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Early mobilization in the critical care unit: A review of adult and pediatric literature

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ABSTRACT

Early mobilization of critically ill patients is beneficial, suggesting that it should be incorporated into daily clinical practice. Early passive, active, and combined progressive mobilizations can be safely initiated in intensive care units (ICUs). Adult patients receiving early mobilization have fewer ventilator-dependent days, shorter ICU and hospital stays, and better functional outcomes. Pediatric ICU data are limited, but recent studies also suggest that early mobilization is achievable without increasing patient risk. In this review, we provide a current and comprehensive appraisal of ICU mobilization techniques in both adult and pediatric critically ill patients. Contra-indications and perceived barriers to early mobilization, including cost and health care provider views, are identified. Methods of overcoming barriers to early mobilization and enhancing sustainability of mobilization programs are discussed. Optimization of patient outcomes will require further studies on mobilization timing and intensity, particularly within specific ICU populations.

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Mobilization has been defined as "physical activity sufficient to elicit acute physiological effects that enhance ventilation, central and peripheral perfusion, circulation, muscle metabolism and alertness and are countermeasures for venous stasis and deep vein thrombosis" [1]. A current definition of *early mobilization* refers to the application of physical activity within the first 2 to 5 days of critical illness or injury [2]; however, it is important to note that some of the research published on "early" mobilization is beyond this window. For example, one study defined *early intervention* as an activity beginning before intensive care unit (ICU) discharge (6.6 ± 5.5 days for sitting on bed) [3]. Delaying mobilization until the acute phase of illness has subsided may not only significantly decrease benefit but also result in less optimal patient outcomes. The goals of this review are to (1) emphasize the practicality and effectiveness of early mobilization and its impact on recovery from a critical illness in both adults and children and (2) highlight the many

perceived barriers to early mobilization, such as cost, health care professional views, and sustainability.

1. Consequences of immobility in the critically ill

Typical critical care interventions that promote immobilization include the administration of analgesics and sedatives to facilitate mechanical ventilation and reduce pain, agitation, and/or anxiety [4,5]. Immobility is associated with ICU delirium, impaired exercise capacity, ICU-acquired weakness (ICU-AW), and poorer functional outcomes and quality of life [6,7]. Intensive care unit–acquired weakness is categorized by both axonal nerve degeneration and myosin loss, and is believed to be the multifactorial result of systemic inflammation, medications, electrolyte disturbances, and immobility [8,9].

Immobility-associated muscle loss begins within 48 hours of critical illness onset or injury [10] and is greatest during the first 2 to 3 weeks of an ICU stay [11]. Up to a 40% loss in muscle strength can occur within the first week of immobilization, with a daily rate of strength loss between 1.0% and 5.5% [6,12]. A 10.3% to 13.9% decrease in cross-sectional measurements of the rectus femoris muscle has been observed within the

first ICU week and is positively correlated with elevated C-reactive protein levels and organ dysfunction severity [13,14]. Diaphragmatic atrophy due to ventilator-induced diaphragm inactivity during positive pressure ventilation is positively correlated with the severity of limb weakness (maximal inspiratory pressure $\rho = 0.35$, $P = .001$; maximal expiratory pressure $\rho = 0.49$, $P < .0001$; vital capacity $\rho = 0.31$, $P = .007$) [15]. Its severity is associated with duration of mechanical ventilation [15–18]. Clinical phenotypes of ICU-AW have been described that may predict nerve and muscle functional recovery and are determined through a combination of factors including increased age, comorbidity, ICU length of stay (LOS), and additional risk differentiators such as cognitive dysfunction [19].

Intensive care unit–acquired weakness affects 25% to 100% of critically ill adult patients [20–22], whereas the incidence of ICU-AW is less frequently reported in the pediatric ICU (PICU) population, likely because of the lack of a feasible and reliable screening tool. In a recent pediatric pilot study, ICU-AW was confirmed in 6.7% of "at-risk" patients and suspected in 30% [23]. Intensive care unit–acquired weakness is age dependent, with 0.7% of very young children and 5.1% of older children exhibiting muscle weakness [23,24].

Intensive care unit–acquired weakness is an independent predictor of mechanical ventilation duration and is associated with longer ICU and hospital stays [9,21]. A 40% loss of lean muscle mass approaches a mortality rate of 100% [25]. Muscle wasting, exercise intolerance, and decreased quality of life ratings persist 1 year post–ICU discharge in affected adult and pediatric survivors [8,20,24,26,27]. Persistent functional impairment and perceived muscle weakness are reported on a 5-year examination of functional outcomes in adult ICU survivors; these outcomes appear to plateau at 1 year, with patients making little substantial gains after that time [27]. Long-term functional outcomes are less clear in pediatric patients and have not been studied prospectively to date.

