CHEST Original Research
CRITICAL CARE

Physiotherapy in Intensive Care

An Updated Systematic Review

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Background: **Although physiotherapy is frequently provided to patients in the ICU, its role has been questioned. The purpose of this systematic literature review, an update of one published in 2000, was to examine the evidence concerning the effectiveness of physiotherapy for adult, intubated patients who are mechanically ventilated in the ICU.**
Methods: **The main literature search was undertaken on PubMed, with secondary searches of MEDLINE, CINAHL, Embase, the Cochrane Library, and the Physiotherapy Evidence Database. Only papers published from 1999 were included. No limitations were placed on study design, intervention type, or outcomes of clinical studies; nonsystematic reviews were excluded. Items were checked for relevance and data extracted from included studies. Marked heterogeneity of design precluded statistical pooling of results and led to a descriptive review.**
Results: **Fifty-five clinical and 30 nonclinical studies were reviewed. The evidence from randomized controlled trials evaluating the effectiveness of routine multimodality respiratory physiotherapy is conflicting. Physiotherapy that comprises early progressive mobilization has been shown to be feasible and safe, with data from randomized controlled trials demonstrating that it can improve function and shorten ICU and hospital length of stay.**
Conclusions: **Available new evidence, published since 1999, suggests that physiotherapy intervention that comprises early progressive mobilization is beneficial for adult patients in the ICU in terms of its positive effect on functional ability and its potential to reduce ICU and hospital length of stay. These new findings suggest that early progressive mobilization should be implemented as a matter of priority in all adult ICUs and an area of clinical focus for ICU physiotherapists.**
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Abbreviations: IMT = inspiratory muscle training; LOS = length of stay; MH = manual hyperinflation; NMES = neuromuscular electrical stimulation; RCT = randomized controlled/comparative trial; VAP = ventilator-associated pneumonia; VH = ventilator hyperinflation

In most developed countries, physiotherapy is seen as an integral component of the multidisciplinary management of patients in ICUs. The role of physiotherapy in the ICU and the treatment techniques used by physiotherapists in the ICU vary considerably between units, depending on factors such as the country in which the ICU is located, local tradition, staffing levels, and expertise. In 2000, Stiller[1] published a literature review investigating the effectiveness of physiotherapy for adult, intubated patients on mechanical ventilation in the ICU, covering a broad range of physiotherapy practice. This concluded that there was only limited evidence concerning the effectiveness of physiotherapy in this setting and identified an urgent need for further research to be conducted to justify the role of physiotherapy in the ICU. The review is frequently cited in articles concerning the role of physiotherapy in the ICU. Given that >10 years have passed since its publication, what new evidence regarding the role of physiotherapy in the ICU has emerged? Does this new evidence confirm the role

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of physiotherapy in the ICU? Does it highlight areas of clinical practice where physiotherapy is most effective?

The objective of this systematic review was to update a summary of the evidence concerning the effectiveness of physiotherapy in the ICU. In keeping with Stiller,[1] this review only considers the management of adult, intubated patients on mechanical ventilation.

Materials and Methods

Search Strategy and Study Selection

The PICOS (population, intervention, comparison, outcome and study design) criteria used in this study were deliberately broad to capture all relevant articles, requiring only that the population comprised adult (aged ≥ 18 years), intubated, mechanically ventilated patients being cared for in an ICU setting and that a physiotherapy intervention had been evaluated or discussed. No limitations were placed on study outcomes. All relevant clinical articles were included and systematic literature reviews, expert opinion papers, and surveys were also eligible for inclusion. The primary literature search was conducted using the PubMed database for articles published from January 1, 1999, to July 31, 2012, using the following search terms: "intensive care" AND "physiotherapy." Additional searches were undertaken on PubMed using the terms "critical care" or "intensive care" AND "physical therapy," "therapeutic exercise," "functional training," "exercise," "exercise therapy," "mobilisation," "rehabilitation" or "ambulation." Secondary searches, using the same time limitations and search terms, were undertaken on MEDLINE, CINAHL, Embase, Cochrane Library, and the Physiotherapy Evidence Database. Titles and abstracts generated by the search strategy were assessed for eligibility and full-text copies of articles deemed to be potentially relevant were retrieved. Duplicate publications were excluded. If relevant articles could not be accessed via the Internet, authors were contacted directly. Given that this was a nonclinical study, institutional review board approval was not sought.

Methodological Quality and Analysis

The methodological quality of randomized controlled or comparative trials (RCTs) was appraised with reference to the National Health and Medical Research Council Guidelines[2] and Consolidated Standards of Reporting Trials (CONSORT) statement.[3] All data were extracted by the author. Marked heterogeneity of study design and outcome measures precluded statistical pooling of results for meta-analysis, hence a descriptive summary of the findings is presented.

Results

Literature Search

The initial PubMed literature search identified 849 items published since 1999, with 50 relevant studies (34 clinical, 16 nonclinical) included in the review. An additional 35 relevant studies (21 clinical, 14 nonclinical) were retrieved in a broader PubMed search or from other databases. Thus, in total, 85 new studies (55 clinical, 30 nonclinical) were reviewed. Articles were most often excluded because they did not study the population and/or intervention of interest (Fig 1).

Systematic Reviews

Twelve systematic literature reviews were identified. Their characteristics, including a summary of their results and conclusions, are shown in Table 1.[4-15] In contrast to the current review, which covers a wide range of ICU physiotherapy practices, these reviews focused on specific areas of physiotherapy practice in the ICU, with the most frequent topic being the early mobilization and rehabilitation of patients in the ICU.[4-10] Despite only limited data being available, most concluded that early mobilization and rehabilitation are safe and effective in the ICU setting, although further research is required to confirm and extend its role.[4-10]

Clinical Trials: Study and Patient Characteristics

The clinical trials reviewed evaluated a variety of physiotherapy interventions, including multimodality respiratory physiotherapy, mobilization, inspiratory muscle training (IMT), and neuromuscular electrical stimulation (NMES). For the sake of clarity, study findings are presented according to the intervention evaluated.

Multimodality Respiratory Physiotherapy: Eighteen clinical trials were identified that evaluated the effectiveness of multimodality respiratory physiotherapy, with the interventions studied including various combinations of positioning, manual hyperinflation (MH), ventilator hyperinflation (VH), chest wall vibrations, and rib-cage compression.[16-33] The characteristics and main findings of these 18 studies are shown in Table 2 (sorted according to methodological quality and sample size). There were five RCTs,[16-20] nine randomized crossover trials,[21-29] one systematically allocated controlled trial,[30] one historical controlled trial,[31] and two observational studies.[32,33]

Four of the five RCTs were well designed and involved samples of at least 101 patients.[16-19] Study populations comprised patients who were intubated and mechanically ventilated after cardiac surgery,[16] mechanically ventilated > 48 h,[17,19] or mechanically ventilated with acquired brain injury.[18] Patients were prospectively randomly allocated to a control group (usually receiving standard medical/nursing care) or a treatment group that received additional multimodality respiratory physiotherapy (comprising a combination of techniques such as positioning, MH, with or without chest wall vibrations). Frequency of this additional multimodality respiratory physiotherapy was as clinically indicated in two studies,[16,17] bid,[19] and six times a day.[18] Medium-term clinical outcomes such as duration of intubation, incidence of ventilator-associated pneumonia (VAP),

