Intensive Care Med
https://doi.org/10.1007/s00134-026-08541-z

NARRATIVE REVIEW

Key principles for rehabilitation of critically ill patients with obesity

Sabrina Eggmann[1,2,3], Danielle E. Bear[4,5], Richard S. Bourne[6,7,8], Amy Freeman-Sanderson[3,9,10,11], Cheryl E. Hickmann[12], Vera Karner[13], David McWilliams[14,15], Dale M. Needham[16], Pierre Singer[17], Margo van Mol[18], Arthur van Zanten[19,20], Carol L. Hodgson[3,21,22,23] and Stefan J. Schaller[13,24*]

Abstract

Purpose: Patients with obesity who are admitted to an ICU bring specific challenges for rehabilitation during and after critical illness. This narrative review explores impact of differences in body compositions and pathophysiology on outcomes to summarise interprofessional, patient-centred rehabilitation strategies across the trajectory of recovery.

Methods: The interprofessional expert panel reviewed major trials and guidelines, integrating their clinical expertise with the current evidence.

Results: Three distinct phenotypes potentially influence outcomes for survivors. Whilst patients with preserved muscle mass may have a survival advantage, the phenotypes characterised by ectopic visceral fat or sarcopenia are frequently complicated by multimorbidity and polypharmacy, likely increasing the risk of adverse effects such as sub-optimal sedation, prolonged ventilation and immobilisation, malnutrition, and impaired recovery. Targeted respiratory interventions, including secretion-clearance techniques and appropriate patient positioning to prevent atelectasis, reduce the work of breathing. Optimisation of communication and swallowing function is an essential component for facilitating safe oral intake and promoting active patient participation in rehabilitation. Concurrently, targeted nutrition strategies combined with early, targeted, progressive mobilisation might mitigate ICU acquired weakness and support functional recovery. The availability of appropriate weight-based equipment is fundamental to ensuring safe mobilisation for both patients and healthcare professionals.

Conclusion: Interprofessional collaboration is central to optimising outcomes and should extend beyond the ICU to structured post-ICU follow-up to address persistent, worsening, or newly emerging health impairments. Early rehabilitation in critically ill patients with obesity should integrate physiological, logistical, and psychosocial considerations to support equitable and functional recovery.

*Correspondence: stefan.schaller@meduniwien.ac.at
[13] Medical University of Vienna, Department of Anaesthesia, Intensive Care Medicine and Pain Medicine, Clinical Division of General Anaesthesia and Intensive Care Medicine, Vienna, Austria
Full author information is available at the end of the article

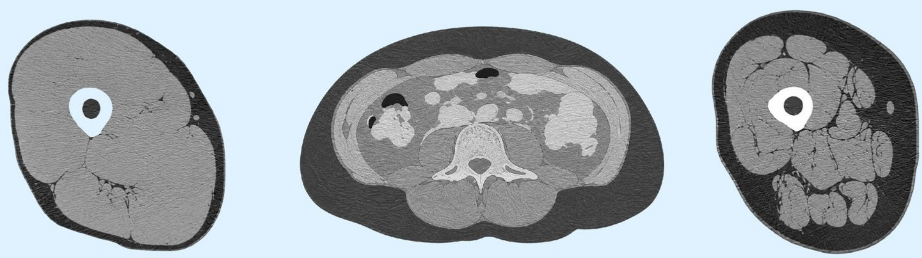
Springer

Visual abstract:

KEY PRINCIPLES FOR REHABILITATION OF CRITICALLY ILL PATIENTS WITH OBESITY

A narrative review

BMI is a poor marker — Body composition is what matters.



Thigh muscle *Abdomen* *Thigh muscle*

Obesity with preserved muscle mass

- Better physiological reserve
- Survival advantage
- Full rehabilitation possible

Obesity with ectopic visceral fat

- Metabolic comorbidities
- Individualized rehab to avoid overload

Sarcopenic obesity

- Worst outcome
- Frailty
- High ICU-acquired weakness risk

Findings

- **Obesity is not one phenotype:** distinguishing preserved muscle mass, visceral obesity, and sarcopenic obesity may fundamentally change rehabilitation strategies.
- **Rehabilitation starts on day 1:** respiratory support, nutrition, mobilisation, positioning, and communication should be integrated into a coordinated, multidisciplinary approach.
- **Beyond BMI:** body composition, frailty, and functional reserve are likely more relevant than BMI alone for predicting recovery and tailoring interventions.
- **From ICU to home:** structured post-ICU follow-up is essential to address physical, cognitive, psychological, and respiratory sequelae in this growing patient population.

Eggmann, S., Bear, D. E., Bourne, R. S. *et al.* Key principles for rehabilitation of critically ill patients with obesity. *Intensive Care Med (2026)*. https://doi.org/**10.1007/s00134-026-08541-z**

ICM Intensive Care Medicine

Keywords: Obesity, Critical care, Critical illness, Rehabilitation, Early ambulation

Introduction

The prevalence of obesity is rising across the world, and critically ill patients with obesity are increasingly common in intensive care units (ICUs). The World Health Organisation (WHO) defines obesity as "excessive fat deposits" with a Body Mass Index (BMI) higher than 30 kg/m^2 [1]—although BMI is a poor marker for body composition [2]. Weight bias—referring to negative beliefs and attitudes towards a person with obesity—can negatively affect ICU care [3], with healthcare professionals often perceiving patients as difficult, non-compliant [4], or even a threat to their own health due to a perceived risk for physical injuries [5]. In addition, multiple obesity-related physiological alterations, including respiratory, cardiovascular, metabolic, and pharmacokinetic changes, present specific challenges in ICU management [6, 7], as discussed in detail below. Obesity does not confer protection against many types of adverse outcomes, despite some metabolic reserve from excess adiposity. Of particular concern is sarcopenic obesity, a condition with high body fat and low skeletal muscle, which is associated with poor outcomes [8]. Additional loss of muscle mass and function during the critical illness—termed ICU acquired weakness (ICUAW)—further increases long-term mortality and morbidity [9]. Rehabilitation of patients with obesity is therefore challenging, requiring optimal allocation of resources and collaboration across disciplines to enhance recovery.

This narrative review discusses how interprofessional rehabilitation can be adapted to the altered pathophysiology of critically ill patients with obesity, considering body composition, pharmacokinetics and recovery trajectories for respiration, nutrition, positioning, early mobilisation, tracheostomy management, and follow-up (Fig. 1). Articles were reviewed non-systematically by an interprofessional expert panel up to 25 February 2026 and selected based on relevance, methodological quality, and clinical impact, integrating clinical expertise with current evidence. Overall, the level of evidence is low, with recommendations mostly based on expert opinion and clinical practice.

Trajectory of recovery

Multicentre cohort studies in critically ill populations suggest that obesity may confer a short-term survival advantage, including a greater likelihood of discharge to home [10, 11]. The mechanisms causing this apparent 'obesity paradox' remain incompletely characterised and are likely confounded by a combination of biological and methodological factors. These include age, medical or surgical conditions, frailty status, and body composition, wrongly classified by BMI. For instance, in a cohort of ICU patients with heart failure, the survival benefit associated with obesity was observed only amongst patients aged $\geq$ 60 years, highlighting potential age-related heterogeneity in the obesity survival relationship [12]. Selection bias might further influence earlier admission, closer monitoring or more aggressive treatment in patients with obesity, contributing to the 'obesity paradox' [6].

Other short-term outcomes appear less favourable in patients with morbid obesity. Extreme obesity (BMI $\geq$ 40 kg/m^2) was associated with an increased incidence of delirium in a large retrospective analysis with 20,193 critically ill patients that adjusted for confounders [13]. Survivors with extreme obesity also seem to experience prolonged mechanical ventilation and extended ICU stays [14]. These issues are known risk factors for ICUAW [9]. In addition, the chronic inflammatory state associated with obesity may exacerbate muscle impairment during critical illness, increasing the risk of ICUAW [15]. However, despite these potential biological mechanisms, the independent influence of obesity on the development of ICUAW is not well understood, with some studies reporting a protective effect on muscle mass and strength through the metabolisation of endogenous fat [16]. Similarly, the impact of obesity on functional recovery after critical illness is uncertain [17, 18]. In a recent multicentre observational study including 1,600 ICU survivors from 10 Brazilian ICUs, no association was observed between BMI categories and the physical component of health-related quality of life or functional independence [19].

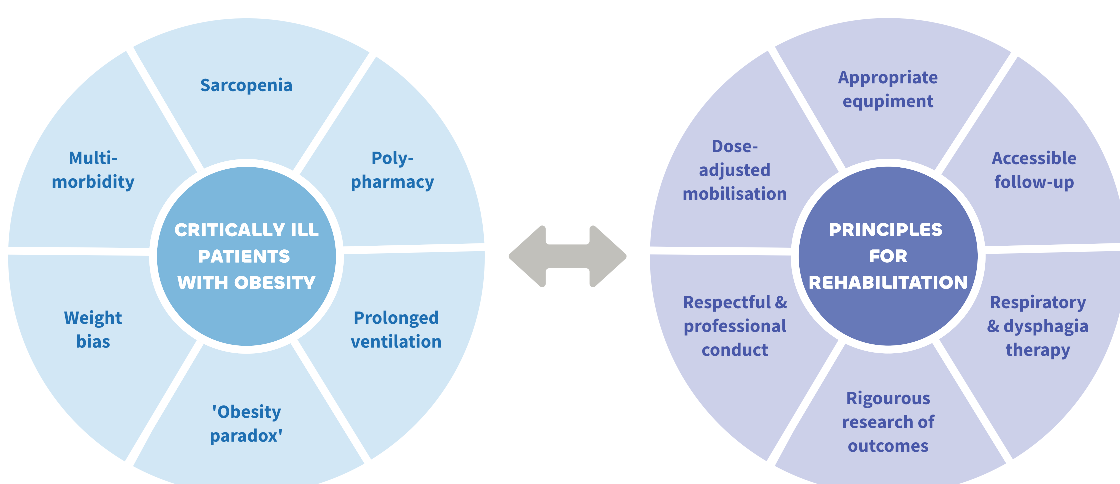


Fig. 1 Challenges for critically ill patients with obesity (left) and key practice principles for their rehabilitation (right)

Phenotypes in obesity

Importantly, obesity can present with either preserved or reduced muscle mass and function. These differences in body composition may differentially influence patient outcomes with three distinct obesity phenotypes (Table 1) [20, 21]. Future research is required to investigate pragmatic bedside identification, which may include combining muscle ultrasound, waist circumference, a clinical frailty scale, and pre-ICU activities [21, 22]. The first phenotype includes persons with obesity and preserved muscle mass [20]. In a single-centre prospective observational cohort of 507 medical ICU patients at a US academic institution, a higher proportion of skeletal muscle mass (assessed by computed tomography scans at ICU admission) was associated with improved 6-month survival and a greater likelihood of discharge home with independent living [23].

