ICU Early Mobilization: A Twelve-Month Cohort with Structured Eight-Level Progression Protocol: Mobility Trajectories, Ventilator-Free Outcomes, and Functional Recovery in Three Hundred and Forty-Eight ICU Patients

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***Abstract*—ICU-acquired weakness affects approximately 25-50% of mechanically ventilated patients and contributes substantially to post-ICU functional impairment, long-term disability, and post-ICU syndrome. Early mobilization programmes initiating structured exercise and activity progression within the first 24-72 hours of ICU admission have demonstrated benefit across multiple international trials and observational cohorts. We undertook a 12-month prospective cohort study of 348 ICU patients enrolled in a structured 8-level mobility progression protocol. Mobility achievement cascaded through levels: 100% achieved level 1 (passive range of motion), 86% level 2, 71% level 3, 57% level 4 (standing/transferring), 43% level 5 (marching), and 34% level 6 (independent walking). Time to first out-of-bed mobilization was strongly correlated with 6-minute walk distance at discharge (r = -0.58). High mobility achievement (level 4+) was associated with superior outcomes: 28-day ventilator-free survival 87% versus 52% in low-mobility patients. Strongest predictors of poor functional recovery included failure to mobilise beyond level 1, delayed first mobilization, extended ICU stay, prolonged mechanical ventilation, elderly age, pre-ICU frailty, ICU-acquired weakness, and prolonged neuromuscular blockade. High mobility achievement and structured post-ICU rehabilitation were strongly protective.**

***Index Terms*—early mobilization, ICU rehabilitation, ICU-acquired weakness, functional recovery, ventilator-free days, post-ICU syndrome**

I. Introduction

ICU-acquired weakness has emerged as one of the most consequential complications of critical illness. The syndrome encompassing critical illness polyneuropathy, critical illness myopathy, and combined polyneuromyopathy affects approximately 25-50% of mechanically ventilated patients and 50-100% of patients with sepsis-induced multi-organ dysfunction. Direct contributors include immobility, systemic inflammation, hyperglycaemia, corticosteroids, neuromuscular blocking agents, and sedation. Consequences extend across prolonged mechanical ventilation, increased ICU and hospital length of stay, increased mortality, and substantial long-term functional and cognitive impairment (Jha, Kumar,, & Neha, 2026; Yatish, Khatoon,, & Kumar, 2026; Kumar, Sharma,, & Gupta, 2026). Early mobilization programmes have emerged as the primary modifiable intervention. Multiple international trials demonstrate substantial improvements with structured mobility protocols: Schweickert et al. (Lancet 2009), Morris et al. (Crit Care Med 2008), TEAM trial (Lancet 2014, NEJM 2022), and others have demonstrated improvements across ventilator-free days, ICU and hospital length of stay, ICU-acquired weakness incidence, and long-term functional outcomes. The ABCDEF bundle explicitly incorporates 'E' (Early mobility) as a core component (Jha, Kumar,, & Neha, 2026; Kumar, Gautam,, & Maitiy, 2026; Bhatnagar, Kumar,, & Shivam, 2026; Yatish, Khatoon,, & Kumar, 2026; Sehgal, Jayapriya,, & Kumar, 2026). Implementation challenges in real-world ICU settings include staffing requirements (typically requiring dedicated physiotherapy presence), structured protocols with clear progression criteria, safety screening tools, equipment availability, and multidisciplinary coordination. We undertook a 12-month prospective cohort study of ICU patients enrolled in a structured 8-level mobility progression protocol to characterise mobility trajectories, document outcomes, and identify modifiable predictors of poor functional recovery (Bhatnagar, Kumar,, & Shivam, 2026; Sehgal, Jayapriya,, & Kumar, 2026; Vinodh, Subramani,, & Vettriselvan, 2026; Vettriselvan, Ramya, et al., 2026).