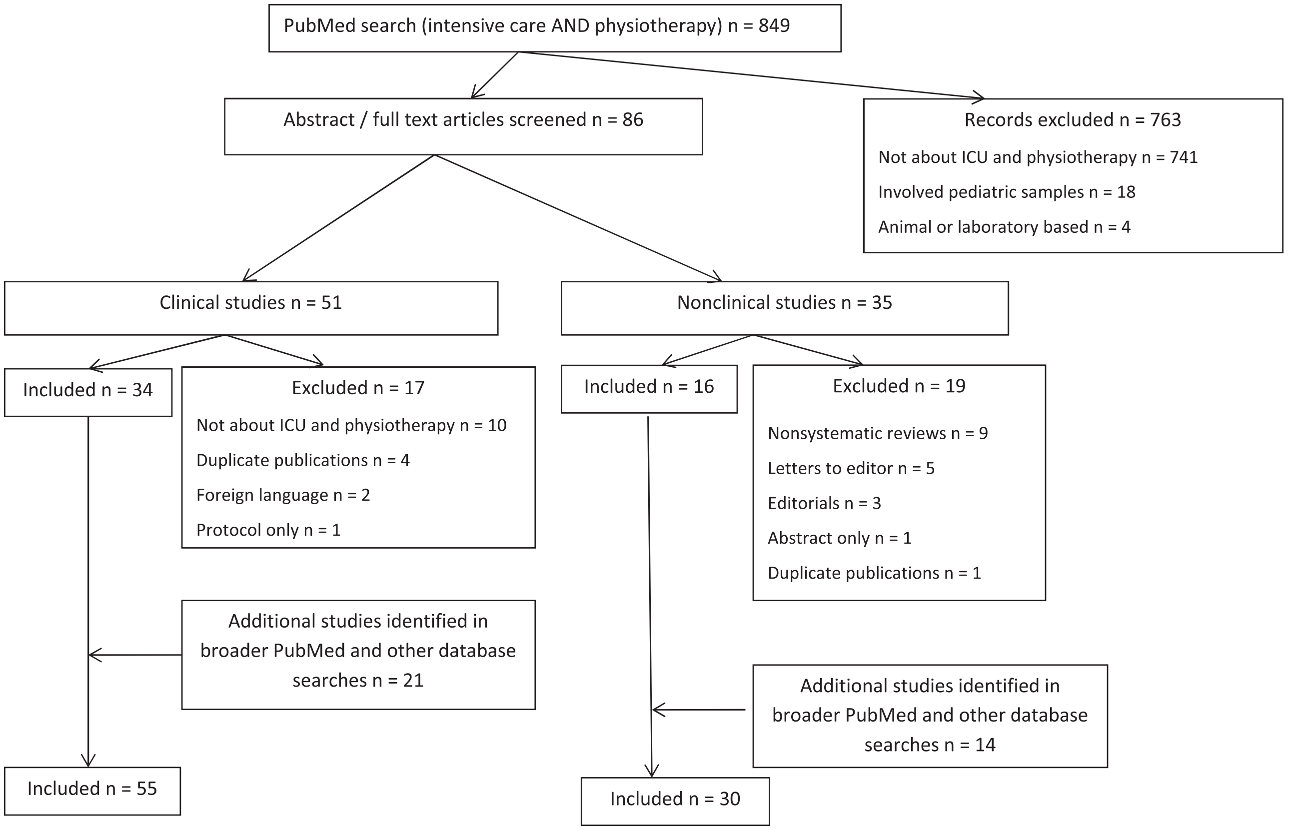

FIGURE 1. Flowchart of selection of eligible studies.

and length of stay (LOS) in the ICU and hospital were measured. Two of the four RCTs found no significant difference between groups for any outcomes,[16,18] one found that the median time for 50% of patients to become ventilator-free was significantly longer in the treatment group,[17] and the final study favored the treatment group, with significant benefits seen in terms of the clinical pulmonary infection score, ventilator weaning and mortality rates.[19] The fifth RCT was methodologically compromised by a small sample size (n = 17) that was further compromised by division into three treatment groups.[20]

The nine randomized crossover trials all had comparatively small sample sizes (n ≤ 46) and prospectively evaluated the physiologic effects of individual respiratory physiotherapy interventions.[21-29] Six of the randomized crossover trials evaluated MH.[21,25-29] Three of these compared MH to VH, when added to a treatment of positioning and suction, with all finding that VH was as effective as MH for outcomes such as sputum clearance and respiratory compliance.[21,26,29] Two studies investigated the addition of MH to a treatment of positioning and suction, with both finding that MH was associated with short-term beneficial physiologic effects such as improved respiratory compliance.[27,28] Hodgson et al[25] compared two different circuits for delivering MH, finding that while MH with a Mapleson C circuit cleared significantly more sputum than MH with a Laerdal circuit, this did not have any consequences in terms of oxygenation or respiratory compliance. Two randomized crossover trials evaluated the effect of expiratory rib-cage compression, finding that it did not add to the effectiveness of positioning and suction in terms of oxygenation, respiratory compliance, or sputum clearance.[22,23] Finally, Berney et al,[24] investigating 20 patients who were mechanically ventilated, found that the addition of a head-down tilt to MH, rather than flat side lying, increased the weight of sputum cleared.

A prospective, systematically allocated, controlled trial involving 60 patients who were mechanically ventilated was undertaken by Ntoumenopoulos et al.[30] While the incidence of VAP was significantly lower in a group that received multimodality respiratory physiotherapy bid compared with a control group, duration of mechanical ventilation, ICU LOS and mortality were not significantly different between groups.

A large historical controlled trial by Malkoç et al[31] (n = 501) found that a group that received multimodality respiratory physiotherapy had a significantly shorter duration of mechanical ventilation and ICU LOS than a historical control group. However, as the treatment group also received mobilization, it is not clear which components of therapy were effective.

Table 1—*Characteristics of Systematic Literature Reviews*

Study	Topic	Studies Reviewed, No.	Summary of Results, Authors' Conclusions
Mobilization/early rehabilitation			
Adler and Malone[4]	Mobilization of critically ill patients with an emphasis on functional outcomes and patient safety.	15	Evidence from the limited number of studies that have examined the early mobilization of critically ill patients supports early mobilization as a safe and effective intervention that can have a significant impact on functional outcomes.
Amidei[5]	Variables that have been used to evaluate physiologic responses to mobilization.	17	Most studies that have investigated the mobilization of critically ill patients evaluated cardiopulmonary function. Future studies evaluating the safety and efficacy of mobilization in this setting should measure multiple physiologic variables, including inflammatory biomarkers, and other measures of physiologic function, such as pain, comfort, anxiety, mood, and sleep.
Amidei[6]	Concept of mobilization in the critical care setting.	61	Mobilization can be defined as an interdisciplinary, goal-directed therapy aimed at facilitating movement and improving outcomes in critically ill patients. The concept of mobilization needs further definition with respect to factors such as the activities it comprises, their quantity, intensity, duration, and frequency, and interdisciplinary roles.
Choi et al[7]	Mobility interventions to improve outcomes in patients undergoing prolonged mechanical ventilation.	10	The studies reviewed support the ability of mobility interventions to improve the outcomes of patients receiving prolonged mechanical ventilation, but there is limited evidence on how to best accomplish this goal.
O'Connor and Walsham[8]	Worldwide availability of mobilization therapy in ICU and its role.	94[a]	There is marked variability between countries in the availability and prescription of mobilization therapy in the ICU setting, with routine mobilization therapy least likely to be available in the United States. The data in support of mobilization therapy for critically ill patients, while of a low level of evidence, are substantial. This justifies a paradigm shift in attitudes toward PT and the prevention of critical illness weakness.
Thomas[9]	Rehabilitation of the patient with critical illness.	33[a]	The evidence available regarding the effectiveness of physical training within the ICU environment is limited to patients with long-term respiratory failure who may not be representative of a general critically ill population.
Thomas[10]	Effect of physical rehabilitation commenced immediately on ICU admission compared with delayed rehabilitation.	46[a]	When the rehabilitation of critically ill patients is commenced early during their ICU admission, it leads to a higher rate of PT consultation, and patient-related benefits are seen, such as decreased time to achieve activity milestones, improved functional outcomes at ICU and hospital discharge, and reduced direct patient costs. Early rehabilitation of the critically ill patient, led by PTs, has the potential to dramatically influence recovery and functional outcomes in this vulnerable patient group.
Respiratory techniques			
Clini and Ambrosino[11]	Rationale and effectiveness of specific PT interventions and use of weaning protocols for patients in a respiratory ICU.	81[a]	Evidence supporting PT Rxs for patients in the ICU is limited due to the lack of long-term studies. While there is strong evidence to support the use of therapist-driven weaning protocols, further studies with larger sample sizes are needed to evaluate the effectiveness of most PT techniques in the ICU.

(Continued)

Table 1—*Continued*

Study	Topic	Studies Reviewed, No.	Summary of Results, Authors' Conclusions
Paulus et al[12]	Benefits and risks of MH in critically ill patients.	19	MH results in short-term beneficial effects on physiologic endpoints such as respiratory compliance, oxygenation, and airway clearance. However, its effect on broader outcomes, such as duration of mechanical ventilation and ICU LOS, is unknown. MH has been associated with side effects, albeit infrequently. Appropriately powered and methodologically sound studies are needed before it can be recommended for routine use.
Other topics			
Elliott et al[13]	Observational and functional assessment instruments used to assess patients in the ICU, post-ICU, and posthospitalization.	107[a]	Studies have used many different outcomes to measure the function of ICU survivors, including muscle strength, functional tests, and health-related quality of life. In general, the sensitivity and validity of these instruments for use with survivors of a critical illness has not yet been established.
Hanekom et al[14]	Identify which outcomes should be measured in the adult critical care environment and which outcomes PTs are currently including in research reports.	35	Research that has investigated the efficacy of PT in ICU has primarily measured physiologic variables or provided descriptions of current practice, without linking these to broader outcomes such as functional status and health-related quality of life. Further work is needed to develop and refine patient-centered and economic measurements that will be sufficiently sensitive to be able to measure the effect of PT service provision in ICU.
Hellweg[15]	Effectiveness of PT and OT for patients in the ICU with traumatic brain injury.	34[a]	Data concerning the effectiveness of PT and OT for patients in the ICU with traumatic brain injury are very limited, making it impossible to offer clear, evidence-based recommendations. Respiratory PT has not been shown to be effective for the prevention or Rx of VAP. The efficacy of other PT and OT interventions must still be demonstrated.