The second phenotype is characterised by excess visceral adiposity irrespective of BMI. This type is commonly accompanied by ectopic fat deposition in the liver, heart, skeletal muscles, and other organs, which are potentially driving the associated metabolic complications (i.e., insulin resistance, glucose intolerance, dyslipidaemia, inflammation) and adverse cardiovascular outcomes [24]. This phenotype is prevalent in sedentary individuals, implying that individualised approaches to early mobilisation and exercise may be required to support patient participation, avoid overexertion, and foster positive training experiences in this previously inactive population (Table 1).

The third phenotype is termed sarcopenic obesity [21], which is associated with an increased short-term mortality, for example, in patients with abdominal sepsis [8]. Sarcopenic obesity can occur across age groups and is consistently linked to poorer functional and clinical outcomes in non-ICU populations [25]. Of relevance to ICU rehabilitation is the vicious circle of a previous sedentary lifestyle leading to weight gain, muscle loss and comorbidities [21]. Clinicians should be suspicious of a history of repeated falls, fatigability and recent illnesses or nutritional events. Whilst these patients commonly present with pre-ICU frailty, impaired mobility and physical function, and risk factors for ICUAW [9], the impact of sarcopenic obesity on long-term recovery after critical illness remains largely unstudied, underscoring the need for future ICU cohorts that incorporate measures of body composition and muscle function to clarify how obesity phenotypes influence post-ICU outcomes.

Relevant pathophysiology

Obesity predisposes to a cascade of metabolic disturbances driven by adipokine-mediated low-grade inflammation, leading to insulin resistance, dyslipidaemia, and lipotoxicity. These processes increase the risk of type 2 diabetes, cardiovascular disease, malignancy, and liver disease [26]. Obesity nearly doubles the long-term risk of multimorbidity [27], which reduces physiological resilience to critical illness [28].

Pre-existing cardiorespiratory dysfunction is particularly relevant in the ICU. Obesity is a major risk factor for hypertension and both heart failure with preserved or reduced ejection fraction. Patients with obesity in the ICU have a higher risk of arrhythmias and obstructive sleep apnoea [7]. Abdominal adiposity reduces functional residual capacity and lung compliance, promoting airway closure and atelectasis; this necessitates tailored airway

Table 1 Phenotypes of obesity with conceptual guidance for clinicians based on expert opinion

Phenotype	Obesity with preserved muscle mass	Obesity with ectopic visceral fat	Sarcopenic obesity
Waist circumference[a]	Normal	High	High
Ectopic fat	Low	High	High
Lean mass	High	–	Low
Metabolic abnormalities	Absent	Present	Present with chronic comorbidities
Lifestyle	Active	Sedentary	Sedentary
Clinical frailty scale	Very fit (1)	Managing well (2–3)	Vulnerable (≥ 4)
Implications for physical rehabilitation	Progressive physical rehabilitation to achieve full recovery	Individualised approach to avoid overexertion and negative experiences associated with physical activity with goal to gradually support lifestyle changes	Pre-status as key driver for individualised approach to previous activity levels
Ventilatory adjustments during rehabilitation	Consider patient's ability to increase oxygen supply to stimulate a training response before adjustments	Meet increased demands, to avoid overexertion and mismatch in oxygen balance to ensure tolerance of early mobilisation	Adjust as need to meet increased demands, to allow functional and meaningful activities

[a] Sex-based normative values: < 102 cm for males and < 88 cm for females [20]

management and ventilatory strategies [29]. Obesity, particularly with the presence of excess visceral adipose tissue, can exert direct adverse effects on the myocardium and vasculature, compounded by obesity-associated comorbidities [30].

The pharmacokinetics and pharmacodynamics of medicines are significantly altered in obesity. Lipophilic medicines exhibit increased volume of distribution due to excess adipose tissue, while hepatic steatosis may reduce clearance, prolonging their effects and increasing the risk of accumulation. These principles are especially relevant for opioids and sedatives, requiring careful dosing and titration to reach the desired pain and sedation goals [31]. Hydrophilic medicines may conversely have reduced distribution and require adjusted dosing strategies.

Multimorbidity is closely linked to polypharmacy. Patients with obesity often present with extensive cardiovascular and antidiabetic medication regimens. Many medications are withheld during an acute critical illness, complicating their reintroduction for the management of both pre-existing and newly developed morbidities [32]. The combination of reduced physiological reserve, treatment burden, and complex medication management contributes to increased risk of deterioration and influences overall management during physical rehabilitation.

Respiratory care

Obesity presents significant challenges for respiratory and ventilation management in the ICU. Patients with obesity typically exhibit obesity-related impairments in respiratory mechanics, including reductions in functional residual capacity and expiratory reserve volume, leading to an increased work of breathing, secretion retention, and ventilation–perfusion mismatches due to small airway closure [29]. These mechanisms, described above, are further exacerbated during critical illness and immobility, with pulmonary compliance reduced substantially as a result of increased pulmonary vascular pressures, chest wall mass, and cephalad displacement of the diaphragm due to the obese abdomen [33]. These physiological changes predispose patients with obesity to respiratory failure and complicate both non-invasive and invasive ventilatory strategies. Effective respiratory management requires an understanding of obesity-related pathophysiology and the application of tailored ventilatory approaches.

Initial respiratory support may involve non-invasive ventilation (NIV) or high-flow nasal cannula therapy to counteract atelectasis, reduce anatomical dead space, improve oxygenation, and decrease the work of breathing. Previous studies have provided moderate evidence that NIV may reduce the need for intubation and reduce both morbidity and mortality compared with oxygen therapy alone [34, 35]. Alongside NIV, patient positioning plays a critical role in respiratory management [36]. Positioning patients in sitting or reverse Trendelenburg positions can reduce abdominal pressure, increasing functional residual capacity and allowing recruitment and aeration of dependent lung areas [37]. Hence, the supine position should be avoided; instead, timely mobilisation into an upright position may reduce atelectasis and ease recruitment of the accessory respiratory muscles [9]. When invasive mechanical ventilation is required, lung-protective ventilation strategies are paramount. Tidal volumes should be calculated based on ideal body weight (calculated based on sex and height), with higher levels of positive end-expiratory pressure (PEEP) often required to counteract significant reductions in functional residual capacity [38]. In cases of severe hypoxemia, prone positioning is feasible and may be effective in obese patients when performed by experienced teams, with extra attention merited for pressure injury prevention.

In patients with obesity who are receiving invasive mechanical ventilation, secretion-clearance mechanisms are significantly impaired. Underlying respiratory insufficiency, poor pulmonary compliance, and higher PEEP settings can increase the risk of retained secretions. Usual physiotherapy techniques, such as alternate side lying to facilitate postural drainage and manually assisted cough manoeuvres, are more challenging due to body size. Mechanical insufflation–exsufflation devices could be helpful to achieve adequate peak expiratory flow rates in these circumstances, along with early mobilisation to improve lung volumes [39].

Weaning and extubation may be prolonged due to increased work of breathing and respiratory muscle inefficiency. Programmes of early and structured rehabilitation are essential to support weaning and recovery. Inspiratory and expiratory muscle training may also be useful, although further studies are required in ventilated patients with obesity [40, 41]. There is high level of evidence for prophylactic NIV after extubation to decrease the risk of respiratory failure and reintubation, as well as mortality [42]. Consideration of pre-existing chronic comorbidities such as obesity, hypoventilation syndrome, or obstructive sleep apnoea further supports NIV in this population.