2. Early mobilization in critically ill patients

Research on early mobilization is growing in the adult population, whereas studies in the pediatric population are still in their infancy. Thirteen prospective studies have been conducted in adults [3,28–39], but only 3 are randomized controlled trials [30,34,39]. A recent Canadian survey, composed of 198 adult ICUs, indicated that although 71% of the units prioritized early mobilization, only 38% of the ICUs had mobilization protocols. Furthermore, only 31% of adult ICUs had access to specialized equipment for the purpose of early mobilization therapies [40].

The most common types of rehabilitation techniques administered in Canadian adult ICUs are functional mobility retraining and therapeutic exercises [41]. Not surprisingly, the majority of early mobilization research has focused on active, rather than passive, therapies. Among critically ill children, rehabilitation is primarily focused on nonmobility interventions, most commonly chest physiotherapy, and only 9.5% receive early mobilization [42,43].

Early mobilization is part of the Awakening and Breathing Coordination, Delirium monitoring/management, and Early exercise/mobility (ABCDE) bundle [44–46]. The bundle approach combines a number of evidence-based patient care interventions with the goal of increasing focus on the aforementioned areas of concern and improving patient outcomes [47]. Specifically, the goal of the ABCDE bundle is to increase liberation from mechanical ventilation, facilitate earlier ICU and hospital discharge, aid in the return to normal brain function, improve independent functional status, and increase patient survival [45]. Some of the ABCDE bundle components have been independently evaluated. The Awake and Breathing Controlled Trial demonstrated the effectiveness of spontaneous awakening and spontaneous breathing trials for decreasing ICU and hospital LOS. It also demonstrated a decrease in 1-year mortality [46]. The creation of delirium screening tools and the identification of sedative medications as modifiable risk factors for

delirium have prompted increased deliberation regarding the types of medications and have encouraged the practice of sedation vacations [46]. The bundle provides an all-or-nothing concept, from which physicians are able to withdraw if clinically indicated [44,47]. Research has shown the ABCDE bundle to be safe and effective. Spontaneous awakening and breathing trials are more likely to occur (50% post–intervention initiation vs 25%, $P = .001$; 84% post–intervention initiation vs 71%, $P = .03$, respectively), and there is an increased likelihood of mobilization in the ICU (2.11; 95% confidence interval, 1.30-3.45; $P = .003$) [44]. Furthermore, the incidence of delirium is reduced following implementation of the ABCDE bundle (48.7% post–intervention initiation vs 62.3%, $P = .02$) [44].

2.1. Active mobilization

Active mobilization in ICU patients is thought to be effective and is recommended in international guidelines [1]. A variety of active mobilization protocols have been utilized, including active or resistive range of motion (ROM) exercises, sitting on a bed or chair, bed exercise (eg, cycling), dangling, transfers, tilting up (arms supported or unsupported), and ambulating (either assisted or unassisted) [3,29,30,35,37,38]. Early mobilization can be safely initiated on the first day of ICU admission and even during mechanical ventilation [29,35], administration of vasopressors [32,39,48], continuous renal replacement therapy (CRRT) [49,50], and with femoral catheters in situ [51,52]. The rate of adverse events ranges between 0% and 3%, and the reported adverse events are not usually serious [3,29,30,35,37,38]. Adverse events typically include cardiovascular events, falls, or tube extractions (Table 1). The adverse events rarely require additional treatment or result in additional cost or LOS [35]. Ambulation distance at ICU discharge was increased in patients who received early active mobilization in the ICU [3] compared with patients for whom mobilization is initiated after ICU discharge [53].

In a retrospective pediatric study including 600 children (mean age = 4.9 years) with primarily medical diagnoses (64.2%), a significantly greater duration of vasoactive medication infusion, PICU LOS, and delirium was present in mobilized patients. Although this may suggest a negative effect of mobilization, the authors postulate that clinicians were inadvertently selecting sicker patients [42].

2.2. Passive mobilization

Passive therapies, such as manual passive exercises, cycle ergometers, and/or continuous passive motion machines [28,39], may be used for patients unable to cooperate with instructions. Cycle ergometry training has been effectively used for passive, active-assisted, and/or active ROM exercise [39]. Continuous passive motion machines passively alternate leg movements to simulate slow walking as early as 38 hours following intubation [28]. Passive exercise is safe in mechanically ventilated adult patients. In one study, continuous passive motion did not have a negative impact on heart rate, blood pressure, or oxygen saturation; and only 16 (3.7%) of the 425 exercise sessions using the cycle ergometer ended prematurely because of an abnormal physiological response [28,39].

Although the safety of early passive exercise in ICU patients has been questioned out of concern for exercise-induced propagation of systemic inflammation [28], nonexhaustive exercise has been demonstrated to have antioxidant effects and to alter levels of inflammatory cytokines [54,55]. Passive exercise has been demonstrated to improve functional exercise capacity, improve perceived functional status, increase quadriceps muscle force, and decrease pain scores [28,39]. Regional limb blood flow is increased by passive exercise, as measured by ultrasound Doppler, because of changes in intramuscular pressure [56]. Passive activity for an average of 14.7 minutes in critically ill patients significantly decreased interleukin (IL)-6 levels and improved the cytokine balance (IL-6/IL-10 ratio), potentially improving recovery [28,57,59].