LOS = length of stay; MH = manual hyperinflation; OT = occupational therapy; PT = physiotherapy or physical therapy; Rx = treatment; VAP = ventilator-associated pneumonia.
[a]Indicates the number of articles in the reference list (number of studies included in review not specifically stated).

Table 2—*Characteristics of Studies Evaluating Multimodality Respiratory Physiotherapy*

Study	Participants, No., Type	Intervention	Outcomes	Results	Summary of Authors' Conclusions
Prospective, randomized, controlled/comparative trials					
Patman et al[16]	210, intubated, mechanically ventilated, post-cardiac surgery.	Control: standard medical/nursing care. Rx: as for control plus PT as indicated, including positioning, MH, suction.	Duration of intubation, ICU and hospital LOS, incidence of postoperative pulmonary complications.	No significant difference between groups for any outcome.	For routine, uncomplicated cardiac surgery subjects, the provision of PT interventions during the postoperative intubation period did not improve outcomes.
Templeton and Palazzo[17]	180, intubated, mechanically ventilated > 48 h.	Control: standard medical/nursing care. Rx: as for control plus respiratory PT as indicated, including positioning, MH, chest wall vibrations, suction.	Time to become ventilator-free, ICU and hospital mortality, ICU LOS.	Median time for 50% to become ventilator-free significantly longer in Rx group. No significant difference between groups for any other outcome.	Standard care is at least as effective as chest PT in patients requiring mechanical ventilation > 48 h.
Patman et al[18]	144, intubated, mechanically ventilated > 24 h, acquired brain injury.	Control: standard medical/nursing care. Rx: as for control plus respiratory PT, including positioning, MH, suction, 6 times/d.	Incidence of VAP, duration of mechanical ventilation, ICU and hospital LOS, CPIS scores, PaO_2/FIO_2.	No significant difference between groups for any outcome.	A regular respiratory PT regimen in addition to routine medical/nursing care did not significantly decrease the incidence of VAP, duration of mechanical ventilation or ICU LOS in adults with acquired brain injury.
Pattanshetty and Gaude[19]	101, intubated, mechanically ventilated > 48 h.	Control: MH and suction bid. Rx: as for control plus positioning, chest wall vibrations.	CPIS score, mortality, weaning success, duration of intubation, ICU LOS.	Reduction in CPIS score significantly greater in Rx group. Weaning success significantly higher in Rx group. Mortality significantly lower in Rx group. No significant difference between groups for duration of intubation or ICU LOS.	Multimodality respiratory PT bid decreased CPIS scores, suggesting a decrease in VAP and mortality rates.
Barker and Adams[20]	17, intubated, mechanically ventilated, ALI.	Group 1: supine 30° head-up, 3-min preoxygenation ($FIO_2 = 1$), suction. Group 2: as for group 1, then positioned (L and R flat side lying), suction. Group 3: as for group 2, plus MH.	PaO_2, $PaCO_2$, dynamic respiratory compliance, peak airway pressure, HR, BP, SVO_2 before and 10-, 30-, and 60-min post-Rx.	Significant changes observed in $PaCO_2$ and compliance over time for all three groups ($PaCO_2$ increased, compliance decreased 10-min post-Rx). PaO_2/FIO_2 and SVO_2 did not significantly change in any group. SVO_2 was significantly lower in group 2. HR and BP showed significant, but not clinically important, changes over time.	Disconnection of patients with ALI from mechanical ventilation for PT Rx can result in significant derecruitment of the lungs and altered physiology. The use of MH does not appear to override the loss of PEEP and the derecruitment effects.

(Continued)

Table 2—*Continued*

Study	Participants, No., Type	Intervention	Outcomes	Results	Summary of Authors' Conclusions
Prospective, randomized, crossover trials					
Dennis et al[21]	46, intubated, mechanically ventilated, atelectasis or consolidation on CXR.	Control: positioning, VH, chest-wall vibrations, suction. Rx: as for control except MH not VH.	Sputum weight, VT, HR, MAP, dynamic respiratory compliance, airway pressure, PaO_2/FIO_2 before, immediately and 30-min post-Rx.	Significantly higher airway pressure with MH than VH. No significant difference between Rxs for other outcomes.	VH was as safe and effective during respiratory PT Rx as MH, when applied with the same parameters and precautions. VH has potential advantages over MH, the biggest being that no ventilator circuit disconnection is required.
Unoki et al[22]	31, intubated, likely to require mechanical ventilation > 48 h.	Control: positioning, suction. Rx: as for control plus 5-min expiratory rib-cage compression presuction.	PaO_2/FIO_2, $PaCO_2$, dynamic respiratory compliance, sputum weight before and 25-min post-Rx.	No significant difference between Rxs for any outcome. No significant difference seen from pre- to post-Rx for any outcome.	The routine use of rib-cage compression is not recommended in a general population of mechanically ventilated patients.
Genc et al[23]	22, intubated, mechanically ventilated.	Control: positioning, 5-min MH, suction. Rx: as for control plus expiratory rib-cage compression during MH.	PaO_2/FIO_2, $PaCO_2$, static respiratory compliance, sputum weight, VT, HR, MAP before and 5- and 20-min post-Rx.	No significant difference between Rxs for any outcome. Compliance and VT significantly increased from pre- to post-Rx. No significant change in other outcomes.	The routine use of rib-cage compression during MH is not recommended in a general population of mechanically ventilated patients.
Berney et al[24]	20, intubated, mechanically ventilated.	Control: side lying flat, MH, suction. Rx: as for control but side lying in head-down tilt.	Sputum weight, PEFR during MH, static respiratory compliance before and immediately post-Rx.	Significantly more sputum and higher PEFR during Rx with head-down tilt. Compliance significantly improved over time, no significant difference between Rxs.	The head-down tilt position should be considered when the primary aim of Rx is sputum removal for intubated, mechanically ventilated patients.
Hodgson et al[25]	20, intubated, mechanically ventilated.	Rx 1: positioning, MH with Mapleson C circuit, suction. Rx 2: as for Rx 1 except MH with Laerdal circuit.	Sputum weight, static respiratory compliance, VT, PaO_2/FIO_2, $PaCO_2$ before, 30-, and 60-min post-Rx.	MH with Mapleson C circuit cleared significantly more sputum. No significant difference between Rxs for other outcomes.	More secretions were cleared using the Mapleson C compared with the Laerdal circuit; however, this had no consequence in terms of oxygenation.
Berney and Denehy[26]	20, intubated, mechanically ventilated.	Rx 1: positioning, MH, suction. Rx 2: as for Rx 1 except VH.	Sputum weight, static respiratory compliance before, immediately and 30-min post-Rx.	No significant difference between Rxs in sputum weight or compliance. Compliance significantly improved after both Rxs.	VH was as effective as MH in sputum clearance and improving respiratory compliance.
Hodgson et al[27]	18, intubated, mechanically ventilated, lung collapse and/or consolidation on CXR, $PaO_2/FIO_2 < 350$.	Control: positioning, suction. Rx: as for control plus MH.	Static respiratory compliance, PaO_2/FIO_2, $PaCO_2$, sputum weight, HR, MAP before, immediately and 20-min post-Rx.	Significantly greater increase in compliance and sputum weight for MH Rx. Increase in compliance seen immediately and 20-min post-Rx. No significant difference between Rxs for other outcomes.	Respiratory compliance and sputum clearance were improved by the addition of MH to a Rx of positioning and suctioning without compromise to cardiovascular stability or gas exchange.