Tracheostomy care, communication, and swallowing

Tracheostomy placement, communication, and swallowing difficulties can be more prevalent in those with obesity; however, evidence is variable. A key determinant in the placement of a tracheostomy tube is the need for prolonged mechanical ventilation. Patients with obesity may

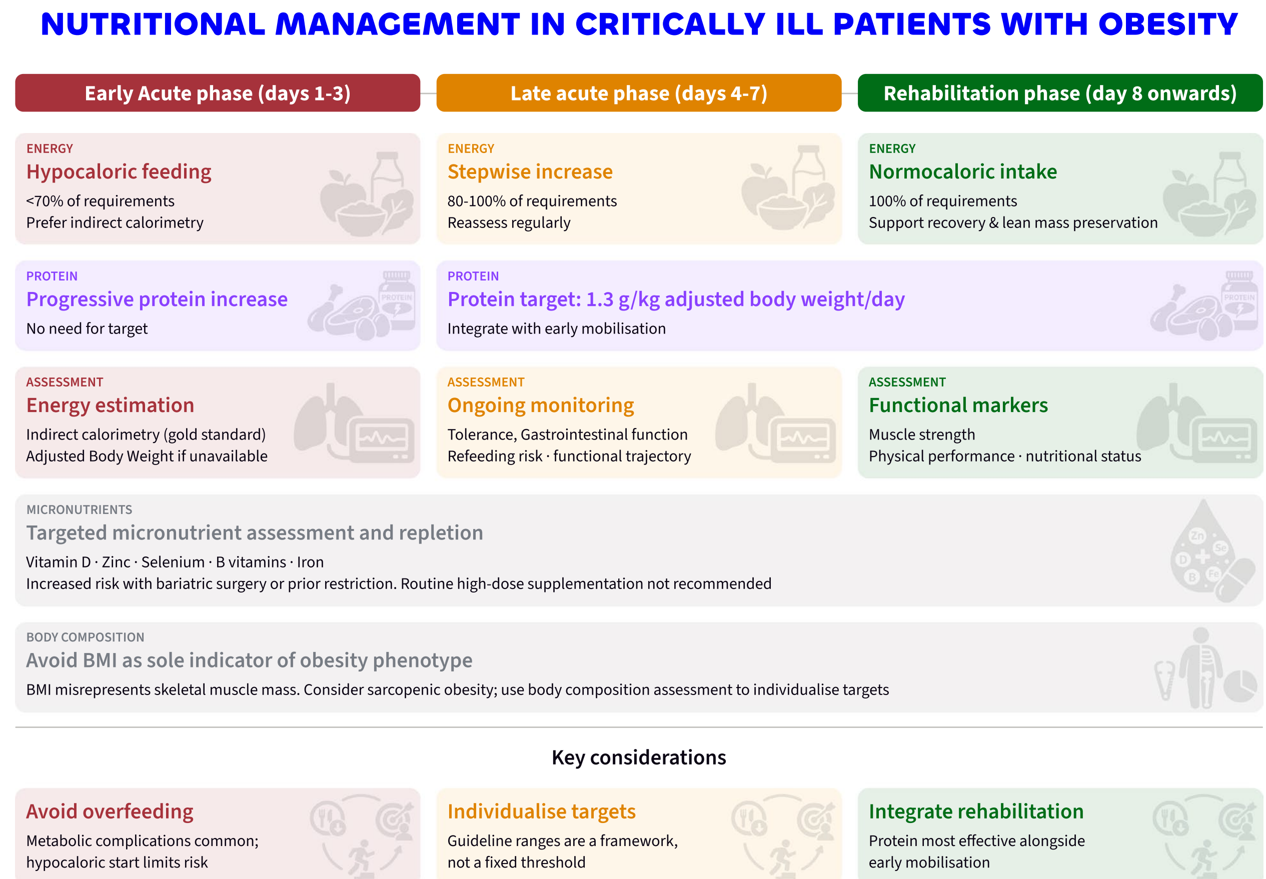


Fig. 2 Nutritional management in critically ill patients with obesity

have increased duration of intubation with an endotracheal tube as observed in a cohort of 1307 patients, with a mean duration of 4 (1–9) days for those diagnosed as obese and 2 (1–6) days for those classified as non-obese ($n = 1082$) [43].

Tracheostomy complications can range from stoma/surgical site infection [44] to decreased success of decannulation [45]. Patients classified as obese are more likely to be diagnosed with laryngeal pathology, such as posterior glottic stenosis, subglottic stenosis, granulation tissue, and vocal fold immobility, thereby preventing decannulation (OR 3.1, 95%CI 1.4–6.6, $p = 0.004$) [45]. In addition to prolonged tracheostomy cannulation, the presence of these laryngeal pathologies can negatively impact patients' communication abilities due to disordered voice quality.

Dysphagia, or disordered swallowing, can significantly impact an individual's ability to safely and effectively consume oral intake. Although critically ill adults are at known significant risk of new dysphagia, increased BMI is associated with a slight reduction in the odds of dysphagia for those requiring mechanical ventilation [46]. However, more recent evidence has highlighted the increased risk of post-extubation dysphagia for patients with ICUAW, with those patients diagnosed with ICUAW having a significantly higher BMI at ICU admission [47]. The lack of evidence emphasises the importance of personalised patient assessments to identify rehabilitation needs for swallowing and communication, highlighting the necessity of evaluating these functions to determine each patient's specific rehabilitation requirements. Assessment and rehabilitation should be performed interprofessionally, including early access to speech and language therapists to optimise communication function and enable instrumental swallowing assessment [48]. Rehabilitation principles should address the sensory and motor functions of both respiratory and upper-airway muscles and set goals that consider the patient's function, activities, and participation [49].

Nutrition interventions

Appropriate nutrition assessment and intervention are central to rehabilitation in critically ill patients with

Equipment	Purpose	Specifications	Rationale for rehabilitation
Bariatric bed 	Support safe positioning and in-bed mobilisation	Weight capacity >250kg, width (>91cm), adjustable height, option to tilt into sitting/ standing position, bariatric scale	Patient comfort, enables safe patient handling including early verticalisation or turning, facilitates in-bed rehabilitation, accurate weight measurement to assess the weight capacity of other equipment
Pressure-redistributing mattresses 	Pressure injury prevention	Support surface that redistributes pressure, reduces shear and supports microclimate	Protects skin integrity during immobility, avoids heat and moisture trapping, reduces risk of pressure injuries
Lifts or hoists 	Transfers or repositioning	Weight capacity >250kg, compatible with bariatric slings	Reduces injury risk for healthcare professionals, enables safe mobilisation in severely weak patients
Slide sheets or transfer devices 	Transfers or repositioning	Low-friction surfaces that ease gliding	Reduces manual handling strain and shear for repositioning or transfers out-of-bed
Bariatric chairs 	Supported sitting	Weight capacity >250kg, wide seat	Facilitates functional activities and independence
Mobility aids (e.g. standing hoists, walker) 	Early ambulation	Weight capacity >250kg, reinforced frame	Facilitates functional activities and independence
Training tools (e.g. elastic bands, weights, pulley, respiratory muscle trainer) 	Functional exercises and respiratory muscle training	Adjustable weights starting from 0.5kg; Respiratory muscle devices (threshold or electronic based)	Gradual progression of functional training exercises for in or out-of-bed Inspiratory and expiratory muscle training with daily repetitions starting from 30% of maximal strength

Fig. 3 Bariatric equipment options for the rehabilitation of critically ill patients with obesity. The conceptual illustrations were created by the authors using generative artificial intelligence (version GPT-5.2)

obesity (Fig. 2). Critical illness accelerates catabolism and anabolic resistance, and emerging evidence suggests that patients with greater fat mass have more pronounced skeletal muscle loss compared with their lean counterparts [50]. This underscores the importance of targeted nutrition strategies to prevent severe ICUAW and support functional recovery [51].

Accurate calculation of energy requirements is particularly challenging in patients with obesity. Use of actual body weight risks overfeeding, while ideal body weight may underestimate requirements. Further, utilising BMI alone to classify obesity risks misrepresents skeletal muscle mass [50], a primary determinant of energy expenditure. For these reasons, indirect calorimetry remains the gold standard for determining energy expenditure [52] and should be used where available, as predictive equations perform poorly in this population [53]. Where indirect calorimetry is unavailable, current ESPEN guidelines recommend weight-based estimates using adjusted body weight as a pragmatic alternative with regular reassessment as clinical status evolves [52]. Hypocaloric feeding strategies during the acute phase (< 70% of measured or estimated requirements), transitioning to normocaloric feeding (100% of requirements) during rehabilitation, may help preserve lean mass while minimising metabolic complications, although research targeted to patients with obesity remains limited. Whilst higher protein provision has not been shown to be beneficial in this population [54], adequate protein intake (1.3 g/kg adjusted body weight/day achieved progressively over the first week of critical illness [52]) integrated with early mobilisation and resistance-based rehabilitation may improve muscle protein synthesis and functional recovery, although definitive outcome data are not yet available. These targets represent a range within which clinicians should exercise judgement based on tolerance, clinical trajectory, and available monitoring, rather than a prescriptive threshold applied uniformly.

Micronutrient deficiencies are common in critical illness and may be exacerbated in specific obesity phenotypes associated with reduced intake and altered absorption. Deficiencies in vitamin D, zinc, selenium, B vitamins, and iron can impair muscle function, immune recovery, and rehabilitation capacity. Routine high-dose supplementation is not generally recommended, but targeted assessment and repletion are appropriate in prolonged ICU stays and post-ICU rehabilitation.

Pressure injury prevention

Monitoring for pressure injuries in critically ill patients with obesity should begin immediately after ICU admission incorporating a structured risk assessment, skin inspection, and care [55]. Support surfaces with pressure redistribution and microclimate control is equally important for patients with obesity who are vulnerable to heat and moisture trappings [55]. Regular repositioning is recommended to reduce the risk of pressure injuries (based on moderate-to-strong evidence) [36, 55]. Thereby, a sufficiently wide surface is required to safely turn patients (> 91 cm for patients with a BMI > 35; > 127 cm for patients with a BMI > 45) (Fig. 3) [55]. In addition, each ICU should have adequate equipment that eases manual handling, reduces friction and shear, and sufficiently supports patients in maintaining their position [55].

Early physical rehabilitation including mobilisation

Early mobilisation can reduce the odds of developing ICUAW (OR 0.45 [95% CI 0.26–0.77]) [9], shorten the duration of delirium (mean difference − 1.34 days [95% CI − 1.85 to − 0.83]) and mechanical ventilation (1.07 days [95% CI − 1.64 to − 0.50]) [56], and improve survivors' physical function up to 6 months [57]. Current guidelines (strong to conditional recommendations) recommend individualised early mobilisation for all critically ill patients, commencing within the first 72 h of ICU admission [36, 58]. However, the evidence for critically ill patients with obesity is less certain, as many trials, including landmark trials [59–61], do not report subgroup details. Despite these limitations, early ambulation can be safe and feasible even in patients who are morbidly obese (BMI ≥ 40) [62].