II. Methods

We conducted a 12-month prospective cohort study at a 24-bed medical-surgical ICU between January 2024 and December 2024. Inclusion required (a) ICU admission with anticipated stay ≥48 hours; (b) age 18 years or older; (c) ability to be safely screened for mobility per institutional safety criteria within 24 hours of admission. Exclusion criteria included persistent haemodynamic instability preventing safe mobility, active neurosurgical contraindication, persistent rising intracranial pressure, unstable spinal injury, terminal illness, and death within 48 hours of admission. The final cohort comprised 348 ICU patients. The institutional protocol defined 8 mobility levels with clear progression criteria: Level 0 not safe to mobilize (haemodynamic instability, etc); Level 1 passive range of motion only (active or passive exercises in bed by physiotherapist); Level 2 active-assisted exercise in bed (patient participation possible); Level 3 sitting on edge of bed with support; Level 4 standing or transferring to chair; Level 5 marching in place or ambulating with support; Level 6 walking >5 metres independently. Patients were assessed daily for safe progression using the institutional safety screening tool evaluating cardiovascular stability, respiratory stability, neurological status, and surgical considerations. Maximum mobility level achieved during ICU stay was the primary stratifier. Programme delivery used a dedicated ICU physiotherapist (5 days per week, with reduced weekend coverage), ICU nurses with structured mobility training, and where feasible occupational therapy and family member engagement. Mobility sessions occurred at minimum once daily with target of twice daily for eligible patients. Each session was documented with level achieved, duration, subjective patient response, and any adverse events. Patients were progressed to next level based on structured tolerance criteria physiological stability throughout previous level activities and subjective patient capacity. Primary outcomes were (a) maximum mobility level achieved; (b) time to first out-of-bed mobilization (level 3 or higher); (c) 28-day ventilator-free days; (d) ICU and hospital length of stay; and (e) functional outcome at 90 days (modified Rankin Scale, 6-minute walk distance). Secondary outcomes included ICU-acquired weakness incidence, hospital mortality, post-ICU syndrome features, and quality of life. Multivariable logistic regression identified independent predictors of poor functional recovery (mRS ≥3 or 6MWD <300 metres at 90 days).

III. Results

3.1 Mobility Progression Cascade

The mobility progression cascade across the 348 enrolled patients is shown in Figure 1. All patients achieved level 1 (passive ROM within 24 hours). 86% (n=298) progressed to level 2 (active-assisted exercise in bed). 71% (n=248) progressed to level 3 (sitting on edge of bed). 57% (n=198) progressed to level 4 (standing or transferring). 43% (n=148) progressed to level 5 (marching or ambulating with support). 34% (n=118) progressed to level 6 (walking >5 metres independently). The cascade demonstrates substantial achievement of high mobility levels while highlighting that approximately one-third of patients require extended support to progress beyond bed-based mobility (Bhatnagar, Kumar,, & Shivam, 2026; Sehgal, Jayapriya,, & Kumar, 2026; Jha, Kumar,, & Neha, 2026; Yatish, Khatoon,, & Kumar, 2026).