(Continued)

Table 2—*Continued*

Study	Participants, No., Type	Intervention	Outcomes	Results	Summary of Authors' Conclusions
Choi and Jones[28]	15, intubated, mechanically ventilated, VAP.	Control: supine, suction. Rx: as for control plus MH.	Static respiratory compliance, airway resistance before, immediately and 30-min post-Rx.	Significantly greater increase in compliance for MH Rx. Significant decrease in airway resistance 30-min post-MH Rx but not control Rx.	Suction alone did not cause deterioration in compliance and airway resistance and can probably be used safely in patients with VAP. The addition of MH improved respiratory mechanics compared with suction alone.
Savian et al[29]	14, intubated, mechanically ventilated.	Rx 1: positioning, MH, suction. Rx 2: as for Rx 1 except VH.	PEFR, VT, PaO_2/FIO_2, static respiratory compliance, HR, MAP, sputum weight, $\dot{V}CO_2$ before, immediately and 30-min post-Rx.	Significantly higher PEFR with MH. Significantly higher VT with VH. $\dot{V}CO_2$ significantly different between Rxs (upward trend MH, downward trend VH). No significant difference between Rxs for other outcomes.	VH promoted greater improvements in respiratory mechanics with less metabolic disturbance than MH. Other variables such as sputum production, hemodynamics and oxygenation were affected similarly by both techniques.
Prospective, systematically allocated, controlled trial					
Ntoumenopoulos et al[30]	60, intubated, mechanically ventilated ≥48 h.	Control: side lying, suction as required. Rx: positioning, expiratory chest wall vibrations, suction, bid.	Incidence of VAP, CPIS score, duration of mechanical ventilation, ICU LOS, ICU and 28-d mortality.	Significantly lower incidence of VAP and CPIS score in Rx group. No significant difference between groups for other outcomes.	Respiratory PT was independently associated with a reduction in VAP.
Prospective, historical controlled trial					
Malkoç et al[31]	510, intubated, mechanically ventilated.	Control (historical): standard nursing care. Rx: positioning, percussion, vibration, coughing, deep breathing, suction, bed exercises, mobilization (not described), bid, 5 d/wk.	Duration of mechanical ventilation, ICU LOS.	Significantly shorter duration of mechanical ventilation and ICU LOS in Rx group.	PT can reduce the period of Rx required in ICU.

(Continued)

Table 2—*Continued*

Study	Participants, No., Type	Intervention	Outcomes	Results	Summary of Authors' Conclusions
Prospective, observational studies					
Thomas et al[32]	34, intubated, mechanically ventilated with or without pulmonary infiltrates on CXR.	90° side lying.	Pa_{O_2}/F_{IO_2}, Pa_{CO_2}, VT, dynamic respiratory compliance, airway pressure, MAP, HR, cardiac index, adverse events before, during, and 30- and 120-min post-Rx.	No significant change in Pa_{O_2}/F_{IO_2}, Pa_{CO_2}, MAP, HR. Compliance and VT significantly decreased during positioning, cardiac index significantly increased 30-min post-Rx. 21% incidence of adverse events (minor, transient).	The results did not support the use of lateral positioning to improve oxygenation in ventilated patients without lung pathology or with pulmonary infiltrates.
Clarke et al[33]	25, sedated, intubated, mechanically ventilated.	Manual hyperventilation with Mapleson C circuit.	VT, peak airway pressure, Pa_{O_2}, Pa_{CO_2} before, during, and immediately post-Rx.	Significant negative correlation between average VT and lung injury score. Significant positive correlation between average peak airway pressure and lung injury score. Pa_{O_2} significantly improved from pre- to immediately post-Rx. No significant change in Pa_{CO_2}.	Manual hyperventilation causes higher inflation pressures and smaller VTs as the lung score increases, suggesting an increased potential for barotrauma or volutrauma in susceptible lungs.

ALI = acute lung injury; CPIS = clinical pulmonary infection score; CXR = chest radiograph; HR = heart rate; L = left; MAP = mean arterial BP; PEEP = positive end expiratory pressure; PEFR = peak expiratory flow rate; R = right; Sv_{O_2} = mixed venous oxygen saturation; $\dot{V}_{CO_2}$ = CO_2 output; VH = ventilator hyperinflation; VT = tidal volume. See Table 1 legend for expansion of other abbreviations.

From the two prospective observational studies, Thomas et al[32] found that lateral positioning had no significant effect on oxygenation of 34 patients on mechanical ventilation and Clarke et al,[33] studying 25 patients on mechanical ventilation, reported that manual hyperventilation can result in higher inflation pressures in patients with susceptible lungs.

Mobilization: For the purposes of this review, the definition of mobilization provided by Stiller[1] has been used, whereby mobilization is a broad term that encompasses active limb exercises, actively moving or turning in bed, sitting on the edge of the bed, sitting out of bed in a chair (via mechanical lifting machines, slide board, or standing transfer), standing, and walking. Twenty-six clinical trials were identified that evaluated the use of mobilization interventions.[34-59] Table 3 summarizes their characteristics. There were three RCTs,[34-36] five nonrandomized controlled trials,[37-41] one historical controlled study,[42] and 17 observational studies.[43-59]

The largest prospective RCT, by Schweickert et al,[34] involved 104 patients who had been mechanically ventilated for < 72 h and were likely to require ventilation for a further 24 h. The patients were randomly allocated to receive daily sedative interruption followed by therapy that concentrated on mobilization activities (eg, range of motion exercises, functional tasks, sit/stand/walk) or daily sedative interruption and standard medical/nursing care. Compared with the control group, the treatment group demonstrated a significantly shorter duration of delirium and mechanical ventilation, and significantly more patients in the treatment group achieved an independent functional status at hospital discharge. The second prospective RCT, involving 90 patients whose ICU LOS was anticipated as being > 7 days, investigated the effectiveness of adding cycling exercise using a bedside cycle ergometer to a standard physiotherapy mobilization regimen (ie, limb exercises, walk).[35] While no significant differences were found between groups at ICU discharge, the treatment group achieved significantly higher distances in the 6-min walk test than the control group at hospital discharge and their quadriceps strength improved significantly between ICU and hospital discharge. The third RCT, by Chang et al,[36] prospectively investigated the effect of sitting out of bed (for at least 30 min, most often on a daily basis) on the respiratory muscle strength of 34 patients over a 6-day study period. The patients in the control group were positioned supine or semirecumbent in bed. No significant differences were seen between groups.

Two of the five nonrandomized controlled studies prospectively allocated patients to a control group (standard medical/nursing care) or a treatment group (progressive

Table 3—*Characteristics of Studies Evaluating Mobilization*

Study	Participants, No., Type	Intervention	Outcomes	Results	Summary of Authors' Conclusions
Prospective, randomized, controlled/comparative trials					
Schweickert et al[34]	104, intubated, mechanically ventilated < 72 h, likely to continue ≥ 24 h.	Control: daily sedative interruption and standard care (included PT and OT per primary care team). Rx: daily sedative interruption for PT and OT (eg, ROM exercises, bed mobility, functional and ADL tasks, sit/stand/walk).	Return to independent functional status at hospital DC, duration of delirium and mechanical ventilation, ventilator-free days, ICU and hospital LOS, adverse events.	Return to independent functional status at hospital DC occurred in significantly more Rx group patients. Duration of delirium and mechanical ventilation significantly shorter in Rx group. Ventilator-free days, and ICU and hospital LOS not significantly different between groups. Serious adverse events: 0.2%.	Sedation interruption and PT/OT in the earliest days of critical illness was safe and well tolerated, resulted in better functional outcomes at hospital DC, shorter duration of delirium, and more ventilator-free days.
Burtin et al[35]	90, critically ill, anticipated ICU LOS > 7 d postrecruitment.	Control: standard PT mobilization (limb exercises, walk), 5 d/wk. Rx: as for control plus cycling exercise (bedside cycle ergometer), 20 min, 5 d/wk.	6MWD at hospital DC, quadriceps force, functional status (sit-to-stand [BBS] and physical functioning [SF-36]) at ICU and hospital DC, adverse events.	6MWD and SF-36 subscore significantly higher in Rx group at hospital DC. Quadriceps force improved significantly more between ICU and hospital DC in Rx group. Ability to stand independently (BBS ≥ 2) not significantly different between groups. Serious adverse events: 0%.	When instituted early in ICU survivors with a prolonged stay, exercise training may enhance recovery of functional exercise capacity, functional status, and quadriceps force at hospital DC.
Chang et al[36]	34, mechanically ventilated ≥ 72 h, able to transfer to chair with two nurses.	Control: positioned supine to semi-recumbent, no PT. Rx: sit in chair, 30-120 min, at least 3 d/wk.	Rapid shallow breathing index, V_T, respiratory muscle strength before and 30-min postintervention over 6-d trial period.	No significant differences between groups for any outcome over 6-d trial period.	6 d of chair sitting was ineffective at improving respiratory muscle function in mechanically ventilated patients in the ICU.
Prospective, nonrandomized, controlled trials					
Morris et al[37]	330, intubated, mechanically ventilated, acute respiratory failure.	Control: standard medical/nursing care. Rx: progressive mobilization (eg, ROM exercises, functional tasks, sit/stand/walk) from a mobility team, 7 d/wk.	Proportion receiving ICU PT, days until first out of bed, ventilator days, ICU and hospital LOS, adverse events.	ICU PT provided to significantly more patients in Rx group. Rx group first out of bed significantly earlier. ICU and hospital LOS significantly shorter in Rx group. Ventilator days not significantly different between groups. Serious adverse events: 0%.	Implementation of an early mobility protocol by a mobility team resulted in more PT sessions and was associated with a shorter LOS for hospital survivors.