Early mobilisation is generally progressed from in-bed exercises in supine or sitting position to functional, out-of-bed activities such as sitting on the edge of the bed, standing, or walking [36, 63]. Progression should be individualised, based on patients' prehospital function and cardiorespiratory reserve using established safety criteria, yet the optimal dose of mobilisation (i.e., frequency, duration, intensity) remains poorly understood [9]. This is particularly relevant for the mobilisation of critically ill patients with obesity, where the risks and benefits must be carefully evaluated individually for each patient [58]. Due to their distinct characteristics, close monitoring of cardiorespiratory parameters is key. For example, an exploratory analysis of cardiorespiratory parameters during and after 716 mobilisation sessions highlighted an increased risk for hypotension in patients with an elevated BMI. Importantly, the critical care team should be aware that hypotension is most likely to occur during the recovery phase, i.e., within 15 min after mobilisation [64].

Right-ventricular dysfunction is commonly present in patients with obesity due to underlying cardiovascular comorbidity, but may further limit exercise tolerance and contribute to haemodynamic instability [65]. Similarly, in patients with diabetes, a common diagnosis for patients with obesity, a high dose of early mobilisation was associated with an increased mortality in a secondary analysis; therefore, caution is warranted [66]. Notably, approximately 40% of the 750 patients in this study had a BMI > 30 [61]. The subsequent meta-analysis did not find an increase in adverse events or mortality; thus, low-dose, progressive, and individually adjusted early mobilisation is likely safe in this population [67]. More concerning might be the delay in the mobilisation of critically ill patients with obesity [68], risking muscle loss and dysfunction [9]. Early mobilisation and repositioning can be challenging due to patients' excessive weight, combined with ICUAW and well-recognised organisational and logistical barriers, including sedation, staffing constraints, weight bias, and limited access to appropriate bariatric equipment [55, 69, 70]. The experience of weight bias can lead patients to mistrust with increased fear of falling and ultimately patient refusal [55]. In contrast, healthcare professionals fear personal injury and fatigue [5, 55]. Early mobilisation in critically ill patients with obesity, therefore, requires a careful approach that includes the patient, interprofessional team, and adequate equipment and training to make the intervention feasible and safe. Regular assessment and goal setting should start early to avoid delays and to coordinate efforts [71]. Early consideration will also allow the timely organisation of necessary equipment, such as lifters, bariatric chairs, and beds [72] (Fig. 3). Before its use, equipment must be checked for the appropriate weight capacity, and healthcare professionals should complete necessary training to familiarise themselves with the device to ensure safe handling. This is particularly important when equipment is rented or if team training is not regularly conducted. Many beds offer auxiliary functions, such as a tilt-table, that allow for early upright positioning, potentially easing the work of breathing and reducing the burden on staff. Robotics might play a role in the future, yet research remains very limited, and to date, preliminary studies have been unable to show a reduction in the number of healthcare personnel required [73, 74]. In the end, positioning and early mobilisation will depend on sufficient staffing, education against discrimination, team training in ergonomic mobilisation, and appropriate equipment to facilitate implementation [38, 55].

Finally, as discussed earlier, patients with obesity often have increased work of breathing even at rest. The decision to commence more active mobilisation may require consideration of tailored respiratory adjustments (Table 1), such as increased respiratory support, to meet increased oxygen demands and to ensure tolerance of early mobilisation [38, 75]. Ventilatory adjustments should be individualised as excessive levels may induce ventilator-induced lung injury or precipitate haemodynamic compromise, particularly in patients with obesity-related cardiac dysfunction. However, data on how to optimise ventilatory support are limited, with observational studies indicating that early mobilisation may induce lung recruitment and improve oxygenation [76].

Follow-up

Admission to an ICU and surviving a critical illness may have a substantial impact on both short- and long-term quality of life [77]. Health-related impairments across the physical, cognitive, psychological, and social domains are collectively referred to as post-intensive care syndrome (PICS) [78], with an estimated pooled prevalence of 50% during follow-up within 1 month of ICU discharge [79]. In patients with obesity, physical impairments, such as muscle weakness, reduced mobility, and fatigue, may be masked or erroneously attributed to pre-existing obesity, leading to under-recognition of PICS. Moreover, a lower health-related quality of life in the mental component compared with normal-weight patients has been reported [19]. Rehabilitation planning and structured ICU follow-up may be valuable for detecting PICS-related symptoms in ICU survivors with obesity [80].

Rehabilitation after the ICU should account for pre-existing chronic cardiorespiratory comorbidities, as outlined above, which substantially influence recovery trajectories. Particularly, obesity hypoventilation syndrome and obstructive sleep apnoea with home NIV are highly prevalent in this cohort, potentially impairing ventilatory reserve, sleep quality, and participation in physical rehabilitation [81]. Failure to integrate cardiorespiratory assessment and management of these conditions risks suboptimal rehabilitation progression, increased fatigue, and a higher risk of readmission. A more comprehensive, multidisciplinary approach that incorporates respiratory support planning, management of sleep-disordered breathing, and assessment of cardiac function is therefore essential to deliver safe, individualised, and effective rehabilitation for patients with obesity recovering from critical illness.

In patients with obesity, interpretation of post-ICU functional recovery can be challenging, particularly when pre-morbid limitations are present. A staged follow-up approach may be considered [82], with a pragmatic threshold for reassessment and referral based on clinical need. In this context, ICU follow-up may be regarded not merely as an evaluative process but also as an early predictive tool for identifying patients in need of further rehabilitative support [83]. Although specialised in-person follow-up for ICU survivors with obesity is largely absent, and structured post-ICU assessment and support remain poorly developed, highlighting a clear need for targeted pathways. ICU follow-up provides an important setting to evaluate functional impairments in relation to obesity-related baseline limitations and post-ICU sequelae [84]. For example, previous home NIV settings might need adjustment or optimisation. Nevertheless, the ability to reliably differentiate pre-existing from new or worsened impairments is currently limited, highlighting the need for more robust approaches to assess pre-morbid functional status [82].

Psychosocial factors warrant particular attention in patients with obesity. Feelings of shame or prior negative healthcare experiences may contribute to underreporting of symptoms and avoidance of care [3, 85]. A proactive, non-judgmental approach, with explicit normalisation of PICS-related symptoms, seems essential to overcome these barriers and to facilitate timely access to appropriate interventions. To this end, digital health applications may ease follow-up for patients with obesity, offering low thresholds for safe interactions with healthcare professionals and solutions in cases of limited mobility that impede regular hospital visits. Telemedicine and app-based monitoring may lower barriers due to perceived weight bias, improve accessibility, support longitudinal assessment of recovery, and enable timely intervention [86, 87]. ICU follow-up for patients with obesity should be embedded within an interprofessional framework, with early collaboration amongst doctors, nurses, rehabilitation clinicians, dietitians, pharmacists, and psychosocial care providers [88]. The primary objective of such follow-up should not be weight reduction, but rather the restoration of physical, mental, and cognitive functioning, with a focus on overall quality of life. This approach may help prevent undertreatment and may more effectively address the complex recovery needs of ICU survivors with obesity.

Current challenges

Rehabilitation of critically ill patients with obesity is characterised by several interconnected challenges (Fig. 1). First, clinical complexity arises from multimorbidity, altered respiratory mechanics, and reduced physiological reserve, which complicate mobilisation, weaning, and recovery trajectories. Second, evidence gaps remain substantial, as critically ill patients with obesity are underrepresented in rehabilitation trials and subgroup analyses are rarely reported. Third, logistical barriers, including limited availability of bariatric equipment, increased staffing requirements, and concerns regarding staff safety, frequently delay or limit mobilisation. Fourth, psychosocial factors such as weight bias may further hinder rehabilitation. Finally, the heterogeneity of obesity phenotypes, particularly sarcopenic obesity, is insufficiently captured in current clinical practice, limiting the ability to individualise interventions.

Future directions

Future research should prioritise the inclusion of patients with obesity in critical care trials and ensure systematic reporting of this subgroup. A key priority is the development of phenotype-driven approaches that incorporate body composition, muscle function, and frailty. Further work is needed to define optimal dosing, timing, and modality of rehabilitation interventions tailored to obesity-specific physiological constraints. The integration of respiratory support strategies with mobilisation protocols is another important area of investigation, particularly in critically ill patients with obesity. In addition, implementation research addressing logistical barriers, including equipment, staffing models, and training, is essential to translate evidence into practice. Finally, structured post-ICU pathways, including digital and telemedicine-supported follow-up, should be developed and evaluated to address long-term impairments and improve continuity of care.

Conclusions

Despite the global increase in critically ill patients with obesity, this group remains marginalised and significantly under-researched, with limited evidence to inform rehabilitation practices. Key knowledge gaps include a better understanding of short- and long-term outcomes, ranging from the 'obesity paradox' to survivorship trajectories that encompass physical, mental, cognitive, and social health. Key research priorities include identifying obesity-specific phenotypes, treatment responders, as well as the optimal timing, dose, type, and adaptation of rehabilitation interventions across the continuum of recovery [9].

Optimising rehabilitation outcomes in this population likely requires early, tailored, and interprofessional approaches (Box 1). Adequate respiratory support, including NIV and positioning, should be implemented early to address obesity-related respiratory limitations and optimise lung recruitment, reduce the work of breathing, and minimise weaning failure. Patients with obesity are also at increased risk of laryngeal and upper-airway pathology, necessitating individualised assessment and management of communication and swallowing. Nutritional strategies should prioritise the preservation of muscle mass and function by using indirect calorimetry or adjusted body weight to guide energy provision, ensuring adequate protein delivery in line with the current guidelines, and addressing potential micronutrient deficiencies, particularly in emerging phenotypes of sarcopenic obesity. Early mobilisation should be initiated promptly, with careful consideration of obesity-related risks and barriers. Interventions should be individually adapted, progressing from in-bed exercises to functional activities such as sitting and standing. Successful implementation requires close interprofessional collaboration, staff training, and access to appropriate bariatric equipment. Beyond the ICU, structured follow-up is essential. Particular attention should be paid to psychosocial health, with flexible and accessible follow-up models to identify post-ICU sequelae while accounting for pre-existing comorbidities and functional limitations.