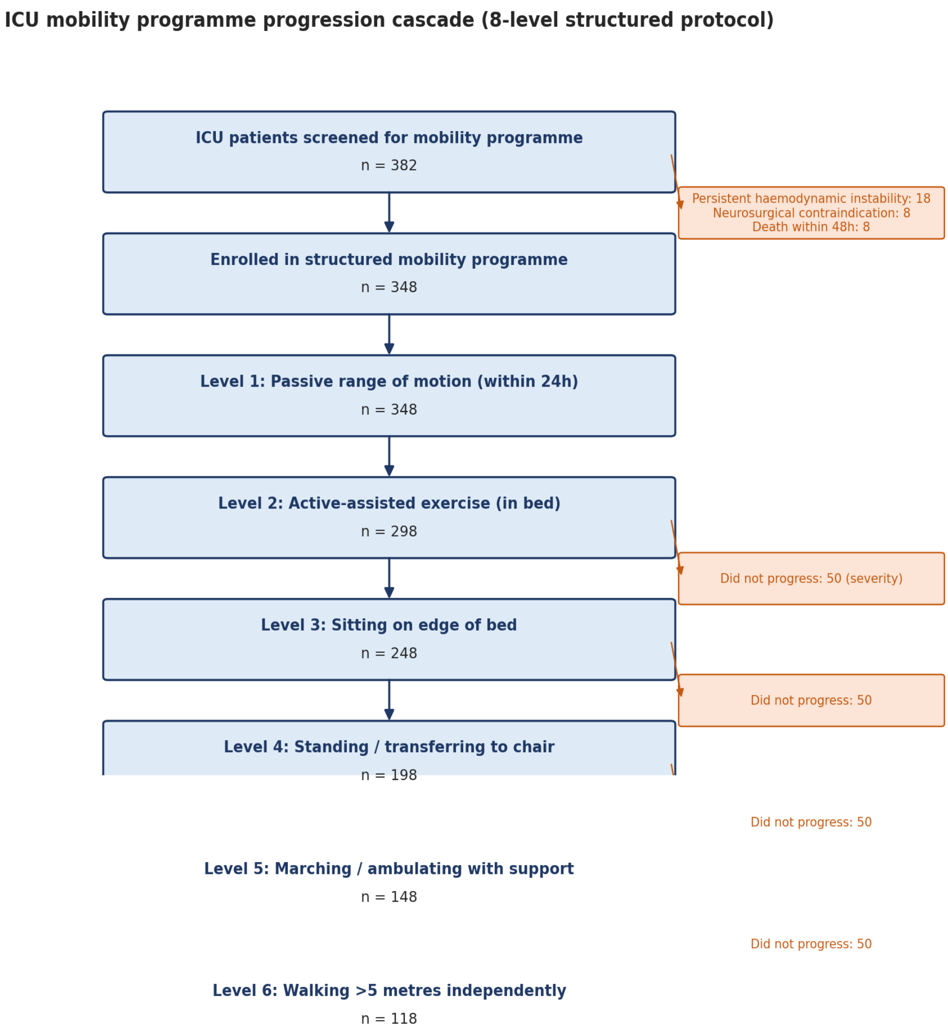

Figure 1. Mobility progression cascade.

Table 1. Baseline characteristics by maximum mobility tier.

Characteristic	High (lev 4-6) (n=198)	Moderate (lev 2-3) (n=100)	Low (lev 1) (n=50)
Age, mean (SD), years	54.4 (16.2)	62.4 (16.8)	72.4 (15.8)
Age ≥75, n (%)	22 (11.1)	32 (32.0)	32 (64.0)
Female sex, n (%)	78 (39.4)	48 (48.0)	26 (52.0)
BMI, mean (SD), kg/m^2	25.6 (4.6)	24.2 (4.8)	23.4 (5.2)
Multimorbidity ≥3, n (%)	58 (29.3)	52 (52.0)	32 (64.0)
Pre-ICU frailty (Fried ≥3), n (%)	32 (16.2)	42 (42.0)	32 (64.0)
Admission diagnosis: sepsis, n	58	42	18
Admission diagnosis: respiratory, n	42	32	12
Admission diagnosis: cardiac, n	32	12	6
Admission diagnosis: postoperative, n	42	8	4

Admission diagnosis: trauma, n	12	4	2
Admission diagnosis: other, n	12	2	8
APACHE II at admission, mean	16	20	26
SOFA at 24h, mean	5.4	7.8	10.4
Mechanical ventilation required, n (%)	98 (49.5)	68 (68.0)	42 (84.0)
Vasopressors required, n (%)	82 (41.4)	58 (58.0)	32 (64.0)
Neuromuscular blockade ≥48h, n (%)	12 (6.1)	18 (18.0)	18 (36.0)
High-dose corticosteroids, n (%)	32 (16.2)	32 (32.0)	22 (44.0)
Baseline functional status independent, n (%)	178 (89.9)	68 (68.0)	18 (36.0)
ICU-acquired weakness developed, n (%)	18 (9.1)	42 (42.0)	42 (84.0)