Low-activity levels inversely correlates with the endothelial cell adhesion molecule E-selectin [58].

Another understudied intervention with potential benefits for critically ill ICU patients is neuromuscular electrical stimulation (NMES). This method creates passive contractions in skeletal muscles by way of low-voltage electrical impulses and is believed to mimic the effect of mild exercise and as such reduce muscle atrophy [59]. Studies of NMES have indicated greater improvement/maintenance in strength of stimulated muscles when compared with nonstimulated controls and/or baseline measures [60,61]. Furthermore, NMES administered daily upon ICU admission has been shown to preserve lower extremity muscle mass [13]. Electrical stimulation, as a form of passive muscular activity, may be more advantageous than current active exercise training regimens because it causes less ventilatory stress [62]. Although extensively researched in chronically ill patients, insufficient research exists in patients with acute critical illness [63]. Future research should compare the efficacy of electrical stimulation vs traditional mobilization therapies or the efficacy of using both together [64].

2.3. Progressive exercise and mobility

Level 1 *progressive* mobility techniques introduce passive ROM for unconscious adult patients. As patients become more interactive, they may be advanced to active ROM exercises, active resistance physical therapy, bed mobility exercises, sitting on the edge of bed, balance training, activities of daily living, transfer training, pregait exercises, and walking [31,32,34,36,65]. Similarly to passive exercise, progressive mobilization is safe and effective, with only 1 (0.2%) serious adverse event in 498 interventions [34]. Patients who received progressive early therapy are able to mobilize out of bed sooner (5 vs 11 days, $P \leq$ .001) and have significantly shorter ICU and hospital stay lengths (5.5 vs 6.9 days, $P = $ .025, and 11.2 vs 14.5 days, $P = $ .006, respectively) [32]. In addition, these patients were found to have a shorter duration of delirium (2.0 vs 4.0 days, $P = $ .02), a greater number of ventilator-free days (23.5 vs 21.1 days, $P = $ .05), and better independent functional status at hospital discharge (59% vs 35%, $P = $ .02) [34].

2.4. Pediatric mobilization

Research examining pediatric early mobilization is markedly lacking, despite studies indicating that muscle weakness is a concern for critically ill children. Muscle weakness in children has been identified as early as day 4 following ICU admission [24]. In the same study, muscle wasting in proximal and distal muscles was identified in 57% of patients with ICU-AW (n = 14/830, 1.69%). At 3-month follow-up, 57% of these children had persistent proximal weakness; and 14% were unable to walk independently [24].

As previously described, a recent pediatric pilot study predicted ICU-AW in 30% of patients and confirmed ICU-AW in 6.7% of at-risk patients [23]. Diagnosis of ICU-AW in children is hindered by the lack of a suitable diagnostic tool [23]. The Medical Research Council (MRC) grading tool is unreliable and unfeasible in children, and handheld dynamometry is best used as a simple screening tool for ICU-AW in alert patients [23,66]. Dynamometry and MRC scoring are volitional measures that are confounded by the need for patient effort, alertness, and motivation. The aforementioned variables are affected by patient's levels of consciousness and by the levels of sedative and analgesic medications [10,66,67]. As neither dynamometry or MRC scoring is capable of identifying the early onset of ICU-AW, there is a need for an objective measure of evoked muscle force, which would be more suitable for use in pediatric populations [66,67].

Pediatric data on early mobilization interventions are scarce. A pilot study of 8 children, aged 3 to 16 years, admitted to a medical/surgical PICU demonstrated that upper limb mobilization using virtual reality, by way of interactive gaming consoles, is safe and feasible [68]. In addition, a pediatric progressive mobility protocol administered to 25 medical/surgical PICU patients aged 3 to 18 years using cycle ergometry and/or interactive video gaming interventions in the PICU is practical [69]. Neither of the described pediatric studies reported any adverse events despite 50% to 52% of children being mechanically ventilated while receiving the intervention [68,69].

Older children are more likely to receive early mobilization [43]. The authors postulated that this may be due to the perception of greater safety and superior cognitive and functional maturity in older children. Nonphysician health care team members are often the ones to identify children's needs for rehabilitation. More than half (54.5%) of children admitted to ICU are not mobilized during their ICU stay [42]. Mobilization protocols mandating physiotherapy consults for every PICU patient could improve short- and long-term functional outcomes. The efficacy of early mobilization, appropriate patient selection, and risk stratification for who could benefit most from this intervention, however, has yet to be evaluated in prospective clinical trials in pediatrics.