In summary, there is an urgent need for obesity-inclusive rehabilitation research and guideline development in critical care. Future studies must intentionally include and report on patients with obesity, adopt phenotype-driven and outcomes-focussed designs, and evaluate tailored interventions across the entire recovery pathway to ensure equitable, effective, safe, and person-centred rehabilitation for this patient population.

Box 1. Key principles for rehabilitation of critically ill patients with obesity.

Trajectory of recovery	Outcomes of physical, mental, and cognitive health for patients with obesity remain uncertain ranging from an apparent benefit 'obesity paradox' to an increased rate of complications
Phenotypes	Potential relevant phenotypes for targeted, individualised rehabilitation include: (1) obesity with preserved muscle mass, (2) obesity with ectopic visceral fat, and (3) sarcopenic obesity
Pathophysiology	Cardiorespiratory dysfunction is common in patients with obesity and requires adjusted rehabilitation with close monitoring of activities and rest. Exercise may have a positive impact on metabolic disturbances
Respiratory care	Non-invasive ventilation or high-flow nasal cannula therapy should be considered before and after invasive ventilation. Secretion clearance techniques and sitting positions potentially reduce atelectasis and ease recruitment
Communication & swallowing	The risk of laryngeal pathology may be increased; a personalised patient assessment may identify rehabilitation needs to optimise both swallowing and communication
Nutrition	Targeted nutrition strategies may help to preserve muscle mass, but need to be adjusted carefully to avoid over- or underdosing
Positioning & early mobilisation	Progression from in-bed to sitting to out-of-bed exercises should be individualised with close monitoring of cardiorespiratory parameters, the use of adequate equipment and consideration of pre-ICU lifestyle
Follow-up	A proactive, non-judgmental approach may help to address the complex recovery needs of ICU survivors with obesity

Author details
[1] Department of Intensive Care and Neonatology and Children's Research Center, University Children's Hospital Zurich, University of Zurich, Zurich, Switzerland. [2] Department of Physiotherapy, Inselspital, Bern University Hospital, Bern, Switzerland. [3] Australian and New Zealand Intensive Care Research Centre, School of Public Health and Preventive Medicine, Monash University, Melbourne, Australia. [4] Nutrition and Dietetics Department, Royal Adelaide Hospital, Adelaide, Australia. [5] Department of Nutritional Sciences, King's College London, London, UK. [6] Departments of Pharmacy and Critical Care, Sheffield Teaching Hospitals NHS Foundation Trust, Sheffield, UK. [7] Division of Pharmacy and Optometry, School of Health Sciences, Faculty of Biology, Medicine and Health, The University of Manchester, Manchester, UK. [8] National Institute for Health and Care Research (NIHR) Greater Manchester Patient Safety Research Collaboration (PSRC), School of Health Sciences, Faculty of Biology, Medicine and Health, University of Manchester, Manchester, UK. [9] Graduate School of Health, University of Technology Sydney, Sydney, NSW, Australia. [10] Speech Pathology Department, Royal Prince Alfred Hospital, Sydney, NSW, Australia. [11] Critical Care Division, Faculty of Medicine, The George Institute for Global Health, UNSW Sydney, Sydney, Australia. [12] Exercise and Movement Laboratory, Department of Motor Sciences, Haute École Provinciale du Hainaut (HEPH) Condorcet, Tournai, Belgium. [13] Medical University of Vienna, Department of Anaesthesia, Intensive Care Medicine and Pain Medicine, Clinical Division of General Anaesthesia and Intensive Care Medicine, Vienna, Austria. [14] Centre for Care Excellence, Coventry University, Coventry, UK. [15] Critical Care, University Hospital Coventry and Warwickshire NHS Trust, Coventry, UK. [16] Pulmonary & Critical Care Medicine, and Physical Medicine & Rehabilitation, School of Medicine, and School of Nursing, Johns Hopkins University, Baltimore, USA. [17] Intensive Care Unit, School of Medicine, Herzlia Medical Center, Reichman University, Herzlia, Israel. [18] Department of Intensive Care Adults, Erasmus MC, University Medical Centre Rotterdam, Rotterdam, The Netherlands. [19] Department of Intensive Care Medicine & Research, Gelderse Vallei Hospital, Ede, The Netherlands. [20] Division of Human Nutrition and Health, Chair Group Nutritional Biology, Wageningen University & Research, Wageningen, The Netherlands. [21] Department of Physiotherapy, Bayside Health, Melbourne, Australia. [22] Department of Critical Care, The University of Melbourne, Melbourne, Australia. [23] The George Institute for Global Health, Sydney, Australia. [24] Charité - Universitätsmedizin Berlin, Corporate Member of Freie Universität Berlin and Humboldt Universität zu Berlin, Institute of Medical Informatics, Berlin, Germany.

Funding
Open access funding provided by Medical University of Vienna. Institutional funds only.

Data availability
No data collected.

Declarations

Conflicts of interest
AFS is funded by an NHMRC Investigator Grant (GNT2033850). RSB is supported by a National Institute for Health and Care Research (NIHR) Senior Clinical and Practitioner Research Award (NIHR304524). The views expressed in this publication are those of the author and not necessarily those of the NHS, the National Institute for Health and Care Research or the Department of Health and Social Care. DMN was the principal investigator on a NIH-funded, multi-centred randomised trial (R01HL132887) evaluating nutrition and exercise in acute respiratory failure and, related to this trial, received an unrestricted research grant and donated an amino acid product from Baxter Healthcare Corporation and an equipment loan or donation from Reck Medical Devices/Enable ME LLC. PS has received institutional grants and speaker fees from Nestle, Fresenius Kabi, BAXTER and/or ART MEDICAL, limited stock options in respect of value commensurate with consultancy services from ARTMEDICAL. AvZ reports that no specific funding was received for this manuscript. In the past 36 months, research grants from Danone-Nutricia, AOP Pharma, PAION, and Rousselot were paid to the ICU Research Foundation. He has received honoraria and support for lectures and educational activities from Abbott, AOP Pharma, Baxter, Cardinal Health, Dutch Medical Food, Fresenius Kabi, GE Healthcare, InBody, Nestlé Healthcare, Nutricia-Danone, and PAION. He has also received travel support from these companies. All payments were made to the author unless otherwise specified. He serves in unpaid leadership roles within ESPEN (guideline committees on adult ICU and cardiology nutrition), is Associate Editor for Clinical Nutrition and Critical Care, is Chair of NESPEN, and Treasurer of SepsisNet Netherlands. The author declares no other conflicts of interest related to the content of this manuscript. CLH is funded by a NHMRC Investigator Grant (GNT203103). SJS received grants and non-financial support from Reactive Robotics GmbH (Munich, Germany), ASP GmbH (Attendorn, Germany), STIMIT AG (Biel, Switzerland), ESICM (Geneva, Switzerland), as well as grants, personal fees, and non-financial support from Fresenius Kabi

Deutschland GmbH (Bad Homburg, Germany), grants from the Innovationsfond of the Federal Joint Committee (G-BA) and EU/European Commission, personal fees from Springer Verlag GmbH (Vienna, Austria) for educational purposes, and Advanz Pharma GmbH (Bielefeld, Germany), and non-financial support from national and international societies (and their congress organisers) in the fields of anaesthesiology and intensive care medicine, outside the submitted work. Dr. Schaller holds small amounts of stock in Alphabet Inc., Ascendis Pharma Inc., Bayer AG, and Siemens AG; these holdings have not influenced any decisions regarding his research or this study. SJS reports that he is an associate editor of ICM and that he did not participate in the review or decision-making process for the current manuscript. All other authors report no conflict of interest.

Publisher's Note

Springer Nature remains neutral with regard to jurisdictional claims in published maps and institutional affiliations.