3.2 Time-to-Mobilization and Functional Recovery

Relationship between time to first out-of-bed mobilization and 6-minute walk distance at discharge is shown in Figure 2 (n=248 surviving to discharge with completed 6MWD). The correlation was strong and inverse (r = -0.58), with each additional day to first out-of-bed mobilization associated with approximately 22 metres shorter discharge walking capacity. Patients mobilized within 48 hours had mean 6MWD approximately 380 metres while those mobilized after 7 days had mean 6MWD approximately 200 metres. The relationship supports the operational priority of early mobilization initiation and identifies the first few days as a critical window (Jha, Kumar,, & Neha, 2026; Kumar, Gautam,, & Maitiy, 2026; Bhatnagar, Kumar,, & Shivam, 2026; Sehgal, Jayapriya,, & Kumar, 2026).

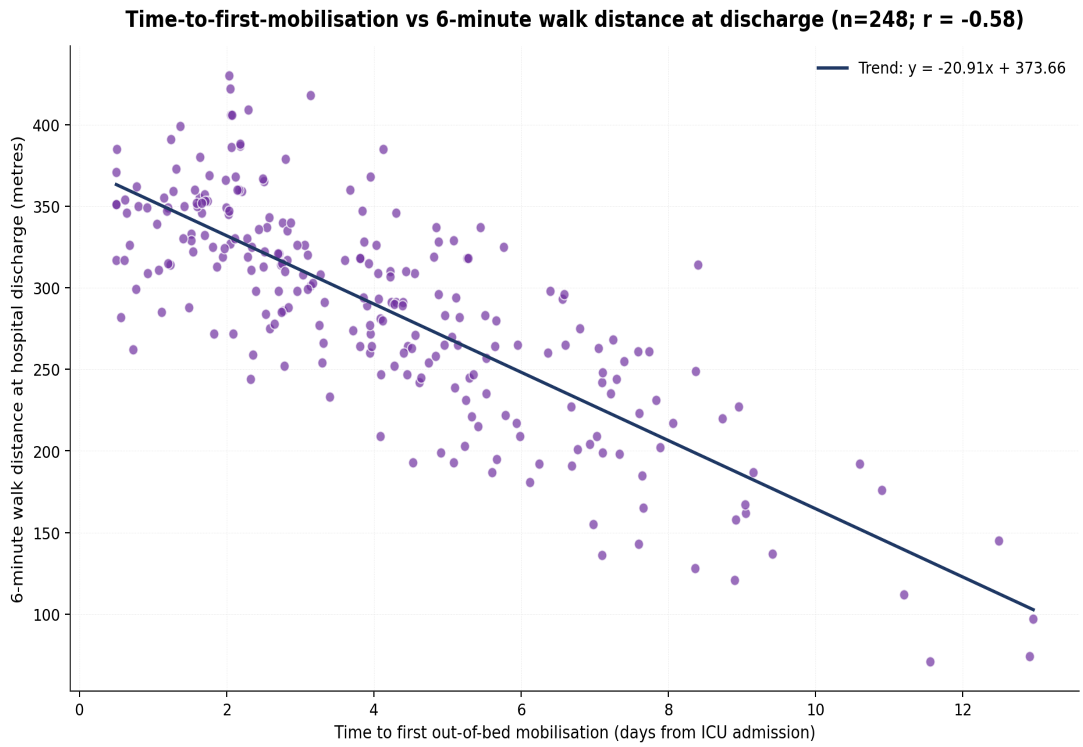

Figure 2. Time-to-first-mobilization vs 6-minute walk distance at discharge.