2.5. Summary of early exercise mobilization

The literature indicates that early mobilization is safe and feasible in critically ill adult and pediatric patients, including those that are mechanically ventilated and/or unconscious (Table 1). All 3 types of rehabilitation—passive, active, or a combination of the 2—are associated with decreased ICU and hospital LOSs [31–33,36], shortened durations of delirium [33,34], fewer ventilator-dependent days [34], greater ambulation distance [3,39], and better functional status upon hospital discharge [31,33,34,36,39]. Additional research is required, especially in pediatric populations and specialized adult ICUs, to determine the most effective methods of early mobilization.

Research on early mobilization currently focuses predominantly on adults admitted to medical ICUs. Recently, research interest has expanded with regard to early mobilization in trauma/burn, neurological, and surgical ICUs because of the unique considerations facing these populations. In the trauma ICU, patients are typically younger and healthier compared with medical ICU patients [70]. Patients with various types of fractures of the upper and lower extremities, pelvis, and acetabulum can tolerate ROM and varying levels of weight-bearing activities [70]. In addition, early mobilization improves pain, swelling, and stiffness while enhancing patient satisfaction [71]. Traumatic craniofacial, thoracic, and abdominal/vascular injuries may require special considerations. Generally, there are no restrictions to mobilization; however, patients with an open abdomen, traumatic aortic injuries, and in situ lumbar drains may need to have certain aspects of mobilization limited [70].

There are minimal data pertaining to early mobilization in neurological ICUs. Common diagnoses of patients admitted to the neurological ICU include acute ischemic and hemorrhagic stroke, subdural hematoma, subarachnoid or intracranial hemorrhage, hydrocephalous, status epilepticus, neuromuscular disorders, brain tumors, and traumatic brain injury [31,72]. Special considerations in this population include intracranial pressure levels, altered motor control, reduced motor tone, and alterations in perception and cognition [70,72]. Physiotherapy in this population tends to be less frequent (median 2.1 [1.2-5.1] sessions per week vs 5.3 [3.5-7.0], $P < .0001$) and less intense (ROM accounts for 29% vs 9% of sessions, $P < .0001$) compared with interventions provided following ICU discharge [72]. Despite clinicians' reluctance, the initiation of early progressive mobilization programs in neurocritical care units have shown significant improvements in mobility levels, LOS, and complications (Table 1).

Surgical patients have unique considerations regarding mobilization including surgical wound pain, unstable fractures, open wounds, drains, and the patient's proximity to or from surgery [73]. A study of postsurgical, noncritical inpatients demonstrates that rehabilitation that incorporates ambulation starting day 1 postoperatively results in decreased LOS, fewer complications, and a faster recovery [74].

Table 1
Summary of reviewed literature

Author(s)	Study details	Demographic information and timing	Safety/feasibility	Efficacy
Adult				
Zafiropoulos et al, 2004 [37]	Observational Active mobilization Sessions occurred once per day (days 1 through 6 postoperatively) • Supine • Sit on bed • Standing • Walking on the spot	• 17 patients admitted to medical ICU postoperatively • Required mechanical ventilation	None Did note that hemodynamic instability was greatest during initial positional change from supine to sitting	Increase of tidal volume (from 712.7 ± 172.8 to 883.4 ± 196.3 mL; $P = .008$) and respiratory rate (21.4 ± 5.0 to 24.9 ± 4.5 breaths/min; $P = .03$) due to positional change from supine to standing
Bailey et al, 2007 [3]	Prospective cohort study Active mobilization: 1449 sessions • Sit on bed • Sit in chair • Ambulate (assisted or unassisted)	• 103 patients admitted to respiratory ICU • Mechanically ventilated for at least 4 d	0.96% event incident • Fall (to knees, without injury, 36%) • SBP < 90 mm Hg (29%) • Oxygen desaturation (21%) • Feeding tube extubation (7%) • SBP > 200 mm Hg (7%) None serious	69% of patients could ambulate greater than 100 f. at ICU discharge
Bourdin et al, 2010 [29]	Prospective observational study Active mobilization: 424 sessions • Chair-sitting • Tilting-up (supported) • Tilting-up (unsupported) • Walking	• 20 patients admitted to medical ICU for at least 1 wk • Mechanically ventilated for at least 2 d	3% event incident • Decreased muscle tone (54%)[a] • Hypoxemia (31%) • Extubation (8%) • Orthostatic • Hypotension (8%) None serious	NA
Needham et al, 2010 [33]	Prospective quality improvement project Active mobilization • Sitting in bed/on edge of bed • Transfers • Walking	• 57 patients admitted to medical ICU • Mechanically ventilated for at least 4 d	4 feeding or rectal tube removals or displacements None serious	Increased functional ability (sitting or better, 78% vs 56%, $P = .03$) Decreased delirium (21% vs 53%, $P = .003$) Decreased ICU LOS (4.9 vs 7.0, $P = .02$) Decreased hospital LOS (14.1 vs 17.2, $P = .03$)
Zanni et al, 2010 [38]	Prospective observational 50 rehabilitation treatments Interventions based on patient's impairments. Included: • Stretching • Strengthening • Balance training • Functional activities	• 19 patients admitted to medical ICU • Mechanically ventilated for at least 4 d • Eligible for rehabilitation	None	Decreased upper and lower extremity muscle weakness (19% vs 53% and 43% vs 79%, respectively)
Denehy et al, 2013 [30]	Randomized control trial • Marching in place • Sit to stand transfers • Arm and leg AROM	• 150 patients admitted to medical/surgical ICU • Admitted to ICU for at least 5 d	No adverse events	NA
Sricharoenchai et al, 2014 [35]	Prospective observational study Active mobilization: 5267 sessions • In-bed exercise • In-bed cycling • Sitting • Transfers • Standing • Walking	• 1110 patients admitted to medical ICU for at least 24 h • Received active physical therapy	0.6% event incident • Arrythmia (29%)[a] • MAP > 140 mm Hg (24%) • MAP < 55 mm Hg (15%) • Oxygen desaturation (12%) • Fall (9%) • Feeding tube extubation (6%) • Radial arterial catheter removal (3%) • Chest tube removal (3%) None serious	NA
Burtin et al, 2009 [39]	Randomized control trial Passive & active therapy: • Cycle ergometry	• 90 patients with expected prolonged medical/surgical ICU stay • Cardiorespiratory stability by day 5 at earliest	3.76% event incident • Spo$_2$ < 90% (50%) • SBP > 180 mm Hg (37.5%) • >20% decrease of diastolic BP (12.5%) None serious	At hospital discharge: • Greater ambulation distance (196 vs 143 m, $P < .05$) • Greater perceived functional status (SF-36 PF score 21 vs 15 points, $P < .01$)