Received: 13 March 2026 Accepted: 25 June 2026
Published online: 17 July 2026

References

1. Obesity and overweight. https://www.who.int/news-room/fact-sheets/detail/obesity-and-overweight.
2. Potter AW, Chin GC, Looney DP, Friedl KE (2025) Defining Overweight and Obesity by Percent Body Fat Instead of Body Mass Index. J Clin Endocrinol Metab 110:e1103–e1107. https://doi.org/10.1210/clinem/dgae341
3. Ryan L, Coyne R, Heary C, Birney S, Crotty M, Dunne R, Conlan O, Walsh JC (2023) Weight stigma experienced by patients with obesity in healthcare settings: a qualitative evidence synthesis. Obes Rev 24:e13606. https://doi.org/10.1111/obr.13606
4. Hales C, de Vries K, Coombs M (2016) Managing social awkwardness when caring for morbidly obese patients in intensive care: A focused ethnography. Int J Nurs Stud 58:82–89. https://doi.org/10.1016/j.ijnurstu.2016.03.016
5. Shea JM, Gagnon M (2015) Working with patients living with obesity in the intensive care unit: a study of nurses' experiences. ANS Adv Nurs Sci 38:E17-37. https://doi.org/10.1097/ANS.0000000000000074
6. Schetz M, De Jong A, Deane AM, Druml W, Hemelaar P, Pelosi P, Pickkers P, Reintam-Blaser A, Roberts J, Sakr Y, Jaber S (2019) Obesity in the critically ill: a narrative review. Intensive Care Med 45:757–769. https://doi.org/10.1007/s00134-019-05594-1
7. Anderson MR, Shashaty MGS (2021) Impact of Obesity in Critical Illness. Chest 160:2135–2145. https://doi.org/10.1016/j.chest.2021.08.001
8. Ji Y, Cheng B, Xu Z, Ye H, Lu W, Luo X, Fu S, Fang X (2018) Impact of sarcopenic obesity on 30-day mortality in critically ill patients with intra-abdominal sepsis. J Crit Care 46:50–54. https://doi.org/10.1016/j.jcrc.2018.03.019
9. Eggmann S, Parry SM, Broadley T, Lynch GS, Bongetti AJ, Ridley EJ, Ayre E, Bailey M, Bellomo R, Berney S, Bradley S, Buhr H, Campbell MK, Casey K, Chapple LS, Connolly B, Darvall J, Deane A, Febbraio MA, Gosselink R, Granger CL, Haines K, Hanekom S, Harhay MO, Harrold M, Hayes K, Hermans G, Higgins A, Jain S, Kho ME, Kumar Tirupakuzhi Vijayaraghavan B, Lambell K, Lang JK, Leditschke IA, Levinger I, Magana Cruz S, Marshall AP, Needham DM, Ntoumenopoulos G, Nydahl P, Patel BK, Paton M, Puthucheary Z, Rooyackers O, Schaller SJ, Serpa Neto A, Stoppe C, Tronstad O, Vanhorebeek I, Z'Graggen WJ, Hodgson CL (2025) The intensive care medicine research agenda for the management of ICU acquired weakness: a multinational, interprofessional perspective. Intensive Care Med 51:2199–2212. https://doi.org/10.1007/s00134-025-08186-4
10. Yeo HJ, Kim TH, Jang JH, Jeon K, Oh DK, Park MH, Lim CM, Kim K, Cho WH (2023) Obesity paradox and functional outcomes in sepsis: a multicenter prospective study. Crit Care Med 51:742–752. https://doi.org/10.1097/ccm.0000000000005801
11. Zhou D, Wang C, Lin Q, Li T (2022) The obesity paradox for survivors of critically ill patients. Crit Care (London, England) 26:198. https://doi.org/10.1186/s13054-022-04074-1
12. Xu F, Zhang C (2024) Obesity and 1-year all-cause survival of adult intensive care patients with heart failure: data from the MIMIC-IV. Diabetol Metab Syndr 16:190. https://doi.org/10.1186/s13098-024-01428-3
13. Fu J, Zhang X, Zhang G, Wei C, Fu Q, Gui X, Ji Y, Chen S (2024) Association between body mass index and delirium incidence in critically ill patients: a retrospective cohort study based on the MIMIC-IV Database. BMJ Open 14:e079140. https://doi.org/10.1136/bmjopen-2023-079140
14. Martino JL, Stapleton RD, Wang M, Day AG, Cahill NE, Dixon AE, Suratt BT, Heyland DK (2011) Extreme obesity and outcomes in critically ill patients. Chest 140:1198–1206. https://doi.org/10.1378/chest.10-3023
15. Fuentes-Aspe R, Gutierrez-Arias R, González-Seguel F, Marzuca-Nassr GN, Torres-Castro R, Najum-Flores J, Seron P (2024) Which factors are associated with acquired weakness in the ICU? An overview of systematic reviews and meta-analyses. J Intensive Care 12:33. https://doi.org/10.1186/s40560-024-00744-0
16. Goossens C, Marques MB, Derde S, Vander Perre S, Dufour T, Thiessen SE, Güiza F, Janssens T, Hermans G, Vanhorebeek I, De Bock K, Van den Berghe G, Langouche L (2017) Premorbid obesity, but not nutrition, prevents critical illness-induced muscle wasting and weakness. J Cachexia Sarcopenia Muscle 8:89–101. https://doi.org/10.1002/jcsm.12131
17. Wardell S, Wall A, Bryce R, Gjevre JA, Laframboise K, Reid JK (2015) The association between obesity and outcomes in critically ill patients. Can Respir J 22:23–30. https://doi.org/10.1155/2015/938930
18. Hogue CW Jr, Stearns JD, Colantuoni E, Robinson KA, Stierer T, Mitter N, Pronovost PJ, Needham DM (2009) The impact of obesity on outcomes after critical illness: a meta-analysis. Intensive Care Med 35:1152–1170. https://doi.org/10.1007/s00134-009-1424-5
19. Barbosa MG, Sganzerla D, Buttelli ACK, Teixeira C (2024) Lower quality of life in obese ICU survivors: a multicenter cohort study. Qual Life Res 33:361–371. https://doi.org/10.1007/s11136-023-03523-w
20. Preda A, Carbone F, Tirandi A, Montecucco F, Liberale L (2023) Obesity phenotypes and cardiovascular risk: From pathophysiology to clinical management. Rev Endocr Metab Disord 24:901–919. https://doi.org/10.1007/s11154-023-09813-5
21. Donini LM, Busetto L, Bischoff SC, Cederholm T, Ballesteros-Pomar MD, Batsis JA, Bauer JM, Boirie Y, Cruz-Jentoft AJ, Dicker D, Frara S, Fruhbeck G, Genton L, Gepner Y, Giustina A, Gonzalez MC, Han HS, Heymsfield SB, Higashiguchi T, Laviano A, Lenzi A, Nyulasi I, Parrinello E, Poggiogalle E, Prado CM, Salvador J, Rolland Y, Santini F, Serlie MJ, Shi H, Sieber CC, Siervo M, Vettor R, Villareal DT, Volkert D, Yu J, Zamboni M, Barazzoni R (2022) Definition and diagnostic criteria for sarcopenic obesity: ESPEN and EASO consensus statement. Obes Facts 15:321–335. https://doi.org/10.1159/000521241
22. Bald A, Daum N, Schaller SJ (2026) Peripheral muscle ultrasound in the ICU: current evidence, limitations, and future directions. Intensive Care Med. https://doi.org/10.1007/s00134-026-08415-4
23. Jaitovich A, Dumas CL, Itty R, Chieng HC, Khan M, Naqvi A, Fantauzzi J, Hall JB, Feustel PJ, Judson MA (2020) ICU admission body composition: skeletal muscle, bone, and fat effects on mortality and disability at hospital discharge-a prospective, cohort study. Crit Care (London, England) 24:566. https://doi.org/10.1186/s13054-020-03276-9
24. Piché M-E, Tchernof A, Després J-P (2020) Obesity phenotypes, diabetes, and cardiovascular diseases. Circ Res 126:1477–1500. https://doi.org/10.1161/CIRCRESAHA.120.316101
25. Saito H, Matsue Y, Kamiya K, Kagiyama N, Maeda D, Endo Y, Ueno H, Yoshioka K, Mizukami A, Saito K, Ogasahara Y, Maekawa E, Konishi M, Kitai T, Iwata K, Jujo K, Wada H, Hiki M, Dotare T, Sunayama T, Kasai T,