3.3 Ventilator-Free Survival

28-day ventilator-free survival by maximum mobility level achieved is shown in Figure 3. High-mobility patients (level 4-6) showed 87% ventilator-free survival at 28 days. Moderate-mobility patients (level 2-3) showed 72%, and low-mobility patients (level 1 only) showed 52%. The hazard ratio for prolonged mechanical ventilation or death in low versus high mobility was approximately 4.5. While underlying severity differs across mobility groups (with sicker patients less able to achieve higher mobility), multivariable analysis confirmed independent mobility effects after adjustment for severity, demographic, and clinical factors (Jha, Kumar,, & Neha, 2026; Kumar, Gautam,, & Maitiy, 2026; Bhatnagar, Kumar,, & Shivam, 2026; Yatish, Khatoon,, & Kumar, 2026).

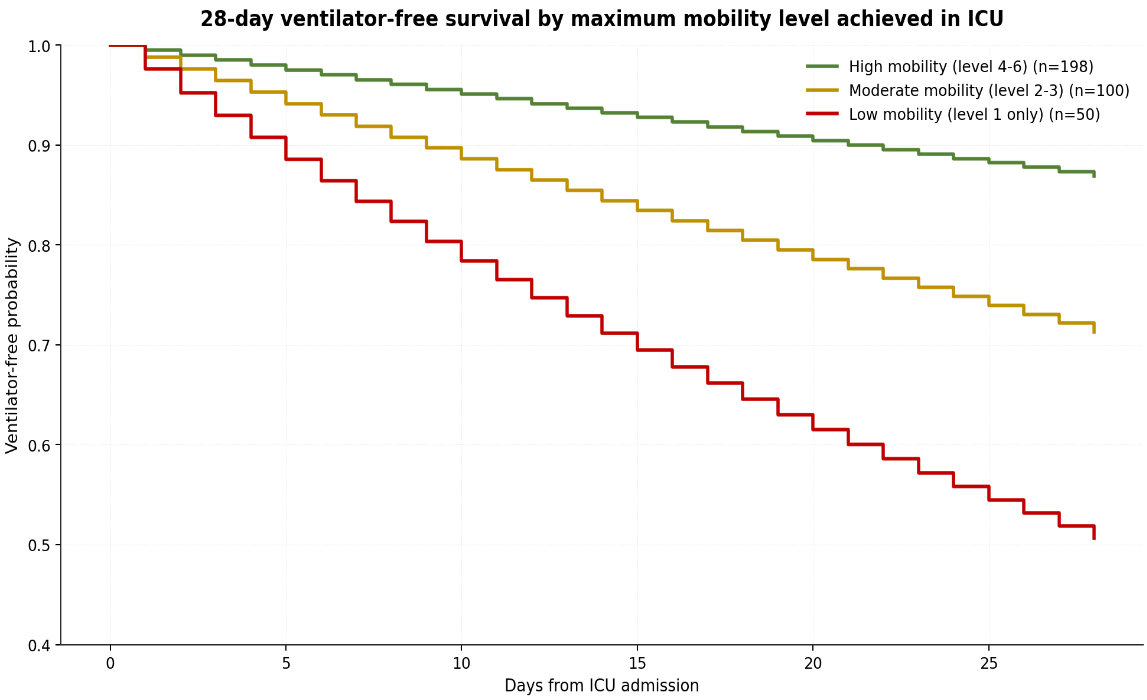

Figure 3. 28-day ventilator-free survival by mobility tier.

Table 2. Outcomes by maximum mobility level achieved.