Table 1 (continued)

Author(s)	Study details	Demographic information and timing	Safety/feasibility	Efficacy
Amidei and Sole, 2013 [28]	Quasiexperimental within-subjects repeated measures Passive therapy: • Continuous passive motion device	• 30 patients from 3 critical care units (trauma/burn; medical; neuroscience) • Enrolled within 48 h of mechanical ventilation	Heart rate, blood pressure, and oxygen saturation did not differ from baseline	• Improved quadriceps muscle force (1.83 ± 0.91 vs 2.37 ± 0.62 N/kg, $P < .01$) • Decreased pain ($P = .02$) • Decreased IL-6 ($P = .03$)
Morris et al, 2008 [32]	Prospective cohort study Progressive, passive, & active therapies: • PROM • Active resistance PT • Sitting in bed • Sitting on edge of bed • Chair transfer	• 330 patients with acute respiratory failure admitted to medical ICU • Mechanical ventilation on admission	None	• Out of bed sooner (5 vs 11 d, $P \leq .001$) • Shorter ICU LOS (5.5 vs 6.9 d, $P = .025$) • Shorter hospital LOS (11.2 vs 14.5 d, $P = .006$)
Schweickert et al, 2009 [34]	Randomized control trial 498 sessions Progressive, passive, & active therapies: • PROM • AROM • Sitting • Balance activities • Activities of daily living • Transfer training • Pregait exercises • Walking	• 104 patients admitted to medical ICU • Mechanically ventilated for less than 72 h and expected to continue for another 24 h	4.0% event incidence • Patient instability: perceived patient-ventilator asynchrony • 0.2% Serious (desaturation <80%)	• Shorter delirium duration (2.0 vs 4.0 d, $P = .02$) • Fewer ventilator dependent days (21.1 vs 23.5 d, $P = .05$) • Better independent functional status (59% vs 35%, $P = .02$)
Titsworth et al, 2012 [36]	Prospective cohort study Progressive Upright Mobility Program (PUMP) Specific protocol with 11 steps from head of bed elevation to ambulating unassisted	• 3291 patients admitted to neurointensive care unit pre– and post–PUMP initiation	No significant difference pre- and postimplementation	• More patients sat up in bed ($P < .05$), were out of bed ($P < .001$), and were able to walk to bathroom ($P < .001$) • Shorter ICU LOS (3.46 vs 4.0 d, $P < .004$) • Shorter hospital LOS (8.6 vs 12.0 d, $P < .01$) • Decreased VAP incidence (0 vs 2.14 ± 0.95/1000 ventilator days, $P < .001$).
Clark et al, 2013 [65]	Retrospective cohort study Progressive early mobilization	• 2176 patients admitted to trauma/burn ICU pre– and post– early mobilization program	None	• Decreased incidence of airway ($<.001$), pulmonary ($\leq.001$), and vascular ($\leq.001$) complications post– program initiation
Klein et al, 2014 [31]	Prospective cohort study 16-level early progressive mobility protocol	• 637 patients admitted to neurological ICU pre– and post– early progressive mobilization program	Adverse events not validated	• Increased number of patients able to bear weight, pivot, and ambulate (21.2% vs 42.7%, $P < .001$) • 33% decrease in hospital LOS ($P < .001$) • 45% decrease in neurological ICU LOS ($P < .001$) • 11.3% increase in patients discharged home ($P = .002$)
Pediatric				
Abdulsatar et al, 2013 [68]	Prospective cohort study Active mobilization: Virtual reality interactive gaming console At least once per day for a maximum of 2 d	• 8 patients aged 3-16 y admitted to PICU for at least 48 h	No adverse events reported	• Greater upper limb activity compared with rest of day ($P = .049$)
Choong et al, 2014 [69]	Prospective cohort study Progressive passive, & active therapies: • Cycle ergometry • Virtual reality interactive gaming console	• 25 patients aged 3-18 y admitted to PICU	No adverse events reported	NA

