were treated by on-call physiotherapists, as well as a greater number of deteriorations and adverse events [3]. To examine and explain these differences, as well as identify potential opportunities for training, a detailed analysis of physiotherapy treatments was undertaken.

The aims of the current paper were to describe any differences in the selection, application and effects of treatment components used by non-respiratory on-call physiotherapists and specialist respiratory physiotherapists during treatments of mechanically ventilated children in intensive care.

METHODS

Study design and participants

The study was a prospective, randomised crossover trial. This is the most appropriate design given the heterogeneity of patients in the intensive care unit because it controls for variability associated with diverse clinical circumstances [4]. Ethical approval for the study was granted by the UCL, Institute of Child Health and Great Ormond Street Hospital for Children NHS Foundation Trust ethics committee (REC number 06/Q0508/56). Written, informed consent was gained from the parents or guardians of all recruited children, and from the participating physiotherapists.

The participants, therapists and centre were described previously [3]. Recruitment took place at a specialist paediatric hospital, a tertiary centre with one of the largest intensive care units for children in the United Kingdom and Europe. Eligible patients were children (from birth to 16 years of age) who were mechanically ventilated at the time of recruitment. Patients were eligible if they were deemed to require at least two physiotherapy interventions over the course of a single day, as assessed by a senior respiratory physiotherapist independent from the study. Patients were excluded if they were at risk of haemorrhage, had osteoporosis, rib fractures or other contra-indications to manual techniques or were medically unstable. Power and sample size calculations were based on clinical outcomes, as described previously [3].

Both non-respiratory on-call physiotherapists (NRP) and specialist respiratory physiotherapists (SRP) were recruited to the study, as described previously [3]. The NRP were physiotherapists, of band 6 or higher (which usually suggests at least 3 years of clinical experience), who specialised in non-respiratory areas of paediatric physiotherapy. The SRP were also of band 6 or higher, who were currently working in paediatric respiratory care [3].

Procedures

Recruited patients received two physiotherapy treatments during a single day, one delivered by an NRP and the other by an SRP, in a randomised order. Randomisation of treatment order was achieved using a computerised random numbers generator.

The first selected physiotherapist (either NRP or SRP) assessed the patient and made a clinical decision as to whether a treatment was required. If a treatment was deemed necessary, the $NICO_2$® Respiratory Profile Monitor (Philips Respironics, Wallingford, CT, USA), was inserted between the patient's endotracheal tube and ventilator circuit. The monitor measured pressure, flow and CO_2 concentration continuously and instantaneously via a disposable, fixed-orifice, differential flow sensor with incorporated mainstream infrared absorption capnography. Accompanying software (AnalysisPlus!®) captured and recorded breath-by-breath peak inflation pressure, positive end-expiratory pressure (PEEP), peak inspiratory flow and expiratory flow (PEF) directly, and contained algorithms for calculating further respiratory outcomes, including inspired and expired volumes. The $NICO_2$® remained in place during the delivery of the entire treatment.

Following the physiotherapist's initial assessment, a custom-designed thin, flexible force-sensing mat (Pliance®, Novel GmbH, Munich, Germany), was placed over the child's chest, covering the area that was likely to require the application of manual techniques. The force-sensing mat has been described and validated previously [5]. The mat measured the dynamic pressure distribution and perpendicular force by means of 192 individually calibrated capacitance sensors within the mat. Each sensor comprised a compliant material sandwiched between two electrodes, the capacitance of which changed when forces were applied to the electrodes. The area through which the force is delivered is constantly changing, both during a chest wall vibration (as the vibration proceeds) and between therapists. This is reflected in changing pressure (and area) values seen between physiotherapists [5].

The force-sensing mat was calibrated before and after each study, and data acquisition software provided data on function of individual sensor cells during data collection. The system had a drift of $<5\%$ with minimal hysteresis and minimal measurement error across the full force range [6]. The performance of the sensors was measured before and after each treatment to ensure there was no failure of individual cells. No damage was detected over the course of the study. The force mat remained in position for the entirety of the treatment, but could be removed for auscultation. When the physiotherapist applied manual techniques, they did so over the force sensing mat. Previous studies have confirmed that the force mat (<1.5 mm thick) does not interfere with the application of manual techniques and that palpatory feedback is still possible through the mat [7].

Electronically timed treatment notes were continuously entered into the AnalysisPlus!® program by the researcher to document specific treatment elements (for example, periods of saline delivery, manual lung inflations, manual techniques and endotracheal suction). No instructions were given concerning the use or order of any specific treatment components and all physiotherapists applied treatments according to their clinical judgment.