(Continued)

Table 3—*Continued*

Study	Participants, No., Type	Intervention	Outcomes	Results	Summary of Authors' Conclusions
Yang et al[38]	126, mechanically ventilated > 14 d.	Control: routine passive joint exercises by nurses 5-10 min, bid. Rx: breathing training, progressive mobilization (eg, passive/active ROM exercises, sit/stand/walk), 30 min, daily, 5 times/wk.	Rapid shallow breathing index, BI, weaning success. Timing not clear.	Rapid shallow breathing index did not significantly change. BI significantly improved over time in Rx group (not clear what happened to control). Weaning success rate higher in Rx group (significance not stated).	Not stated.
Winkelman et al[39]	75, mechanically ventilated > 48 h, likely to continue ≥ 24 h.	Control phase: standard medical/nursing care. Rx phase: progressive mobilization (per Morris et al[37]), 20 min, daily, 2-7 d.	Inflammatory biomarkers, HR, RR, systolic BP, Spo_2, adverse events over 7-d trial period. Duration of mechanical ventilation, ICU LOS.	Daily exercise linked to increased IL-10. HR, RR, systolic BP, Spo_2 not significantly different between control and Rx phases. Serious adverse events: < 5%. Duration of ventilation not significantly different between phases. ICU LOS significantly shorter during Rx phase.	The results should encourage clinicians to add mobility protocols to the care of patients in the ICU.
Needham et al[40]	57, mechanically ventilated > 4 d.	Control phase: standard medical/nursing care. Rx phase: reduced sedation, early progressive mobilization (eg, sit/stand/walk).	Prevalence of deep sedation and delirium, functional mobility, ICU and hospital LOS, adverse events.	Prevalence of deep sedation and delirium significantly lower during Rx phase. Functional mobility significantly better during Rx phase. Significantly shorter ICU and hospital LOS during Rx phase compared with prior year. Serious adverse events: 0%.	Reducing deep sedation and increasing early mobilization resulted in substantial improvements in ICU delirium and functional mobility, with a decrease in ICU and hospital LOS.
Chiang et al[41]	32, mechanically ventilated > 14 d.	Control: standard medical/nursing care including promotion of mobilization (eg, exercises, walk). Rx: progressive mobilization (eg, strengthening and ROM exercises, sit/stand/walk), 5 times/wk for 6 wk.	Respiratory muscle strength, upper and lower limb strength, BI, FIM, ventilator-free time at 3 and 6 wk.	Respiratory muscle and limb strength significantly increased at 3 and 6 wk in Rx group but not control group. BI and FIM scores significantly higher in Rx group than control group at 3 and 6 wk. Ventilator-free time increased significantly in Rx group but not control group at 6 wk.	A 6-wk physical training program may improve limb muscle strength and ventilator-free time and improve functional outcomes in patients requiring prolonged mechanical ventilation.
Prospective, historical controlled trial					
Bassett et al[42]	260, not stated.	Control: historical control. Rx: progressive mobilization (eg, ROM exercises, functional tasks, sit/stand/walk).	Ventilator days, ventilator-free days, ICU and hospital mortality, ICU and hospital LOS, days to standing and ambulating.	No significant differences between groups for any outcomes.	An early mobility program improved ICU team focus on the process of early mobility, but no significant differences were seen in quantitative outcomes.

(Continued)

Table 3—*Continued*

Study	Participants, No., Type	Intervention	Outcomes	Results	Summary of Authors' Conclusions
Prospective, observational studies					
Leditschke et al[43]	106, all patients in ICU.	Usual practice.	Frequency of mobilization (sit/stand/walk), adverse events, barriers to mobilization.	Patients were mobilized on 54% of days audited. Adverse events: 1%. Avoidable barriers included location of vascular access lines, scheduling of mobilization, sedation.	Critically ill patients can be safely mobilized.
Thomsen et al[44]	104, transferred from general ICU to a specific respiratory ICU, mechanically ventilated > 4 d, respiratory failure.	Early progressive mobilization (eg, sit/walk) following transfer.	Frequency of ambulation.	Probability of ambulation significantly increased after transfer to the respiratory ICU. After 2 d, number of patients ambulating increased threefold compared with pretransfer.	The ICU environment may contribute to the unnecessary immobilization of patients with acute respiratory failure.
Bailey et al[45]	103, mechanically ventilated > 4 d, respiratory failure.	Early progressive mobilization (eg, sit/walk).	Feasibility, adverse events.	Total of 1,449 early mobilization activities. Adverse events: < 1%.	Early mobilization is feasible and safe in respiratory failure patients.
Clini et al[46]	77, tracheostomized, difficult to wean.	Early rehabilitation including progressive mobilization (eg, limb exercises, sit/stand/walk), weaning protocol, nutritional support.	Mortality, weaning success, BADL score at baseline and ICU DC, adverse events.	Hospital mortality: 87%. Weaning success: 74%. BADL score improved. Adverse events: 0%.	Early rehabilitation contributes to BADL recovery in difficult-to-wean patients.
Garzon-Serrano et al[47]	63, all patients in ICU.	Mobilization (eg, limb exercises, bed mobility, sit/stand/walk) by nursing or PT staff.	Level of mobilization achieved, adverse events.	PTs mobilized patients to a significantly higher level of mobility than nursing staff. Adverse events: 0%.	Routine involvement of PTs in directing mobilization Rx may promote early mobilization of critically ill patients.
Zanni et al[48]	32, mechanically ventilated > 4 d.	Mobilization (eg, limb exercises, balance, functional activities, sit/stand/walk).	HR, BP, Spo_2 before and postsession, ROM, muscle strength, functional outcomes, adverse events.	HR, BP, Spo_2: minimal changes during sessions. Lower-limb joint contractures frequent, did not improve during hospitalization. Limb weakness common, improved during hospitalization. Adverse events: 0%.	Rehabilitation therapy appeared safe without significant physiologic changes or adverse effects, but was only provided infrequently.
Stiller et al[49]	31, any patient in ICU being mobilized by PTs.	Mobilization (eg, sit/stand/walk).	HR, BP, Spo_2 before, during and immediately postsession, adverse events.	HR and BP increased significantly during sessions. No significant change in Spo_2. Adverse events: 4% (minor, transient).	Acutely ill patients in the ICU can be safely mobilized without major deterioration in their clinical status.
Bahadur et al[50]	30, tracheostomized, mechanically ventilated.	Usual care, including sitting.	Frequency of sitting out of bed.	63% sat out of bed on a median of two occasions.	Despite a culture of early mobilization, some patients were considered too unwell for it to occur.

(Continued)