SBP indicates systolic blood pressure; NA, not applicable; AROM, active range of motion; MAP, mean arterial pressure; Spo$_2$, saturation of peripheral oxygen; ; SF-36 PF, Short Form–36 Physical Functioning scale; PROM, passive range of motion; PT, physical therapy; VAP, ventilator-associated pneumonia.

[a] Because of rounding, proportions may not total 100%.

3. Barriers and limitations to early mobilization

3.1. Restrictive parameters and contraindications

Patient safety is paramount in any exercise intervention. Patients with high illness severity, coma, and/or delirium are particularly vulnerable; and the utmost care must be undertaken during exercise interventions [75]. A survey of Canadian PICU practices found that medical instability, risk of device and/or catheter dislodgement, and mechanical ventilation are perceived barriers to mobilization [43]. Despite literature that demonstrates the safety of early mobilization in high-acuity patients, physicians are reluctant to integrate mobilization into their practices [34,38,75]. Objective parameters should be implemented to assist health care workers in assessing patient exercise tolerance. Parameters varied widely between studies (Tables 2 and 3) but typically included limits in heart rate, blood pressure, and respiratory rate. Exercise programs have been questioned in ICU patients with raised intracranial pressure [28,34], active gastrointestinal blood loss [34], active myocardial ischemia [32,34], intermittent or continuous renal replacement therapy [29,34,48], and vasoactive medication requirements [3,32,34,48]; however, research has indicated that early mobilization in adult ICU patients receiving vasopressor infusions [32,39,48] or CRRT [49,50] can be safe. As such, further research is warranted to find ways to alleviate perceived barriers to early mobility. Pediatric algorithms include mechanical ventilation with positive end-expiratory pressure greater than or equal to 10 and high-frequency oscillation ventilation as contraindications, although these recommendations do not appear to be evidence based [76].

Early passive mobilization has been implemented safely in high-acuity patients [32,34]. A mobilization program consisting of early passive exercise that progresses to more active components including mobilization and resistance training is likely to be most effective. Special considerations must be given to PICU patients because children admitted to the PICU typically have complex medical histories, have a multitude of cognitive and functional abilities, and require specialized mobility devices [68].

3.2. Personnel resources, attitudes, and perceptions

Physicians, nurses, and physical therapists are the primary personnel involved in patient mobilization and physical therapy. Overall, health care professionals are able to identify the benefits associated with early mobilization; however, 21% of physicians and 18% of nurses believe that the potential risks outweigh the benefit of early mobilization [77]. Additional perceptions from critical care professionals indicate that the majority (68% of physicians, 76% of nurses, and 92% of physical therapists) do not believe that ROM alone is sufficient to preserve muscle strength [77].

Three of the top 5 perceived barriers to early mobilization reported by physicians were the time required by nursing staff, physical therapists, and respiratory therapists to implement early mobilization procedures. This observation is echoed by nursing and physical therapist staff [77]. In fact, health care worker resource limitations are one of the most limiting factors of mobilization protocols. A recent study indicated that physical therapy was not provided in a median of 56% of ICU days because of staffing restrictions [38]. Progressive mobilization requires a dedicated team of specialists, including a physical therapist, respiratory therapist, nurse, nursing assistant, and/or critical care technician [3,32].

In addition to, or in lieu of, a dedicated exercise team, the bedside nurse could provide early mobilization. The degree of mobilization a patient receives is dependent upon the type of health care professional responsible for facilitating physical therapy [78]. Physical therapists are able to achieve a higher level of mobilization compared with nurses on an optimal mobilization scale of 0 to 4 (level 2.3 ± 1.2 vs level 1.2 ± 1.2, $P < .0001$) and have a greater number of patients achieve standing and ambulating (38% vs 13%, $P < .05$) [78]. The difference between how physical therapists and nurses perceive barriers for advancing