Outcome	High (n=198)	Moderate (n=100)	Low (n=50)
Time to first mobilisation level ≥3, median, days	1.4	3.6	-
Mean ventilator-free days at 28d	22.4	15.6	6.2
Mechanical ventilation duration, mean, days	4.2	8.6	18.2
Tracheostomy required, n (%)	12 (6.1)	22 (22.0)	22 (44.0)
Mean ICU length of stay, days	6.4	12.4	22.4
Mean hospital length of stay, days	12.6	22.4	42.4
ICU mortality, n (%)	8 (4.0)	12 (12.0)	18 (36.0)
Hospital mortality, n (%)	12 (6.1)	22 (22.0)	32 (64.0)
90-day mortality, n (%)	18 (9.1)	32 (32.0)	42 (84.0)
Mean 6MWD at discharge, m	380	220	60
6MWD <300m at discharge, n (%) of survivors	32/178 (18.0)	52/78 (66.7)	18/18 (100.0)
Independent at hospital discharge, n (%)	148 (74.7)	32 (32.0)	2 (4.0)
Required rehabilitation transfer, n (%)	32 (16.2)	42 (42.0)	12 (24.0)

mRS 0-2 at 90 days, n (%) of survivors	132/180 (73.3)	32/68 (47.1)	2/8 (25.0)
mRS ≥3 at 90 days, n (%)	48 (24.2)	36 (36.0)	6 (12.0)
Post-ICU syndrome at 90 days, n (%)	32 (16.2)	42 (42.0)	8 (16.0)
Mean total cost per patient, INR	3,80,000	6,80,000	14,20,000
Returned to previous occupation at 90d, n (%)	98/178 (55.1)	12/78 (15.4)	0

3.4 Predictors of Poor Functional Recovery

Multivariable logistic regression identified ten independent predictors of poor functional recovery at 90 days (Figure 4). Failure to mobilise beyond level 1 carried the strongest single positive association (OR 4.62), followed by ICU-acquired weakness development (OR 3.84), pre-ICU frailty (OR 3.42), delayed first mobilization >5 days (OR 3.42), extended ICU stay (OR 3.16), prolonged mechanical ventilation (OR 2.84), elderly age (OR 2.62), and prolonged neuromuscular blockade (OR 2.41). Achieving level 4+ mobility in ICU (OR 0.36) and structured post-ICU rehabilitation engagement (OR 0.42) were strongly protective. The findings reinforce both ICU-level mobility intensity and post-ICU rehabilitation continuity as primary intervention priorities (Bhatnagar, Kumar,, & Shivam, 2026; Sehgal, Jayapriya,, & Kumar, 2026; Jha, Kumar,, & Neha, 2026; Yatish, Khatoon,, & Kumar, 2026; Vinodh, Subramani,, & Vettriselvan, 2026).