Table 3—*Continued*

Study	Participants, No., Type	Intervention	Outcomes	Results	Summary of Authors' Conclusions
Bourdin et al[51]	20, mechanically ventilated ≥ 2 d, ICU stay ≥ 7 d.	Early progressive mobilization (eg, sit/tilt table/walk).	Feasibility, HR, RR, MAP, Spo_2 before and postsession, adverse events.	Chair sitting significantly decreased HR and RR. HR and RR significantly increased with tilting-up and walking. Spo_2 significantly decreased with walking. Adverse events: 3% (minor).	Early mobilization is feasible and safe for patients in ICU for > 7 d.
Nordon-Craft et al[52]	19, mechanically ventilated ≥ 7 d, ICU acquired weakness.	Progressive mobilization (eg, limb exercises, sit/stand/walk), 30 min, 5 d/wk.	Adverse events, feasibility, muscle strength, functional outcomes.	Adverse events: 0%. 170 sessions provided. Patients DC home had higher strength and functional scores.	Early mobilization and PT were safe and feasible for patients with ICU acquired weakness.
Norrenberg et al[53]	16, patients in ICU.	Passive limb movements.	$\dot{V}o_2$, CIX, O_2ER before and during intervention.	$\dot{V}o_2$ significantly increased during intervention: achieved by increase in O_2ER in patients with cardiac dysfunction, by increase in CIX in patients without cardiac dysfunction.	Simple maneuvers like passive limb movements can influence the hemodynamic status of patients in ICU.
Chang et al[54]	15, intubated, mechanically ventilated > 5 d.	Standing on a tilt table (70° from horizontal), 5 min.	$\dot{V}E$, V_T, RR, Pao_2, $Paco_2$ before, during, immediately and 20-min postintervention.	$\dot{V}E$, RR, and V_T significantly increased during and immediately post-tilt, not significant by 20 min post-tilt. Pao_2 and $Paco_2$: no significant change.	Standing on a tilt table produced a transient increase in ventilation in critically ill patients.
Zafiropoulos et al[55]	15, intubated, mechanically ventilated, elective major abdominal surgery.	Early mobilization (eg, sit/stand/walk) while spontaneously breathing on $F_{IO_2} = 1.0$.	Rib cage and abdomen displacement, V_T, RR, $\dot{V}E$, HR, BP, Spo_2, Pao_2, $Paco_2$ before, during, and 20-min postintervention.	Standing significantly increased rib cage displacement, V_T, RR, and $\dot{V}E$. No further significant changes seen with walking. BP and HR significantly increased when the patients sat on edge of bed. Pao_2 and $Paco_2$: no significant change.	Changes in V_T, RR, and $\dot{V}E$ during mobilization were largely due to positional change from supine to standing.
Skinner et al[56]	12, tracheostomized, mechanically ventilated.	Progressive mobilization (eg, limb exercises, sit/stand/walk).	Responsiveness and reliability of the physical function ICU test, adverse events.	The test was easy to perform, responsive and reliable. Adverse events: 0%.	This test may be used to prescribe and evaluate exercise for weak, debilitated patients in ICU.
Thelandersson et al[57]	12, mechanically ventilated, unable to actively move, severe head injury.	Passive ROM exercises upper and lower limbs.	ICP, CPP, CBFV, PI, BP, and HR before, during, and 10 min postintervention.	ICP significantly decreased postintervention. No significant change in other outcomes.	Passive ROM exercises can be used safely in critically ill neurosurgical patients in ICU.

(Continued)

Table 3—*Continued*

Study	Participants, No., Type	Intervention	Outcomes	Results	Summary of Authors' Conclusions
Thelandersson et al[58]	12, mechanically ventilated, unable to actively move, severe head injury.	Passive ROM exercises to one leg.	Blood flow velocity and resistance index of common femoral artery, HR, BP before and ≤10-min postintervention.	No significant change in any outcome.	Passive ROM does not alter blood flow velocity or resistance index in the common femoral artery in comatose and/or sedated critically ill patients.
Hashim et al[59]	1, mechanically ventilated, fractured ribs.	Standing on a tilt table, daily.	Descriptive data.	Tilt table prompted faster standing than other approaches and improved respiratory function.	Early mobilization using a tilt table may enhance respiratory function and shorten recovery.

6MWD = 6-min walk distance; ADL = activities of daily living; BADL = basic activities of daily living; BBS = Berg Balance Scale; BI = Barthel Index; CBFV = cerebral blood flow velocity; CIX = cardiac index; CPP = cerebral perfusion pressure; DC = discharge; FIM = functional independence measure; ICP = intracranial pressure; O_2ER = oxygen extraction ratio; PI = pulsatility index; ROM = range of motion; RR = respiratory rate; SF-36 = Medical Outcomes Study 36-Item Short Form Health Survey; Sp_{O_2} = percutaneous oxygen saturation; $\dot{V}_E$ = minute ventilation; $\dot{V}_{O_2}$ = oxygen consumption. See Table 1 and 2 legends for expansion of other abbreviations.

mobilization [eg, limb exercises, sit/stand/walk]).[37,41] Despite marked differences in sample size (n = 330[37]; n = 32[41]), both demonstrated advantages for the treatment group, including significantly better functional ability, which translated into benefits such as a significantly shorter ICU and hospital LOS. Two nonrandomized controlled studies prospectively compared a control phase, where patients received standard medical/nursing care, to a treatment phase following the introduction of a progressive mobilization program.[39,40] Needham et al[40] demonstrated benefits following implementation of the mobilization program (which included reduced sedation), including significantly better functional mobility in the ICU and significantly shorter ICU and hospital LOS. Similarly, Winkelman et al[39] found that the ICU LOS was significantly shorter after implementation of a progressive mobilization program, although no significant difference was found for duration of mechanical ventilation. Yang et al[38] found that progressive mobilization enhanced the success rate of ventilator weaning.

Bassett et al[42] compared outcomes between a historical controlled group, where data were collated retrospectively, and a treatment group after the implementation of an early mobilization program across 13 ICUs. While details are scarce, no significant differences were seen between the two groups for outcomes such as the length of mechanical ventilation, and ICU and hospital LOS.

The 17 observational studies recorded outcomes regarding the feasibility, safety, and physiologic effects of mobilization on patients in the ICU.[43-59] Overall, mobilization activities were found to be feasible and safe, although associated at times with short-term changes in physiologic parameters, with the frequency of serious adverse events ≤ 1%. Garzon-Serrano et al[47] prospectively compared the level of mobility achieved for 63 patients in the ICU according to whether mobilization was performed by nursing or physical therapy staff, finding that physical therapists mobilized patients to a significantly higher level than nursing staff. Barriers to the mobilization of patients in the ICU that were identified included the ICU culture,[44] sedation,[48] limited rehabilitation staffing,[48] and patients being medically unfit.[50] Skinner et al[56] developed a clinical exercise outcome measure for use in the ICU, namely, the physical function ICU test (PFIT), finding it easy to use, responsive, and reliable in a study of 12 patients in the ICU.

Inspiratory Muscle Training: Five clinical trials were found that evaluated the effectiveness of IMT in the ICU.[60-64] These studies are summarized in Table 4. There were two RCTs,[60,61] two case series,[62,63] and one single case report.[64]

Cader et al,[60] in a well-designed prospective RCT involving 41 elderly patients who were mechanically ventilated for > 48 h due to type 1 respiratory failure, found that daily progressive IMT using a threshold training device was associated with significant benefits (eg, shorter weaning time) compared with a control group. In contrast, the prospective RCT by Caruso et al,[61] whose study sample comprised 25 patients likely to require mechanical ventilation > 72 h, found that IMT using the trigger sensitivity on the ventilator did not have significant benefits in terms of weaning duration or rate of reintubation.

Threshold IMT was found to be effective in terms of weaning ventilator-dependent patients in the case series by Sprague and Hopkins[63] involving six patients, and a single case study by Bissett and Leditschke.[64] Bissett et al,[62] in another case series, evaluated the safety of IMT, with no deleterious effects on physiologic parameters or clinically important adverse effects recorded.

Neuromuscular Electrical Stimulation: Three clinical studies, summarized in Table 4, were identified that evaluated the effectiveness of NMES.[65-67] There were two prospective, stratified RCTs[65,66] and one within-subject RCT.[67]

The RCT by Routsi et al[65] involved 52 critically ill patients, stratified according to age and sex, and evaluated the effect of daily NMES to the quadriceps and peroneous longus muscles. They demonstrated a significantly lower incidence of critical-illness polyneuromyopathy and reduced weaning time in the treatment group. The stratified RCT by Gruther et al[66] allocated 33 patients to a daily session of NMES to the quadriceps muscle or a sham treatment, with the sample stratified according to ICU LOS. While no significant difference was seen between the treatment and sham groups for short-stay patients (< 7 days), longer-term patients (> 14 days) who received NMES had a significant increase in muscle thickness at 4 weeks, whereas the sham group had no significant change in muscle thickness. The within-subject RCT by Poulsen et al,[67] involving eight male patients in the ICU with septic shock, found no significant difference in quadriceps muscle volume between patients' control and treatment sides after 7 days.

Other Clinical Trials: Three other clinical trials that investigated physiotherapy interventions in the ICU are summarized in Table 4.[68-70] Zeppos et al[68] documented a low incidence of adverse physiologic effects associated with all physiotherapy interventions in the ICU; De Freitas[69] found that patients who received physiotherapy were predominantly male, elderly, nonsurgical, and with high disease severity and mortality; and Clavet et al[70] reported that patients with joint contractures in the ICU had a significantly longer ICU LOS and lower ambulatory level at the time of hospital discharge than those without joint contractures.