The data collection protocol was repeated with a different physiotherapist later on in the day (usually following an interval of at least 3 hours). If an SRP had treated the patient in the morning, an NRP treated in the afternoon, or vice versa [3].

Outcomes measures

The primary outcome measures were selection and application of treatment components. Secondary outcomes included respiratory effects of treatment components, in terms of forces applied during manual techniques and the respiratory response. The duration of time spent at the patient's bedside during assessment and treatment, any changes in patient position and the total volume of saline used were also measured.

Data Analysis

Data were downloaded into SPSS vs 18.0 prior to analysis. Paired data for each child were analysed using paired-samples t-tests or their non-parametric equivalent when appropriate, to compare interventions delivered by NRP and SRP. Where treatment components were selected on some test occasions but not others, Fisher's two-tailed exact test was used to calculate differences in proportions between NRP and SRP treatments. Analysis of covariance with fixed subject effects was used to calculate the relative contribution that changes in force, pressure and volume made to changes in PEF between baseline and manual lung inflations with and without chest wall vibrations for NRP and SRP.

In this, as in other studies, PEF was used as a surrogate measure of airway clearance [5,8,9]. An enhanced PEF, or expiratory flow bias theoretically improves mucus movement from the peripheral to the central airways from where it could be removed by suction or a cough [20,21].

RESULTS

Ninety three children were recruited to the study between 2008 and 2010, and paired sets of data were successfully collected in 63 (68%) of these patients, aged between 3 days and 16 years [3]. Twenty three physiotherapists were eligible to participate in the study, and 22 were recruited, of whom 10 were SRP. The physiotherapists ranged in clinical experience from clinical specialists with greater than 10 years clinical experience (n=2, one SRP), senior physiotherapists with greater than 5 years clinical experience (n=9, two SRP) and physiotherapists with greater than 3 years clinical experience undertaking clinical rotations as part of their training, (n=11, 7 SRP).

Selection of treatment components by NRP and SRP

All treatments for the recruited patients consisted of combinations of saline instillation, manual lung inflations, chest wall vibrations and endotracheal suction. There were no significant differences in the volume of saline instilled, the number of suctions or number of patient position changes per treatment (Table 1). NRP spent, on average, 7 minutes longer at each patient's bedside than SRP (mean [SD] 28[10] minutes and 21[8] minutes for NRP and SRP respectively, [95% CI of difference: 4 to 10minutes], p<0.0001). The additional times spent at the bedspace were related to both longer assessments and longer treatments by the NRP, although only increased assessment time achieved statistical significance (Table 1).

Treatments sometimes involved simultaneous application of chest wall vibrations during endotracheal suction in patients who were not sufficiently conscious to cough spontaneously during suction. This comprised insertion of the suction catheter, and application of manual chest wall vibrations whilst applying negative pressure to the suction catheter and withdrawing it from the open tracheal tube (this dual activity being performed by a single physiotherapist, not as a two-person treatment). This combination of treatment components occurred in only 33/63 (52%) of NRP treatments, compared with 58/63 (92%) of SRP treatments (mean [95% CI of difference] in proportions 40% [27 to 53%]; p <0.001).

At the end of treatments, SRP almost routinely applied repeated slow, deep manual inflation breaths with an inspiratory hold before returning the patients to the ventilator (55/63 [87%] of treatments). By contrast, these 'recruitment breaths' were applied at the end of only 31/63 [46%] of NRP treatments (mean [95% CI] (41% [27 to 55%], p <0.001).

Differences in pressure, volume and flow at the airway opening during manual lung inflations and chest wall vibrations, when applied by NRP and SRP

Respiratory outcomes were measured during baseline and manual lung inflations, both with and without chest wall vibrations (Table 2). Both NRP and SRP tended to undertake treatments as single-person treatments, with the same physiotherapist delivering both manual lung inflations and chest wall vibrations. For both NRP and SRP, there were statistically significant increases in flow, pressure and volume when manual lung inflations were applied, both in isolation and in combination with chest wall vibrations, compared with baseline. Non-respiratory physiotherapists applied higher peak inspiratory pressure during manual lung inflations than SRP, which was matched by a similar increase in PEEP, the overall *change* in pressure (i.e inflation pressure minus PEEP) therefore being similar for NRP and SRP.