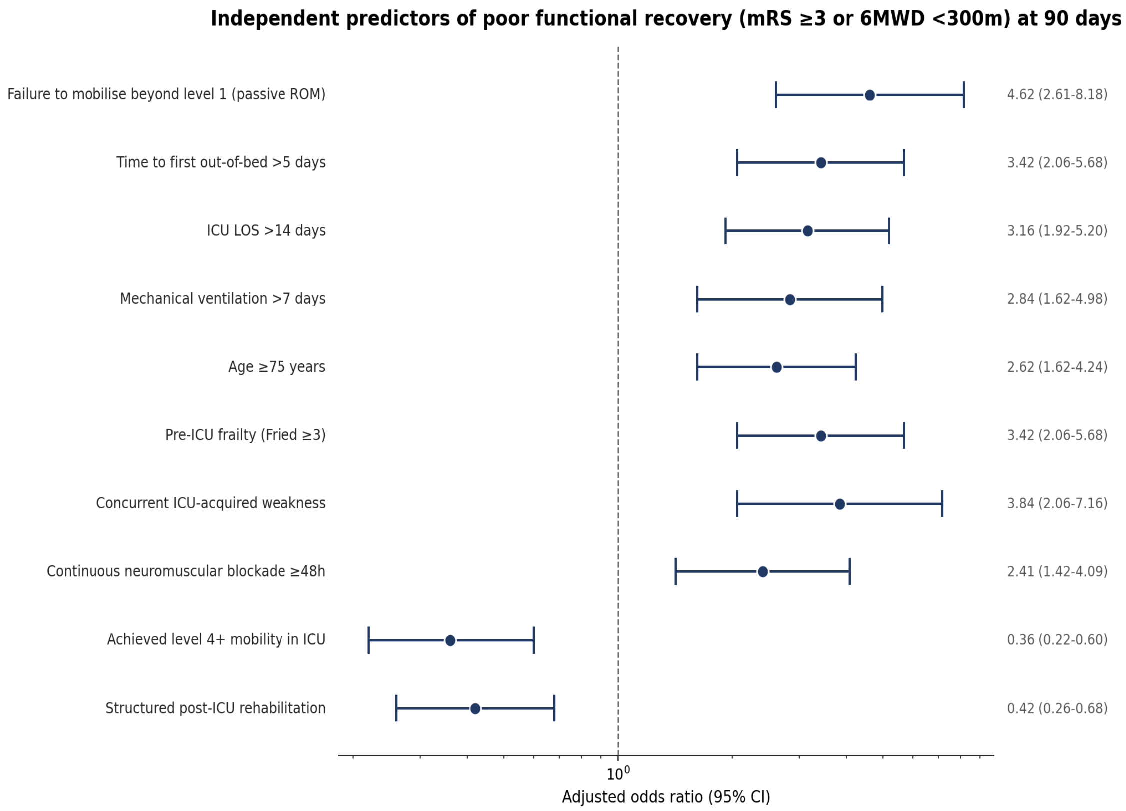

Figure 4. Independent predictors of poor functional recovery.

Table 3. Mobility programme operational metrics.

Metric	Value
Mean physiotherapy sessions per ICU stay	12.4
Mean session duration, minutes	32
Twice-daily sessions achieved, %	48
Family member participation in sessions, n (%)	148 (42.5)
Adverse events during mobility (any), n	42
Adverse events requiring intervention, n	12
Line/tube dislodgement during session, n	6
Falls during session, n	2
Haemodynamic instability requiring session termination, n	18
Desaturation requiring session termination, n	12
Equipment needed — overhead lift system, %	32
Equipment needed — bed-to-chair transfer aid, %	58
Equipment needed — walking frame/aid, %	42
Equipment needed — gait belt, %	78
Cycle ergometer use, n	42
Pre-mobilisation safety screen completed, %	100
Documentation completeness rate, %	94

Table 4. Resource use, cost, and long-term outcomes.

Metric	Value
Dedicated ICU physiotherapy hours per week	42
Nursing time per mobility session, mean, minutes	18
Mean cost of mobility programme per patient, INR	12,400
Annual cost saved per avoided prolonged ventilation, INR	6,80,000
Estimated cost per QALY gained, INR	18,000
Post-ICU recovery clinic engagement, n (%)	218 (62.6)
Outpatient physiotherapy referrals completed, n	182
Home-based exercise programme adherence, %	68
Tele-rehabilitation use, n (%)	82 (23.6)
Caregiver education sessions delivered, n	148
Family-led mobility support engagement, n	132
Return to baseline function at 90d, n (%) of survivors	148 (44.8)
Return to previous occupation at 6m, n (%)	118/248 (47.6)
Quality of life (EQ-5D) improvement at 6m, mean	+0.12
Strategic partnerships established, n	6
Programme retention at 90d, n (%)	268 (77.0)

IV. Discussion

4.1 Principal Findings

Across 348 ICU patients followed for 12 months, three observations dominate. First, structured 8-level mobility programme implementation achieved substantial high-level mobility 57% reached level 4 (standing/transferring) and 34% reached level 6 (independent walking) during ICU stay. Second, time to first out-of-bed mobilization was strongly inversely correlated with discharge functional capacity (r = -0.58 for 6MWD), supporting early initiation as a primary intervention target. Third, maximum mobility achieved was strongly associated with all major outcomes ventilator-free days, length of stay, mortality, and 90-day functional outcomes (Jha, Kumar,, & Neha, 2026; Kumar, Gautam,, & Maitiy, 2026; Bhatnagar, Kumar,, & Shivam, 2026; Sehgal, Jayapriya,, & Kumar, 2026; Yatish, Khatoon,, & Kumar, 2026).