Nagamatsu H, Ozawa T, Izawa K, Yamamoto S, Aizawa N, Wakaume K, Oka K, Momomura SI, Minamino T (2022) Sarcopenic obesity is associated with impaired physical function and mortality in older patients with heart failure: insight from FRAGILE-HF. BMC Geriatr 22:556. https://doi.org/10.1186/s12877-022-03168-3
26. Jin X, Qiu T, Li L, Yu R, Chen X, Li C, Proud CG, Jiang T (2023) Pathophysiology of obesity and its associated diseases. Acta Pharm Sin B 13:2403–2424. https://doi.org/10.1016/j.apsb.2023.01.012
27. Delpino FM, Dos Santos Rodrigues AP, Petarli GB, Machado KP, Flores TR, Batista SR, Nunes BP (2023) Overweight, obesity and risk of multimorbidity: a systematic review and meta-analysis of longitudinal studies. Obes Rev 24:e13562. https://doi.org/10.1111/obr.13562
28. Stewart J, Bradley J, Smith S, McPeake J, Walsh T, Haines K, Leggett N, Hart N, McAuley D (2023) Do critical illness survivors with multimorbidity need a different model of care? Crit Care 27:485. https://doi.org/10.1186/s13054-023-04770-6
29. De Jong A, Wrigge H, Hedenstierna G, Gattinoni L, Chiumello D, Frat J-P, Ball L, Schetz M, Pickkers P, Jaber S (2020) How to ventilate obese patients in the ICU. Intensive Care Med 46:2423–2435. https://doi.org/10.1007/s00134-020-06286-x
30. Powell-Wiley TM, Poirier P, Burke LE, Després J-P, Gordon-Larsen P, Lavie CJ, Lear SA, Ndumele CE, Neeland IJ, Sanders P, St-Onge M-P, On behalf of the American Heart Association Council on L, Cardiometabolic H, Council on C, Stroke N, Council on Clinical C, Council on E, Prevention, Stroke C (2021) Obesity and cardiovascular disease: a scientific statement from the American Heart Association. Circulation 143:e984–e1010. https://doi.org/10.1161/CIR.0000000000000973
31. Erstad BL, Barletta JF (2020) Drug dosing in the critically ill obese patient—a focus on sedation, analgesia, and delirium. Crit Care 24:315. https://doi.org/10.1186/s13054-020-03040-z
32. Kanodia C, Bourne RS, Mansi ET, Lone NI (2024) Association between critical care admission and chronic medication discontinuation post-hospital discharge: a retrospective cohort study. J Intensive Care Soc 25:255–265. https://doi.org/10.1177/17511437241230260
33. Mafort TT, Rufino R, Costa CH, Lopes AJ (2016) Obesity: systemic and pulmonary complications, biochemical abnormalities, and impairment of lung function. Multidiscip Respir Med 11:28. https://doi.org/10.1186/s40248-016-0066-z
34. Rochwerg B, Brochard L, Elliott MW, Hess D, Hill NS, Nava S, Navalesi PMOTSC, Antonelli M, Brozek J, Conti G, Ferrer M, Guntupalli K, Jaber S, Keenan S, Mancebo J, Mehta S, Raoof SMOTTF (2017) Official ERS/ATS clinical practice guidelines: noninvasive ventilation for acute respiratory failure. Eur Respir J. https://doi.org/10.1183/13993003.02426-2016
35. Jaber S, Delay JM, Chanques G, Sebbane M, Jacquet E, Souche B, Perrigault PF, Eledjam JJ (2005) Outcomes of patients with acute respiratory failure after abdominal surgery treated with noninvasive positive pressure ventilation. Chest 128:2688–2695. https://doi.org/10.1378/chest.128.4.2688
36. Schaller SJ, Scheffenbichler FT, Bein T, Blobner M, Grunow JJ, Hamsen U, Hermes C, Kaltwasser A, Lewald H, Nydahl P, Reisshauer A, Renzewitz L, Siemon K, Staudinger T, Ullrich R, Weber-Carstens S, Wrigge H, Zergiebel D, Coldewey SM (2024) Guideline on positioning and early mobilisation in the critically ill by an expert panel. Intensive Care Med 50:1211–1227. https://doi.org/10.1007/s00134-024-07532-2
37. Valenza F, Vagginelli F, Tiby A, Francesconi S, Ronzoni G, Guglielmi M, Zappa M, Lattuada E, Gattinoni L (2007) Effects of the beach chair position, positive end-expiratory pressure, and pneumoperitoneum on respiratory function in morbidly obese patients during anesthesia and paralysis. Anesthesiology 107:725–732. https://doi.org/10.1097/01.anes.0000287026.61782.a6
38. Martínez-Camacho M, Jones-Baro RA, Gómez-González A, Morales-Hernández D, Lugo-García DS, Melo-Villalobos A, Navarrete-Rodríguez CA, Delgado-Camacho J (2024) Physical and respiratory therapy in the critically ill patient with obesity: a narrative review. Front Med 11:1321692. https://doi.org/10.3389/fmed.2024.1321692
39. Belli S, Prince I, Savio G, Paracchini E, Cattaneo D, Bianchi M, Masocco F, Bellanti MT, Balbi B (2021) Airway clearance techniques: the right choice for the right patient. Fron Med. https://doi.org/10.3389/fmed.2021.544826
40. Caicedo-Trujillo S, Torres-Castro R, Vasconcello-Castillo L, Solis-Navarro L, Sanchez-Ramirez D, Núñez-Cortés R, Vera-Uribe R, Muñoz-Muñoz I, Barros-Poblete M, Romero JE, Vilaró J (2023) Inspiratory muscle training in patients with obesity: a systematic review and meta-analysis. Front Med. https://doi.org/10.3389/fmed.2023.1284689
41. Villiot-Danger JC, Villiot-Danger E, Borel JC, Pepin JL, Wuyam B, Verges S (2011) Respiratory muscle endurance training in obese patients. Int J Obes (Lond) 35:692–699. https://doi.org/10.1038/ijo.2010.191
42. Pensier J, Naudet-Lasserre A, Monet C, Capdevila M, Aarab Y, Lakbar I, Chanques G, Molinari N, De Jong A, Jaber S (2025) Noninvasive respiratory support following extubation in critically ill adults with obesity: a systematic review and network meta-analysis. EClinicalMedicine 79:103002. https://doi.org/10.1016/j.eclinm.2024.103002
43. De Jong A, Capdevila M, Aarab Y, Cros M, Pensier J, Lakbar I, Monet C, Quintard H, Cinotti R, Asehnoune K, Arnal J-M, Guitton C, Paugam-Burtz C, Abback P, Mekontso-Dessap A, Lakhal K, Lasocki S, Plantefeve G, Claud B, Pottecher J, Corne P, Ichai C, Molinari N, Chanques G, Papazian L, Azoulay E, Jaber S (2025) Incidence, risk factors, and long-term outcomes for extubation failure in ICU in patients with obesity: a retrospective analysis of a multicenter prospective observational study. Chest 167:139–151. https://doi.org/10.1016/j.chest.2024.07.171
44. Aboagye JK, Weldeslase TA, Hartmann B, Akinyemi OA, Lin AM, Williams M (2023) The impact of obesity on early complications following tracheostomy: an evaluation of a nationwide registry. Am Surg 89:3465–3470. https://doi.org/10.1177/00031348231160831
45. Meenan K, Bhatnagar K, Guardiani E (2021) Intubation-related laryngeal pathology precluding tracheostomy decannulation: incidence and associated risk factors. Ann Otol Rhinol Laryngol 130:1078–1084. https://doi.org/10.1177/0003489421995285
46. Zuercher P, Schenk NV, Moret C, Berger D, Abegglen R, Schefold JC (2020) Risk factors for dysphagia in icu patients after invasive mechanical ventilation. Chest 158:1983–1991. https://doi.org/10.1016/j.chest.2020.05.576
47. García-Grimaldo A, Rodríguez-Moguel NC, Godínez-Victoria M, Rodríguez-Llamazares S, Ríos-Ayala MA, Cadeza-Aguilar JD, Osuna-Padilla IA (2025) Associations between Intensive care unit acquired weakness with post-extubation dysphagia and other clinical outcomes-a cohort study in critically ill respiratory patients. Clin Nutr ESPEN 66:194–201. https://doi.org/10.1016/j.clnesp.2025.01.044
48. Likar R, Aroyo I, Bangert K, Degen B, Dziewas R, Galvan O, Grundschober MT, Köstenberger M, Muhle P, Schefold JC, Zuercher P (2024) Management of swallowing disorders in ICU patients—a multinational expert opinion. J Crit Care 79:154447. https://doi.org/10.1016/j.jcrc.2023.154447
49. Clayton NA, Ward EC, Place C, Scott A, Maitz PK, Kol MR (2026) Early dysphagia rehabilitation in critical care: a pilot study of safety, feasibility, and effectiveness of a strength-based dysphagia treatment protocol in intensive care unit-acquired weakness. Austral Crit Care 39:101528. https://doi.org/10.1016/j.aucc.2025.101528
50. Koga Y, Fujita M, Harada K, Shin M, Ayata R, Inoue T, Kaneda K, Tsuruta R (2025) Increased fat accumulation may be associated with severe muscle wasting in critically ill patients: a prospective observational study. Sci Rep 15:11460. https://doi.org/10.1038/s41598-025-96171-8
51. Dickerson RN, Andromalos L, Brown JC, Correia M, Pritts W, Ridley EJ, Robinson KN, Rosenthal MD, van Zanten ARH (2022) Obesity and critical care nutrition: current practice gaps and directions for future research. Crit Care (London, England) 26:283. https://doi.org/10.1186/s13054-022-04148-0
52. Singer P, Blaser AR, Berger MM, Calder PC, Casaer M, Hiesmayr M, Mayer K, Montejo-Gonzalez JC, Pichard C, Preiser JC, Szczeklik W, van Zanten ARH, Bischoff SC (2023) ESPEN practical and partially revised guideline: Clinical nutrition in the intensive care unit. Clin Nutr (Edinburgh, Scotland) 42:1671–1689. https://doi.org/10.1016/j.clnu.2023.07.011
53. Lambell KJ, Tatucu-Babet OA, Miller EG, Ridley EJ (2023) How do guideline recommended energy targets compare with measured energy expenditure in critically ill adults with obesity: a systematic literature review. Clin Nutr (Edinburgh, Scotland) 42:568–578. https://doi.org/10.1016/j.clnu.2023.02.003
54. Tweel LE, Compher C, Bear DE, Gutierrez-Castrellon P, Leaver SK, MacEachern K, Ortiz-Reyes L, Pooja L, León A, Wedemire C, Lee ZY, Day AG, Heyland DK (2024) A comparison of high and usual protein dosing in critically ill patients with obesity: a post hoc analysis of an international,