Nonclinical Studies: Study and Sample Characteristics

Expert Opinion: Three articles, summarized in Table 5, provided expert opinions regarding the role of physiotherapy in the ICU.[71-73] Gosselink et al[71] summarized the findings of the European Respiratory Society and European Society of Intensive Care Medicine Task Force on the effectiveness of physiotherapy for acute and chronic critically ill patients. Despite noting a lack of high-level evidence, they identified the following evidence-based targets for physiotherapy: deconditioning, muscle weakness, joint stiffness, impaired airway clearance, atelectasis, intubation avoidance, and weaning failure. The two studies by Hanekom et al[72,73] used a Delphi process to develop evidence-based clinical management algorithms for the prevention, identification, and management of pulmonary dysfunction in intubated patients in the ICU and for the early physical activity and mobilization of critically ill patients.

Surveys: A total of 15 surveys (Table 5) were identified that evaluated physiotherapy interventions in the ICU.[74-88] Sample sizes ranged from 32[88] to 482;[74] most samples comprised physiotherapists alone,[74-76,78-81,84-86,88] two included physiotherapists and nursing staff,[82,83] one study included ICU directors and physiotherapists,[77] and the last included patients in the ICU.[87] All studies used purpose-designed surveys. Topics surveyed were general physiotherapy service provision,[74,79,80,82,85] use of passive movements,[75,86] rehabilitation and exercise prescription,[78] positioning,[83] VH,[76,84] MH,[88] use of tilt tables,[81] ICU directors' perceptions of their physiotherapy service,[77] and patient satisfaction with the ICU physiotherapy service.[87] The findings of each study are summarized in Table 5.

Discussion

This systematic review updates a summary of the research evidence concerning the effectiveness of physiotherapy in the ICU published in 2000. A total of 85 new studies (55 clinical and 30 nonclinical) were reviewed.

The most striking change in the evidence base since the review published by Stiller in 2000[1] has been the advent and growth of research, particularly in the last 5 years, evaluating the use of early progressive mobilization. In contrast to 2000, when no studies were

Table 4—*Characteristics of Studies Evaluating Inspiratory Muscle Training, Neuromuscular Electrical Stimulation, and Other Interventions*

Study	Study Design	Participants, No., Type	Intervention	Outcomes	Results	Summary of Authors' Conclusions
Inspiratory muscle training						
Cader et al[60]	Prospective, randomized, controlled trial.	41, intubated, mechanically ventilated > 48 h, > 70 y old, type 1 respiratory failure.	Control: usual care. Rx: IMT (threshold device, progressive resistance), 5 min bid, 7 d/wk.	MIP, Index of Tobin (RR/V_T during a 1-min spontaneous breathing trial) before and postweaning, weaning time.	MIP increased significantly more in Rx group. Index of Tobin worsened in both groups, but significantly less so in Rx group. Weaning time significantly shorter in Rx group.	In intubated older people, IMT improves MIP and the Index of Tobin, with a reduced weaning time in some patients.
Caruso et al[61]	Prospective, randomized, controlled trial.	25, likely to require mechanical ventilation > 72 h.	Control: usual care. Rx: IMT (inspiratory trigger sensitivity on ventilator, progressive resistance), up to 30 min per session bid.	MIP daily until weaned, weaning duration, reintubation rate.	No significant difference between groups for any outcome.	IMT from the beginning of mechanical ventilation did not shorten weaning duration or decrease reintubation rate.
Bissett et al[62]	Case series	10, tracheostomized, ventilator dependent.	IMT (threshold device, progressive resistance), daily, 5-6 d/wk.	HR, MAP, Spo_2, RR before and post-sessions until weaned, adverse events.	HR, MAP, Spo_2, RR: no significant change. Adverse events: 0%.	Threshold IMT can be delivered safely in selected ventilator-dependent patients.
Sprague and Hopkins[63]	Case series.	6, tracheostomized, ventilator dependent.	IMT (threshold device, progressive resistance), 30-50 min per session, daily, 6-7 d/wk.	Weaning success, training pressures, MIP.	All patients were weaned from the ventilator after initiation of IMT. Mean training pressures and MIP increased over time.	IMT may promote weaning in patients who are ventilator-dependent.
Bissett and Leditschke[64]	Single case study.	1, tracheostomized, ventilator dependent.	IMT (threshold device, progressive resistance), up to 30 min per session, daily, 7 d/wk.	Weaning success.	Weaned off mechanical ventilation after initiation of IMT.	IMT should be considered as a therapeutic strategy for ventilator-dependent patients.
Neuromuscular electrical stimulation						
Routsi et al[65]	Prospective, stratified, randomized, controlled trial.	52, mechanically ventilated, APACHE II score ≥ 13. Stratified according to age and sex.	Control: no intervention. Rx: NMES to quadriceps and peroneous longus bilaterally, 55 min daily.	MRC muscle strength, frequency of critical illness polyneuromyopathy, weaning period, duration of mechanical ventilation, ICU LOS.	MRC score significantly higher in Rx group. Incidence of polyneuromyopathy significantly lower in Rx group. Weaning period significantly shorter in Rx group. No significant difference between groups for other outcomes.	Daily NMES can prevent critical illness polyneuromyopathy in critically ill patients and can shorten the duration of weaning.

(Continued)

Table 4—*Continued*

Study	Study Design	Participants, No., Type	Intervention	Outcomes	Results	Summary of Authors' Conclusions
Gruther et al[66]	Prospective, stratified, randomized, controlled trial.	33, stratified according to ICU LOS: acute subgroup: ICU LOS < 7 d; long-term subgroup: ICU LOS > 14 d.	Control: sham stimulation. Rx: NMES to quadriceps, daily, 5 d/wk for 4 wk.	Quadriceps muscle layer thickness (ultrasonography) at baseline and 4 wk.	Acute subgroup: muscle thickness significantly decreased over time in both groups, no significant difference between groups. Long-term subgroup: muscle thickness significantly increased over time in Rx group but not control group, thickness significantly greater in Rx group at 4 wk.	NMES could be an effective adjunct in ICU to reverse muscle wasting in long-term patients.
Poulsen et al[67]	Within-subject, randomized, controlled trial.	8, mechanically ventilated, septic shock, predicted ICU LOS ≥ 7 d.	Control side: no intervention. Rx side: NMES to quadriceps, 60 min, daily for 7 d.	Quadriceps muscle volume (CT image) at days 1 and 7.	Muscle volume significantly decreased over time. No significant difference between groups.	Loss of muscle mass in patients with septic shock was unaffected by NMES.
Other interventions						
Zeppos et al[68]	Prospective, observational study.	Any patient in the ICU receiving PT intervention.	Any PT intervention.	Adverse events.	12,281 interventions provided. Adverse events: 0.2%.	PT intervention in ICU is safe.
De Freitas[69]	Prospective, observational study.	146, any patients in the ICU receiving PT intervention.	Not stated.	APACHE II index.	APACHE II index scores reflected severe disease in patients receiving PT.	Provided descriptive data for patients in ICU receiving PT.
Clavet et al[70]	Retrospective, chart review.	155, ICU LOS ≥ 14 d.	Not applicable.	Ambulatory status at hospital DC according to presence/absence of joint contractures in ICU, ICU LOS.	Significantly more patients with contractures in ICU had a low ambulatory level at hospital DC than those without contractures. ICU LOS significantly longer in those with contractures.	The development of joint contractures in ICU adversely affected ambulatory status at DC from hospital.

APACHE = Acute Physiologic and Chronic Health Evaluation; IMT = inspiratory muscle training; MIP = maximal inspiratory pressure; MRC = Medical Research Council; NMES = neuromuscular electrical stimulation. See Table 1-3 legends for expansion of other abbreviations.