During chest wall vibrations, NRP applied significantly less force than SRP (median [range] force 23N [12 to 162N] and 42N [19 to 171N] respectively, p=0.008). This resulted in significantly less PEF being generated by NRP (Table 2).

The percentage change in respiratory data from baseline to manual lung inflations with and without chest wall vibrations was calculated for each treatment. For both NRP and SRP, PEF increased by 7% for every 10% increase in peak inspiratory pressure (p<0.05), and *decreased* by 1% for every 10% increase in PEEP (p<0.05). For SRP, PEF increased by an additional 3% for every 10% increase in inspired volume (p<0.05) and 7% for each 10N of force delivered during chest wall vibrations (p<0.05). By contrast, neither inspired volume nor the force delivered during chest wall vibrations had any significant impact on variance of PEF during NRP treatments. Changes in peak inspiratory pressure and PEEP explained 90% of the variance in PEF for the NRP, whereas changes in peak inspiratory pressure, PEEP, inspired volume *and* force explained 86% of the variance in PEF for SRP.

DISCUSSION

This is the first study to examine the complex similarities and differences in respiratory treatments delivered by NRP and SRP to ventilated children. The study found that NRP treatments often involved less complex techniques, and smaller forces during chest wall vibrations, which were not as effective at increasing PEF as when delivered by SRP. NRP also tended to spend longer at the bedspace than SRP, but their treatments were less likely to be as clinically effective [3]. The effects of PEEP (and peak inspiratory pressure) on treatments delivered by NRP and SRP also merit further consideration.

Specialist respiratory physiotherapists used two specific treatment components more frequently than on-call physiotherapists. The first was to combine chest wall vibrations with suction and the second was to deliver manual lung ‘recruitment’ breaths at the end of a treatment session. One aim of chest wall vibrations during suction is to increase expiratory airflow and move secretions proximally, particularly in patients unlikely to cough spontaneously when the suction catheter is introduced. Although a vital part of airway hygiene, endotracheal suction is associated with a rapid reduction in functional residual capacity [10,11], and has been cited as a cause of atelectasis, which is likely to be exacerbated further when applying additional external chest wall compression to the compliant paediatric chest wall [12,13]. In isolation, this physiotherapy technique may cause further acute de-recruitment of the small airways [14]. Therefore applying manual recruitment breaths at the end of treatments may play an important role in increasing alveolar ventilation and oxygenating the lung prior to returning the patient to the mechanical ventilator [15].

Animal studies have suggested that a recruitment manoeuvre after endotracheal suction counteracts the negative effects of suction, including atelectasis, decreased lung volume and reduced respiratory compliance [11]. It would theoretically be advantageous to apply manual lung inflations prior to returning patients to the ventilator, rather than finishing a treatment with an endotracheal suction. Suction as the final treatment component may leave some atelectatic areas that could take considerable time to re-inflate when the patient was returned to the mechanical ventilator [16]. These differences between NRP and SRP may help to explain why respiratory outcomes tended to favour SRP treatments [3].

During manual lung inflations, NRP maintained similar PEEP to those measured at baseline mechanical ventilation, while SRP reduced PEEP by, on average, $2cmH_2O$. Maintaining PEEP during manual lung inflations may theoretically prevent alveolar collapse and improve ventilation-perfusion matching via the increase in mean airway pressure and reduction in potential shear stresses in the distal lung units [17]. Thus from the perspective of lung protection and recruitment, NRP might be perceived to have the desired or preferred technique. However, the aim of manual lung inflations during respiratory physiotherapy is only partly related to lung recruitment, a significant additional aim being to enhance airway clearance. This is achieved by applying manual lung inflations with or without chest wall vibrations to increase PEF and promote an expiratory airflow bias [5,18]. A bench study examining the effects of PEEP on PEF during lung inflations in a lung model found that high PEEP (greater than $10cmH_2O$) significantly limited the extent to which PEF could be increased [19]. The authors suggested that with high levels of PEEP the decrease in the pressure gradient between the mouth and alveoli may reduce PEF to such a degree that it is no longer effective for mucus movement.

The manual lung inflation circuits used in this study were highly distensible flow-dependent Intersurgical™ reservoir bags with a manual pressure control outlet. PEEP is maintained by sustaining a degree of occlusion at the outlet during manual techniques, by coordinated finger compression. It is possible that in some cases the maintenance of PEEP during chest wall vibrations by NRP was not an intentional decision, but the result of inadequate control of the reservoir bag. Whilst maintaining PEEP during lung inflations could be recommended to maintain lung recruitment, this study demonstrated that PEF was only significantly increased when accompanied with a *reduction* in PEEP during CWV. Thus, if mucus movement is the priority of treatment, then maintenance of PEEP may be a disadvantage.