Table 2
Parameters to be met before the initiation of mobilization therapy

Adult	
Passive	
General:	
• Cardiorespiratory stability [39]	
• Physiologically stable [28]	
Active	
Neurological (alertness/agitation):	Respiratory: blood gas
• Response to verbal stimuli [3]	• Pao$_2$/Fio$_2$ ratio >200 mm Hg [29]
• Absence of agitation, confusion or impaired response to simple orders [29]	• Paco$_2$ < 50 mm Hg [29]
• No increase in intracranial pressure [34]	• pH >7.30 [29]
• No need for increased sedation [34]	• Oxygen saturation >88% [34]
Cardiovascular: heart rate	Respiratory: mechanical ventilation
• Between 40 and 130 bpm [34]	• Fio$_2$ [3]
• No active myocardial ischemia [34]	• PEEP cm H$_2$O [3]
Cardiovascular: blood pressure	Respiratory: respiratory rate
• Absence of orthostatic hypotension [3]	• <35 breaths/min [29], 5-40 breaths/min [34]
• Absence of catecholamine drips, ongoing vasopressors [3]	
• SBP >90 mm Hg [29], < 200 mm Hg [34]	
• MAP between 65 and 110 mm Hg [34]	
General:	
• No ongoing renal replacement therapy [29]	
• No ongoing intravenous sedation [29]	
• No scheduled extubation [29]	
• No active GI blood loss [34]	
• No continuing procedures (eg,, hemodialysis) [34]	

Pediatric	
Neurological (alertness/agitation):	Cardiorespiratory:
• Ability to comprehend instructions [68]	• Overall cardiorespiratory stability [68]
• Ability to perform intervention [68]	
• No cognitive or function disability (POPC/PCPC scores ≥ 4) [68]	

Pao$_2$ indicates partial pressure of arterial oxygen; Fio$_2$, fraction of inspired oxygen; Paco$_2$, partial pressure of arterial carbon dioxide; bpm, beats per minute; PEEP, positive end-expiratory pressure; GI, gastrointestinal; POPC, Pediatric Outcome Performance Category; PCPC, Pediatric Cerebral Performance Category.

mobilization may explain the different patient outcomes. Whereas physical therapists are primarily concerned with neurological function, nurses may delay physical therapy because of hemodynamic instability and the need for CRRT [78]. A culture change is required whereby, instead of limiting the availability of early mobilization through exclusion criteria, we practice more detailed monitoring of patient parameters during mobilization [78].

Nurses and physical therapists also identify risk of self-injury and excessive work stress as barriers to early mobilization programs [77]. The perceived risk of occupational health barriers, including musculoskeletal injuries, may be overcome through education and training, as acceptance and confidence in the ability to safely mobilize patients are correlated with successful implementation and participation in such a program [77,79].

A Canadian survey indicated that 89% of hospitals required a physician consultation before physical therapy initiation [41]. In some instances, patients wait 7 to 12 days between ICU admission and their first physical/occupational therapy consultation [38]. An "exercise team" dedicated to early mobilization therapy in the ICU could optimize patient rehabilitation care and ultimately decrease the demand on nursing resources [32]. Eighty percent of physicians surveyed agreed that an early mobilization order should occur automatically through nursing and physical therapists unless specifically ordered otherwise [77]. An automatic order would promote the idea that early mobilization is to be standard of care [36].

Table 3
Parameters to indicate need to cease individual therapy sessions

Adult	
Passive	
Cardiovascular: heart rate	Respiratory: blood gas
• >70% of predicted maximum [39] • >20% decrease in HR [39] • <50 bpm or >130 bpm [28]	• Oxygen saturation <90% [28]
Cardiovascular: blood pressure	General:
• Clinical indication or cardiorespiratory distress [39] • SBP > 180 mm Hg [39] • MAP <60 mm Hg or >130 mm Hg [28] • >20% decrease in SBP or DBP [39]	• Intracranial pressure >20mm Hg [28]
Active	
Neurological (alertness/agitation):	Respiratory: blood gas
• Agitation [29] • Anxiety [29] • Patient distress [34]	• Oxygen saturation <80% [3] • Oxygen saturation <88% for >1 min [29], <88% [32,34]
Cardiovascular: heart rate	Respiratory: mechanical ventilation
• >130 bpm or 20% from baseline [29], <40 bpm or >130 bpm [34] • New cardiac arrhythmia [29] • New documented myocardial infarction dysrhythmia [32] • Concern for myocardial ischemia [34]	• Increased PEEP [32] • Change to assist mode [32] • Ventilator asynchrony [34] • Concern for airway device integrity [34]
Cardiovascular: blood pressure	Respiratory: respiratory rate
• SBP <90 mm Hg [3,29], >200 mm Hg [3,34], > 180 mm Hg [29] • Administration of new vasopressor agent [32] • MAP <65 mm Hg [32,34] or > 110 mm Hg [34]	• >35 breaths/min [29] • 20% from baseline [29] • <5 breaths/min or >40 breaths/min [34]
General:	
• Extubation [3] • Fall to knees [3] • Tube removal [3] • Diaphoresis [29] • Patient being physically violent [34]	
Pediatric	
Cardiovascular: heart rate	Respiratory: blood gas
• Arrythmia [68] • Persistent tachycardia [68]	• Fall in oxygen saturation to <85% [68]
Cardiovascular: blood pressure	Respiratory: respiratory rate
• Hypo- or hypertension [68]	• Tachypnea for age [68] • Increased work of breathing [68]
General:	
• Tube removal [68] • Musculoskeletal injury [68] • Pain or discomfort requiring increased sedation/analgesia [68]	

HR indicates heart rate; DBP, diastolic blood pressure.