pragmatic, single-blinded, randomized clinical trial. Crit Care Med 52:586–595. https://doi.org/10.1097/ccm.0000000000006117
55. Marshall V, Qiu Y, Jones A, Weller CD, Team V (2024) Hospital-acquired pressure injury prevention in people with a BMI of 30.0 or higher: a scoping review. J Adv Nurs 80:1262–1282. https://doi.org/10.1111/jan.15882
56. Carayannopoulos KL, Chaudhuri D, McNett M, Balas MC, Kho ME, Stollings J, Young B, Krupp A, Kim AJ, Chowdhury SR, Chen JZX, Harris P, Kim S, Manalo J, Kocaqi E, Dearness K, Aldrich JM, Lewis K (2025) Effect of enhanced versus usual mobilization activities in critically ill adults: a systematic review and meta-analysis of randomized controlled trials. Crit Care Med. https://doi.org/10.1097/ccm.0000000000006840
57. Paton M, Chan S, Tipping CJ, Stratton A, Serpa Neto A, Lane R, Young PJ, Romero L, Broadley T, Hodgson CL (2023) The Effect of Mobilization at 6 Months after Critical Illness - Meta-Analysis. NEJM Evid 2: EVIDoa2200234. https://doi.org/10.1056/EVIDoa2200234
58. Hodgson CL, Broadley T, Paton M, Higgins AM, Anderson S, Brennan S, Granger CL, Hammond NE, Magana Cruz S, Lang JK, Leditschke IA, Orford NR, Parry SM, Price B, Taylor P, Udy AA, Green SE (2025) Australian clinical practice guideline for physical rehabilitation and mobilisation in adult intensive care units. Austral Crit Care 38:101235. https://doi.org/10.1016/j.aucc.2025.101235
59. Schweickert WD, Pohlman MC, Pohlman AS, Nigos C, Pawlik AJ, Esbrook CL, Spears L, Miller M, Franczyk M, Deprizio D, Schmidt GA, Bowman A, Barr R, McCallister KE, Hall JB, Kress JP (2009) Early physical and occupational therapy in mechanically ventilated, critically ill patients: a randomised controlled trial. Lancet 373:1874–1882. https://doi.org/10.1016/S0140-6736(09)60658-9
60. Schaller SJ, Anstey M, Blobner M, Edrich T, Grabitz SD, Gradwohl-Matis I, Heim M, Houle T, Kurth T, Latronico N, Lee J, Meyer MJ, Peponis T, Talmor D, Velmahos GC, Waak K, Walz JM, Zafonte R, Eikermann M, International Early S-gMRI (2016) Early, goal-directed mobilisation in the surgical intensive care unit: a randomised controlled trial. Lancet 388:1377–1388. https://doi.org/10.1016/S0140-6736(16)31637-3
61. Hodgson CL, Bailey M, Bellomo R, Brickell K, Broadley T, Buhr H, Gabbe BJ, Gould DW, Harrold M, Higgins AM, Hurford S, Iwashyna TJ, Serpa Neto A, Nichol AD, Presneill JJ, Schaller SJ, Sivasuthan J, Tipping CJ, Webb S, Young PJ, Investigators TS, the ACTG (2022) Early active mobilization during mechanical ventilation in the ICU. N Eng J Med. https://doi.org/10.1056/NEJMoa2209083
62. Korupolu R, Zanni JM, Fan E, Butler M, Needham DM (2010) Early mobilisation of intensive care unit patient: the challenges of morbid obesity and multiorgan failure. BMJ Case Rep. https://doi.org/10.1136/bcr.09.2009.2257
63. Hodgson C, Needham D, Haines K, Bailey M, Ward A, Harrold M, Young P, Zanni J, Buhr H, Higgins A, Presneill J, Berney S (2014) Feasibility and inter-rater reliability of the ICU Mobility Scale. Heart Lung 43:19–24. https://doi.org/10.1016/j.hrtlng.2013.11.003
64. Eggmann S, Irincheeva I, Luder G, Verra ML, Moser A, Bastiaenen CHG, Jakob SM (2022) Cardiorespiratory response to early rehabilitation in critically ill adults: A secondary analysis of a randomised controlled trial. PLoS ONE 17:e0262779. https://doi.org/10.1371/journal.pone.0262779
65. Lewis AJM, Abdesselam I, Rayner JJ, Byrne J, Borlaug BA, Neubauer S, Rider OJ (2022) Adverse right ventricular remodelling, function, and stress responses in obesity: insights from cardiovascular magnetic resonance. Eur Heart J Cardiovasc Imaging 23:1383–1390. https://doi.org/10.1093/ehjci/jeab175
66. Serpa Neto A, Bailey M, Seller D, Agli A, Bellomo R, Brickell K, Broadley T, Buhr H, Gabbe BJ, Gould DW, Harrold M, Higgins AM, Hurford S, Iwashyna TJ, Nichol AD, Presneill JJ, Schaller SJ, Sivasuthan J, Tipping CJ, Poole A, Parke R, Bradley S, Webb S, Zoungas S, Young PJ, Hodgson CL (2024) Impact of high-dose early mobilization on outcomes for patients with diabetes: a secondary analysis of the TEAM trial. Am J Respir Crit Care Med 210:779–787. https://doi.org/10.1164/rccm.202312-2289OC
67. Paton M, Chan S, Serpa Neto A, Tipping CJ, Stratton A, Lane R, Romero L, Broadley T, Hodgson CL (2024) Association of active mobilisation variables with adverse events and mortality in patients requiring mechanical ventilation in the intensive care unit: a systematic review and meta-analysis. Lancet Respir Med 12:386–398. https://doi.org/10.1016/S2213-2600(24)00011-0
68. McWilliams D, Weblin J, Hodson J, Veenith T, Whitehouse T, Snelson C (2021) Rehabilitation Levels in Patients with COVID-19 Admitted to Intensive Care Requiring Invasive Ventilation. An Observational Study. Ann Am Thorac Soc 18:122–129. https://doi.org/10.1513/AnnalsATS.202005-560OC
69. Parry SM, Remedios L, Denehy L, Knight LD, Beach L, Rollinson TC, Berney S, Puthucheary ZA, Morris P, Granger CL (2017) What factors affect implementation of early rehabilitation into intensive care unit practice? A qualitative study with clinicians. J Crit Care 38:137–143. https://doi.org/10.1016/j.jcrc.2016.11.005
70. Hermes C, Nydahl P, Blobner M, Dubb R, Filipovic S, Kaltwasser A, Ulm B, Schaller SJ (2020) Assessment of mobilization capacity in 10 different ICU scenarios by different professions. PLoS ONE 15:e0239853. https://doi.org/10.1371/journal.pone.0239853
71. Eggmann S, Timenetsky KT, Hodgson C (2024) Promoting optimal physical rehabilitation in ICU. Intensive Care Med 50:755–757. https://doi.org/10.1007/s00134-024-07384-w
72. Darragh AR, Campo MA, Frost L, Miller M, Pentico M, Margulis H (2013) Safe-patient-handling equipment in therapy practice: implications for rehabilitation. Am J Occup Ther 67:45–53. https://doi.org/10.5014/ajot.2013.005389
73. Lorenz M, Langer N, Kloss P, Maechler M, Bald A, Warner L, Fuest K, Weiß B, Schaller SJ (2025) RObotic-assisted Early Mobilization in ventilated surgical critically ill patients (ROBEM-I)-A randomized, controlled, outcome-assessor-blinded pilot study. Anaesth Crit Care Pain Med 44:101549. https://doi.org/10.1016/j.accpm.2025.101549
74. Lorenz M, Baum F, Kloss P, Langer N, Arsene V, Warner L, Panelli A, Hartmann FV, Fuest K, Grunow JJ, Enghard P, Schaller SJ (2024) Robotic-assisted in-bed mobilization in ventilated ICU patients with COVID-19: an interventional, randomized, controlled pilot study (ROBEM II Study). Crit Care Med 52:683–693. https://doi.org/10.1097/CCM.0000000000006194
75. González-Seguel F, Camus-Molina A, Jasmén A, Molina J, Pérez-Araos R, Graf J (2021) Respiratory support adjustments and monitoring of mechanically ventilated patients performing early mobilization: a scoping review. Criti Care Explor 3:e0407. https://doi.org/10.1097/cce.0000000000000407
76. Genc A, Ozyurek S, Koca U, Gunerli A (2012) Respiratory and hemodynamic responses to mobilization of critically ill obese patients. Cardiopulm Phys Ther J 23:14–18. https://www.ncbi.nlm.nih.gov/pubmed/22807650
77. Herridge MS, Azoulay E (2023) Outcomes after Critical Illness. N Engl J Med 388:913–924. https://doi.org/10.1056/NEJMra2104669
78. Hermann M, Karner V, Schaller SJ (2026) Update on long-term physical disability after critical illness: the burden of post-intensive care syndrome. Intensive Care Med. https://doi.org/10.1007/s00134-026-08355-z
79. Ho MH, Lee YW, Wang L (2025) Estimated prevalence of post-intensive care cognitive impairment at short-term and long-term follow-ups: a proportional meta-analysis of observational studies. Ann Intensive Care 15:3. https://doi.org/10.1186/s13613-025-01429-z
80. Dimopoulos S, Leggett NE, Deane AM, Haines KJ, Abdelhamid YA (2024) Models of intensive care unit follow-up care and feasibility of intervention delivery: a systematic review. Austral Crit Care 37:508–516. https://doi.org/10.1016/j.aucc.2023.04.005
81. Sequeira TCA, BaHammam AS, Esquinas AM (2017) Noninvasive ventilation in the critically ill patient with obesity hypoventilation syndrome: a review. J Intensive Care Med 32:421–428. https://doi.org/10.1177/0885066616663179
82. Spies CD, Krampe H, Paul N, Denke C, Kiselev J, Piper SK, Kruppa J, Grunow JJ, Steinecke K, Gulmez T, Scholtz K, Rosseau S, Hartog C, Busse R, Caumanns J, Marschall U, Gersch M, Apfelbacher C, Weber-Carstens S, Weiss B (2021) Instruments to measure outcomes of post-intensive care syndrome in outpatient care settings - Results of an expert consensus and feasibility field test. J Intensive Care Soc 22:159–174. https://doi.org/10.1177/1751143720923597
83. Porter LL, Hazeleger L, Bos K, Simons KS, van der Hoeven JG, Yeghaian M, van der Woude MCE, van Santen S, Rettig TCD, de Vries M, van den Boogaard M, Zegers M (2025) Identifying distinct clusters of ICU survivors by integrating demographic, pre-admission quality of life, and clinical data: a large prospective cohort study. Intensive Care Med 51:1603–1614. https://doi.org/10.1007/s00134-025-08052-3
84. Grunow JJ, Hartmann L, Ulm B, Maechler M, Blobner M, Seidenspinner K, Schoennagel L, Weber-Carstens S, Fuest K, Wollersheim T, Schaller SJ (2025) Reliability of pre-admission patient-reported outcome

measures postoperatively assessed via proxies: a prospective, multicenter observational study. Crit Care 29:200. https://doi.org/10.1186/s13054-025-05431-6

85. Puhl RM, Lessard LM, Himmelstein MS, Foster GD (2021) The roles of experienced and internalized weight stigma in healthcare experiences: Perspectives of adults engaged in weight management across six countries. PLoS ONE 16:e0251566. https://doi.org/10.1371/journal.pone.0251566
86. Berger E, Schol C, Meertens-Gunput S, Kiers D, Gommers D, Rose L, van Mol M (2025) Digital health interventions supporting recovery for intensive care patients and their family members: a scoping review. Mayo Clin Proc Digit Health 3:100185. https://doi.org/10.1016/j.mcpdig.2024.11.006
87. da Silva AA, Merolli M, Fini NA, Granger CL, Gustafson OD, Parry SM (2025) Digital health interventions in adult intensive care and recovery after critical illness to promote survivorship care. J Intensive Care Soc 26:96–104. https://doi.org/10.1177/17511437241311105
88. Herbst NP, Danesh V, Lewis A, Sevin CM (2025) Multidisciplinary team approaches to assessing and addressing post intensive care syndrome. Crit Care Clin 41:157–170. https://doi.org/10.1016/j.ccc.2024.07.002