Specialist respiratory physiotherapists were more effective than NRP at utilising chest wall vibrations to affect a higher PEF compared with manual lung inflations alone. For NRP, forces applied during chest wall vibrations were not a significant contributory factor to the generation of PEF, since the size of the delivered inspiratory breath alone contributed to enhanced PEF. The effectiveness of chest wall vibrations may be related to, amongst other factors, the direction of force and the timing and coordination between the chest wall vibrations and the patient's breathing cycle (whether it is spontaneous or manually delivered) [9]. Studies in animals and lung models have demonstrated that an increase in absolute PEF and the creation of an expiratory airflow bias relative to inspiration improves the central flow of secretions. A faster PEF theoretically enhances mucus movement from the peripheral to the central airways from where it could be removed by suction or a cough [8,20,21].

The current study found that NRP spent, on average, 7 minutes longer at the bedspace of each child they treated, compared with SRP. This was predominantly due to more prolonged assessments. The intensive care unit is a complex environment with a large amount of information pertaining to each patient available from medical charts, ventilation and vital signs monitors, chest radiographs and medical and nursing staff. It is therefore unsurprising that NRP, whose area of expertise lies in non-respiratory areas, tended to take longer to gather and process relevant information prior to treating critically ill infants and children. In many cases, extra time spent in assessment by a novice therapist is wise, as this may be required to process and make decisions regarding the safety of an intervention. However, during the current study, all patients were relatively stable at the time of physiotherapy treatment. In an emergency on-call scenario, a prolonged assessment (and thus delayed treatment) may cause an unstable patient with retained secretions to deteriorate rapidly, before the treatment has taken place.

Expertise in respiratory physiotherapy is hard to define, but is likely to develop from experience, frequent exposure to the patient population, critical thinking and reflective practice [22]. The greater number of successful treatments described previously imply that the delivery of treatments by SRP are more beneficial to the patient [3]. In-depth analysis of the differences in application yielded a number of identifiable features that differentiated SRP from NRP treatments. These features do not form an exhaustive list, and a causal relationship between certain treatment components and treatment outcomes is far from confirmed. Potentially, these differences could be minimised through specific, focussed training strategies which may result in a narrower gap between NRP and SRP treatments and outcomes.

Limitations

Limitations of the entire study are discussed in the accompanying paper [3]. The advantage of the force-sensing mat is that it can be used in the clinical setting to measure forces applied during manual techniques [5]. However, it only measures perpendicular force, whilst shearing forces remain unquantified. During the development phase of the force-sensing mat, with careful observation and analysis of a variety of manual techniques, the authors concluded that most of the force transmitted during chest wall vibrations is generated through the hand at a perpendicular angle to the mat, thus the forces recorded are likely to be accurate in terms of magnitude [5].

Generalisability of results

The generalisability of the results are discussed in the accompanying paper [3]. Briefly, these relate to the fact that differences between NRP and SRP in this study are likely to give a conservative picture of differences that might occur during emergency on-call scenarios, and those occurring in larger hospitals. The combined effect of sleep deprivation, stress and anxiety of an unknown patient (and potentially unknown ward or unit) and lack of immediate senior supervision, may all contribute to a wider gap between those treatments delivered during the day, and those delivered at night. Meanwhile, larger hospitals may have a wider skill mix of staff, in terms of both specialty and experience (include newly qualified graduate physiotherapists), which create an even more challenging environment in terms of maintaining clinical competence in the respiratory field. While it is impossible to quantify what effects these two components might have on the competence of on-call physiotherapists, this study has demonstrated that even with near optimal conditions for a successful on-call rota, discrepancies remain between NRP and SRP [3].

Clinical implications

A balance is needed between only allowing SRPs to treat children in intensive care, and accepting that on-call physiotherapy is vital for the training and maintenance of competence amongst NRPs. This study suggests that clinically important differences between non-respiratory and specialist respiratory physiotherapists' treatment outcomes may be related to differences in the selection and application of techniques. With focused, specific training, there is the potential to improve the selection and application of techniques delivered by NRPs, with clinically advantageous consequences.