3.3. Timing of mobilization

The optimal timing for initiation of mobilization has yet to be defined. *Early mobilization* is currently defined as occurring within the first 2 to 5 days of ICU admission [2]. It is known that ICU-AW can begin within the first 48 hours of ICU admission [10]. Further research must occur to provide the rationale to alter the definition of early mobilization.

The optimal timing for cessation of mobilization practices is currently unknown because study protocols generally ceased when the patient was discharged from the ICU or returned to baseline functioning [28,29,35,39]. Only 1 study set a well-defined *functional end point*, defined as the ability to perform 6 tasks of daily living and to walk independently [34]. Significantly more patients in the progressive mobilization group were able to function independently at hospital discharge (59% vs 35%, $P = .02$). There is 1 study of note that conducted whole-body physiotherapy intervention post–ICU discharge and found that patients were able to ambulate a greater distance upon hospital discharge (52 vs 0 ft, $P = .005$) [53]. This latter study suggests that rehabilitation protocols should continue beyond the ICU stay.

3.4. Cost

Another barrier to early mobilization is the perceived cost [80]. Two types of cost contribute to the financial model of incorporating a new program into an ICU: fixed costs and direct variable costs. Fixed costs are items such as salaries, benefits, and overhead [81,82]. The direct variable costs account for less than 20% of total operating costs and include monies associated with supplying medical services and patient consumable costs (ie, blood bank, laboratory, pharmacy, radiology, and respiratory services) [81,82]. Direct variable costs can be 4 times greater on the first day of ICU admission and will decrease during the first 5 days of an ICU stay; as such, when estimating the cost savings to be had over the course of an ICU stay, one should weigh the days accordingly [81].

Costs associated with implementation of an early mobilization program are divided into 3 main categories: personnel, training, and equipment. In an ICU with 900 ICU admissions annually, the estimated cost to implement such a program would be $358 475 [82]. Increased fees would include recruitment and training of personnel; however, the bulk of this would be a one-time setup cost [83]. The primary variable associated with increased savings is decreased LOS, which in turn leads to a reduction in direct variable costs [32,82]. The estimated savings, based on actual admissions and LOS data, due to a reduction in direct variable costs would be $1 176 312. Thus, the net cost savings would equal $817 836 [82]. In this financial analysis, it was determined that smaller ICUs would still observe some savings due to the lower costs associated with initiation of the program, fewer equipment costs, and the potential for mobility team members to be part-time [82].

3.5. Sustainability

Sustainability of an early mobilization program may be perceived as a barrier to program implementation. Sustainability is one of many steps in a program's life cycle (Initiation, Development, Implementation, Sustainability or Discontinuation, Dissemination) and measures whether a program is able to continue to provide beneficial outcomes to patients beyond the implementation phase while maintaining the program in an identifiable form [84]. Many factors may improve program sustainability such as a program champion who oversees day-to-day program implementation and has access to upper management; aligning program goals with those of the organization; being considerate of staff workload; and having quantifiable benefits for stakeholders, staff, and patients [84]. Specific strategies to enhance sustainability of an early mobilization program may be to provide ongoing staff education about the detriments of oversedation and the beneficial impact of early mobilization [65,79], to make early mobilization the standard of care [36,44,77], to enhance nursing support by providing training and education for the safe implementation of the program [77,79], and to conduct periodic chart audits [65].

4. Summary

Our review provides an overview of that which is currently known about early mobilization and illuminates the areas in which the field is

lacking. To date, what is clearly understood about early mobilization is that it is safe, feasible, and effective; however, early mobilization research in critically ill adults is insufficient, whereas pediatric research is even less complete. More focused work on advancing the continuum of mobilization (from early passive exercise transitioning to active and even post–ICU and post–hospital discharge rehabilitation) is required. In addition, the lack of standardized mobility protocols among researchers creates difficulty in comparing outcomes and identifying contraindications to therapy.

For early mobilization to impact clinical practice, it must become a standard of care and include a validated exercise prescription initiated within the first 48 hours of ICU admission and that adapts with improving levels of patient function. To ensure clinical success, the optimal timing of exercise initiation, intensity, frequency, and duration must be elucidated. The aforementioned prescription factors are important components required to standardize the approach to early mobility protocols, which will decrease variability and enhance generalizability among different ICU populations. Future research is needed to expand our knowledge of early mobilization in trauma/burn, neurological, and surgical ICUs. Furthermore, this review reveals the paucity of information needed to determine how we can apply our expanding knowledge of adult early mobilization to the pediatric and geriatric populations and focus on identifying "at-risk" patients. In addition, to enhance sustainability of early mobility programs, it is essential that research focuses on methods to overcome perceived barriers to early mobilization through knowledge translation strategies involving interdepartmental collaboration, communication, education, and training.

Acknowledgements

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