Table 5—*Characteristics of Nonclinical Studies*

Study	Participants, No., Type	Topic	Summary of Results
Expert opinion			
Gosselink et al[71]	10, ERS and ESICM taskforce.	PT for critically ill patients.	Despite a lack of high-level evidence, the following evidence-based targets for PT were identified: deconditioning, muscle weakness, joint stiffness, impaired airway clearance, atelectasis, intubation avoidance, and weaning failure.
Hanekom et al[72]	7, Delphi panelists.	Clinical management algorithm for the prevention, identification, and management of pulmonary dysfunction in patients in the ICU.	The panelists agreed on a series of statements concerning the indications, technique and dosage of PT Rxs for managing pulmonary dysfunction in intubated patients in ICU.
Hanekom et al[73]	7, Delphi panelists.	Clinical management algorithm for the early mobilization of critically ill patients.	The panelists concluded that an individual mobilization plan must be developed for each patient admitted to an ICU, and made a case that early physical activity and mobilization should be the foundation pillars of PT management in ICU.
Surveys			
Hodgin et al[74]	482, US PTs working with critically ill patients.	Current PT practices for patients recovering from critical illness in the US.	PT was commonly administered to patients in the ICU during their recovery. 89% required medical referral to initiate PT. The frequency and type of intervention varied based on hospital type and the clinical scenario.
Stockley et al[75]	165, PTs working in UK ICUs.	Current use of passive movements in UK ICUs.	92% routinely treated ventilated, sedated patients in ICUs. Of these, 99% used passive movements routinely and 78% performed passive movements daily. Joints most commonly treated were the shoulder, hip, knee, elbow, and ankle, for a median of 5 times per area, and joints were taken to the end of ROM. 78% monitored the effects of passive movements, with HR and BP most frequently monitored.
Hayes et al[76]	165, senior PTs working in Australian or NZ ICUs.	Current PT practice with respect to VH, barriers to its use, description of its technique in Australia and NZ.	Only 21% used VH. Lack of training and medical approval were the main barriers to its use. When VH was used, its application varied considerably between respondents.
Jones[77]	54 directors and 103 senior PTs in Australian, UK, Canadian, Hong Kong, and South African ICUs.	ICU directors' perception of their PT service. Senior PTs' qualifications, experience, research, teaching, and job overlap.	79% of ICU directors thought the PT service was outstanding or very good. Secretion removal was seen as the PTs' main role. 60% believed the PTs' work could be covered by other disciplines. 40% of PTs were aware of merging professional boundaries.
Skinner et al[78]	111, PTs working in Australian ICUs.	Exercise prescription by PTs for patients in the ICU in Australia.	94% prescribed exercise routinely for patients in ICU, with active, active-assisted exercises, and mobilization (eg, sit to stand, sit on edge of bed) most commonly prescribed. 34% routinely used outcome measures to monitor exercise prescription, including Spo_2, RR, and functional tests.
Norrenburg and Vincent[79]	102, PTs working in European ICUs.	Profile and role of PTs in European ICUs.	The profile and role of PTs in ICU varied across Europe. 100% reported that PTs were involved in the provision of respiratory therapy, positioning, and mobilization.
Kumar et al[80]	89, PTs working in Indian ICUs.	Role of PTs in Indian ICUs.	55% required medical referral to initiate the provision of PT. 91% were involved in the provision of respiratory therapy and 100% in the provision of mobilization.
Chang et al[81]	86, senior PTs working in Australian ICUs.	Use of tilt tables in the PT management of patients in the ICU in Australia.	67% used tilt tables to assist standing and mobilization. Tilt tables were most frequently used to facilitate weight bearing, prevent muscle contractures, improve lower limb strength, and increase arousal. Title tables most frequently applied to patients with neurologic conditions or prolonged ICU LOS.

(Continued)

Table 5—*Continued*

Study	Participants, No., Type	Topic	Summary of Results
Chaboyer et al[82]	71 nurse managers, 6 PTs working in Australian ICUs.	Availability of PT services in ICUs and role of PTs and nursing staff in provision of "chest PT" in Australia.	87% had weekday PT cover, 66% had weekend PT cover, < 10% had evening PT cover. Nurses were involved in all aspects of "chest PT." PTs were most frequently involved in the provision of mobilization, chest wall vibrations, positioning, percussion, and suction.
Thomas et al[83]	71, PTs and nurses working in Australian ICUs.	Use of positioning in Australian ICUs.	86% believed patients should be turned every 2 h. Positions most frequently used on a daily basis were a quarter turn from supine, supine with the head of bed elevated 30°, and sitting out of bed.
Dennis et al[84]	64, PTs working in Australian ICUs.	Prevalence of using VH during PT Rxs in Australian ICUs.	39% used VH during PT Rxs. VH most frequently used in the setting of sputum retention and respiratory infection.
Matilainen and Olseni[85]	57, PTs working in Swedish ICUs.	Professional role and educational preferences of Swedish ICU PTs.	89% of ICU PTs also worked in other clinical areas. Time spent in ICU ranged from 5-40 h/wk. 100% were involved in the provision of respiratory therapy, mobilization, and limb exercises.
Wiles and Stiller[86]	51, PTs working in Australian ICUs.	Use of passive movements in Australian ICUs.	35% routinely assessed passive limb ROM of all patients in the ICU. 14% routinely provided passive limb exercises as a Rx for all patients in the ICU. Prescription of passive limb ROM exercises was variable between respondents.
Stiller and Wiles[87]	35, patients in the ICU.	Patient satisfaction with PT service in an ICU.	There was a high degree of satisfaction with the personal characteristics of the PTs seen and the PT service provided in ICU.
Hodgson et al[88]	32, PTs working in Australian ICUs.	Use of MH by PTs in Australian ICUs.	91% used MH as a Rx technique. 76% used MH as a routine Rx for ventilated patients. There was strong agreement between respondents on the components of MH, preferred Rx positions, contraindications, and perceived benefits. There was considerable variation between respondents in the duration, number of breaths, and circuits used when performing MH.

ERS = European Respiratory Society; ESICM = European Society of Intensive Care Medicine; NZ = New Zealand; UK = United Kingdom; US = United Statesct. See Table 1-4 legends for expansion of other abbreviations.

identified, the current review included 26 clinical studies on this topic and, while study quality was variable, statistically significant and clinically important benefits resulting from early mobilization were demonstrated. These new clinical studies have shown that early progressive mobilization is feasible and safe, and results in significant functional benefits that may translate into positive effects on the ICU and hospital LOS. Stiller[1] noted that the role of physiotherapy in the ICU would continue to be questioned until physiotherapy has been shown to have a favorable impact on broader outcomes of patients in the ICU. The new evidence demonstrating the beneficial effects of mobilization on broader outcomes such as the ICU and hospital LOS confirms an unquestionable role for physiotherapy in the ICU. Given that the demand for physiotherapy services often outstrips the resources available, and the new evidence demonstrating the effectiveness of physiotherapy interventions aimed at early mobilization, ICU physiotherapists should give priority to interventions aimed at early progressive mobilization. To be successful, implementation of early progressive mobilization relies on an ICU culture that considers mobilization an essential part of multidisciplinary care. Safety guidelines and protocols for progressive mobilization of patients in the ICU are available.[34,37,42,47,89]

Eighteen new clinical trials were identified that evaluated the effectiveness of multimodality respiratory physiotherapy for adult, intubated, mechanically ventilated patients in the ICU. The results of these trials support and extend the conclusions made by Stiller in 2000,[1] namely, that multimodality respiratory physiotherapy may result in short-term improvements in pulmonary function. While there is some new evidence from RCTs that the provision of routine multimodality respiratory physiotherapy can impact positively on outcomes such as duration of intubation and the ICU LOS, there is, however, a similar amount of new high-quality evidence suggesting that it may not. In terms of specific respiratory physiotherapy interventions, there is limited evidence from new randomized crossover trials suggesting that expiratory rib-cage compression is ineffective and that MH may have beneficial short-term effects on respiratory compliance, concurring with the conclusions made in the 2000 review.[1] New evidence has emerged demonstrating that VH is as effective as MH. There is new high-quality evidence concerning the effectiveness of IMT for patients in the ICU; however, this evidence is scarce, hence the routine or selective use of IMT for patients in the ICU cannot be recommended at present. Similarly, the evidence that has been published since 1999 concerning the effectiveness of NMES is limited and, thus, clinical recommendations regarding its use in ICU cannot be made.

Limitations of this systematic review included the variable methodological quality of the studies. The diverse range of study samples and study methodology precluded pooling of results and statistical analysis. The interventions that were provided usually comprised numerous components, making it impossible to determine the effectiveness of individual treatment components.

A strength of this literature review was the inclusion of all clinical studies that have evaluated physiotherapy for adult patients in the ICU, irrespective of study design. Additionally, by reviewing the evidence concerning a broad range of physiotherapy practice, rather than focusing on one specific type of intervention (eg, multimodality respiratory physiotherapy or mobilization alone), it has been possible to highlight the emerging evidence concerning the beneficial effects of early progressive mobilization compared with other physiotherapy interventions.

Conclusions

In summary, the evidence concerning the efficacy of routine multimodality respiratory physiotherapy for adult, intubated patients receiving mechanical ventilation remains unclear. There is strong, albeit limited, evidence published since the review in 2000 showing that physiotherapy intervention focusing on early progressive mobilization is feasible and safe, and results in significant functional benefits, which may translate into a reduced ICU and hospital LOS. This emerging evidence confirms the role of the physiotherapist in ICU and highlights that early progressive mobilization is an effective area of physiotherapy clinical practice for adult, intubated, mechanically ventilated patients. Further research to confirm the efficacy of early progressive mobilization is required, in particular to determine the optimal "dosage" in terms of its most effective components, intensity, duration, and frequency.

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