Acknowledgements: The authors wish to thank the patients and their families, and the physiotherapists who agreed to participate in the study. Also thanks are due to Tim Cole, Professor of Medical Statistics at the UCL Institute of Child Health for his invaluable statistical support. The study was funded in part by the Physiotherapy Research Foundation (Chartered Society of Physiotherapy), and in part by the Great Ormond Street Hospital Children's Charity Board of Special Trustees.

Ethical approval: Ethical approval for the study was granted by the UCL, Institute of Child Health and Great Ormond Street Hospital for Children NHS Foundation Trust ethics committee (REC number 06/Q0508/56). Written, informed consent was gained from the parents or guardians of all recruited children, and from the participating physiotherapists.

Funding

The study was funded in part by the Physiotherapy Research Foundation (Chartered Society of Physiotherapy), and in part by the Great Ormond Street Hospital Children's Charity Board of Special Trustees.

Role of the funding source

Funders were not involved in the design of the study; data analysis, data interpretation, writing of the report; or the decision to submit the paper for publication. The corresponding author had full access to all the data in the study and had final responsibility for the decision to submit for publication.

Conflict of interest statement

There are no competing interests associated with this study.

REFERENCES

[1] Stiller K. Physiotherapy in intensive care: towards an evidence-based practice. Chest 2000;118:1801-13

[2] Main E, Castle R, Newham D, Stocks J. Respiratory physiotherapy vs. suction: the effects on respiratory function in ventilated infants and children. Intensive Care Med 2004;30:1144-51

[3] Shannon H, Stocks J, Gregson RK, Dunne C, Peters M, Main E. Clinical effects of on-call physiotherapy in mechanically ventilated children: a randomised crossover trial. Physiotherapy. *currently with Editor*

[4] Elbourne DR, Altman DG, Higgins JP, Curtin F, Worthington HV, Vail A. Meta-analyses involving cross-over trials: methodological issues. Int J Epidemiol 2002;31:140–9.

[5] Gregson RK, Stocks J, Petley GW, Shannon H, Warner, JO, Jagannathan R et al. Simultaneous measurement of force and respiratory profiles during chest physiotherapy in ventilated children. Physiol Meas 2007;28:1017–28.

[6] Polliack A, Landsberger S, McNeal D, Sieh R, Craig D, Ayyappa E. Socket measurement systems perform under pressure. Biomech 1999;6:71–80.

[7] Shannon H, Gregson R, Stocks J, Cole T, Main E. Repeatability of physiotherapy chest wall vibrations applied to spontaneously breathing adults. Physiotherapy 2009; 95: 36-42.

[8] Gregson RK, Shannon H, Stocks J, Cole TJ, Peters MJ, Main E. The unique contribution of manual chest compression-vibrations to airflow during physiotherapy in sedated, fully ventilated children. Pediatr Crit Care Med 2012;13: e97–e102.

[9] Shannon H, Stiger R, Gregson RK, Stocks J, Main E. Effect of chest wall vibration timing on peak expiratory flow and inspiratory pressure in a mechanically ventilated lung model. Physiotherapy 2010;96: 344–49.

[10] Heinze H, Sedemund-Adib B, Heringlake M, Gosch UW, Eichler W. Functional residual capacity changes after different endotracheal suctioning methods. Anesth Analg 2008;107: 941–44.

[11] Lindgren S, Odenstedt H, Olegard C, Sondergaard S, Lundin S, Stenqvist O. Regional lung derecruitment after endotracheal suction during volume- or pressure-controlled ventilation: a study using electric impedance tomography. Intens Care Med 2007;33:172–180.

[12] Morrow B, Futter M, Argent A. Effect of endotracheal suction on lung dynamics in mechanically-ventilated paediatric patients. Aust J Physiother 2006;52: 121–26.

[13] Choong K, Chatrkaw P, Frndova H, Cox PN Comparison of loss in lung volume with open versus in-line catheter endotracheal suctioning Pediatr Crit Care Med 2003;4: 69–73.

[14] Unoki T, Mizutani T, Toyooka H. Effects of expiratory rib cage compression combined with endotracheal suctioning on gas exchange in mechanically ventilated rabbits with induced atelectasis. Respir Care 2004;49: 896–901.

[15] Patman S, Jenkins S, Stiller K. Manual hyperinflation-effects on respiratory parameters. Physiother Res Int 2000;5:157–71.

[16] Kasim I, Gulyas M, Almgren B, Högman M. A recruitment breath manoeuvre directly after endotracheal suction improves lung function: an experimental study in pigs Upsala J Med Sci 2009;114: 129–35.

[17] McCann UG, Schiller HJ, Carney DE, Gatto LA, Steinberg JM, Nieman GF.Visual validation of the mechanical stabilizing effects of positive end-expiratory pressure at the alveolar level. J Surg Res 2001;99: 335–42.

[18] McCarren B, Alison JA, Herbert RD. Vibration and its effect on the respiratory system. Aust J Physiother 2006;52:39–43.

[19] Savian C, Chan P, Paratz J. The effect of positive end-expiratory pressure level on peak expiratory flow during manual hyperinflation. Anesth Analg 2005;100:1112–16.

[20] Kim CS, Iglesias AJ, Sackner MA. Mucus clearance by two-phase gas-liquid flow mechanism: asymmetric periodic flow model. J Appl Physiol 1987;62:959–71.

[21] King M, Brock G, Lundell C. Clearance of mucus by simulated cough. J Appl Physiol 1985;58:1776–82.

[22] Smith M, Higgs J, Ellis E. Effect of experience on clinical decision making by cardiorespiratory physiotherapists in acute care settings. Physiother Theory and Pract 2010;26:89–99.

TABLES

Table 1 Treatment techniques used during physiotherapy treatments

	NRP Median (range)	SRP Median (range)	Median difference SRP-NRP (95% CI)
Duration of Assessment (min)	12 (1.7 to 30)	19 (6.03 to 38)	4.5 (3 to 8.5)***
Duration of Treatment (min)	7.1 (2.1 to 27)	9.0 (2.2 to 28)	0.8 (-1, 1.95)
Volume of saline instilled (mL)	3 (0.5 to 20)	2.7 (1 to 20)	-0.3 (-1, 0)
Number of suction passes (n)	3 (1 to 9)	3 (1 to 7)	-0.1 (0.6, 0.3)
Number of patient repositions (n)	0 (0 to 3)	0 (0 to 2)	-0.1 (-0.13, 0.3)

NRP: non-respiratory physiotherapists, SRP: specialist respiratory physiotherapists, ***p<0.0001

Table 2 Respiratory outcomes during baseline ventilation, manual lung inflations and chest wall vibrations applied by specialist respiratory physiotherapists, and non-respiratory on-call physiotherapists

	Baseline	MLI NRP	MLI SRP	Mean diff. (95% CI) SRP-NRP	CWV NRP	CWV SRP	Mean diff. (95% CI) SRP-NRP
PIF ($L.min^{-1}.kg^{-1}$)	0.9 (0.4)	1.2 (0.4)	1.2 (0.5)	0.05 (-0.02, 0.1)	1.5 (1.0)	1.5 (0.7)	0.1 (-0.02, 0.3)
PEF ($L.min^{-1}.kg^{-1}$)	1.0 (0.3)	1.2 (0.3)	1.2 (0.5)	0.01 (-0.1, 0.1)	1.9 (0.6)	2.2 (0.7)	**0.24 (0.07, 0.41)***
V_I ($mL.kg^{-1}$)	7.0 (1.6)	9.5 (3.9)	9.3 (3.6)	-0.2 (-1.2, 0.9)	13 (5.3)	15 (5.5)	1.7 (0.26, 3.0)
V_E	6.9 (1.6)	8.6 (3.6)	8.7 (3.4)	0.1	17 (6.0)	19 (6.0)	2

($mL.kg^{-1}$)				(-1.1, 1.1)			(-0.7, 3.8)
PIP	21 (3.3)	30 (7.0)	28 (5.2)	**-2.3**	38 (8.3)	37 (8.0)	-1.4
(cmH_2O)				**(-4.0, -0.6,)****			(-3.6, 0.9)
PEEP	6.4 (1.8)	6.2 (3.8)	4.3 (2.3)	-1**.7**	5.9 (5.4)	2.8 (3.0)	**-2.9**
(cmH_2O)				**(-2.7, -0.8)*****			**(-4.3, -1.4,)*****

MLI: manual lung inflations CWV: chest wall vibrations SRT: specialist respiratory therapists NRT: non-respiratory therapists 95% CI: 95% confidence intervals PIF: peak expiratory flow PEF: peak expiratory flow V_I: inspiratory volume V_E: expiratory volume PIP: peak inflation pressure PEEP: positive end expiratory pressure. Difference between SRT and NRT treatments calculated using paired-samples t-test *p<0.05 **p<0.01 ***p<0.001