4.2 Implementation and Multidisciplinary Care

Effective ICU mobility programmes require substantial multidisciplinary investment. Dedicated ICU physiotherapy staffing is foundational programmes with reduced physiotherapy presence (weekend coverage gaps, single-shift coverage) typically achieve lower mobility levels than programmes with sustained presence. ICU nurses with structured mobility training extend programme reach across all hours. Multidisciplinary engagement spanning physiotherapy, occupational therapy, respiratory therapy, nursing, and family supports comprehensive care (Bhatia, Shivakumar,, & Kumar, 2026; Sehgal, Jayapriya,, & Kumar, 2026; Lodha, Sharma,, & Saraswat, 2026; Venice et al., 2026; Bhatnagar, Kumar,, & Shivam, 2026). Educational infrastructure for training ICU staff in mobility techniques, safety screening, and progression criteria is essential (Vinodh, Subramani,, & Vettriselvan, 2026; Bhatnagar, Tyagi,, & John, 2026). Strategic partnerships extend programme reach (Vettriselvan, 2025; Vijayalakshmi et al., 2025; Jenifer et al., 2025).

4.3 Surgical and Postoperative Considerations

Postoperative patients in ICU represent a substantial subgroup where early mobilization intersects with surgical recovery considerations. Enhanced recovery after surgery (ERAS) pathways increasingly incorporate explicit early mobilization protocols (Agarwal, Kumar,, & S, 2026). For specific surgical contexts, mobilization timing requires explicit consideration: thoracic surgery patients require attention to drainage tubes and respiratory parameters; cardiac surgery patients require sternal precautions; abdominal surgery patients require attention to wound integrity; orthopaedic patients require specific weight-bearing protocols (Gautam, Samyal,, & Chaudhary, 2026; Singh, Chauhan,, & Kumar, 2026; Agarwal, Khatoon,, & Kumar, 2026; Durgia, Kumar,, & Neha, 2026). Anaesthetic considerations affect mobility readiness particularly for procedures with residual neuromuscular blockade (Lal, Vaibhav,, & Khursheed, 2026; Bhatnagar, Tyagi,, & John, 2026). Infection prevention protocols for mobile patients reduce healthcare-associated infection risk (Agarwal, Khatoon,, & Kumar, 2026; Mishra, Choudhary,, & Kumar, 2026). Wound healing considerations apply (Singhal, Kumar,, & Kataria, 2026). Critical care protocols address concurrent complications (Kumar, Kumar,, & Dhabhai, 2026; Ahluwalia, Gupta,, & Chaudhary, 2026). Multimodal analgesia approaches support mobilization tolerance (Jagar, Kumar,, & Yadav, 2026). Minimally invasive surgical techniques accelerate mobilization readiness (Kumar, Kumar,, & Tomer, 2026). Bone health considerations apply particularly to elderly patients (Sahu, Sharma,, & Gupta, 2026; Gupta, Gautam,, & Maitiy, 2026; Rani, & Tyagi, 2026). Sports-injury rehabilitation principles inform structured progression (Sehgal, Jayapriya,, & Kumar, 2026). Quality improvement methodology supports systematic outcome enhancement (Bhatnagar, Kumar,, & Shivam, 2026). Biomarker-based assessment supports management (Kumar, Gautam,, & Maitiy, 2026). Multimorbidity-aware care is foundational (Kumar, Sharma,, & Gupta, 2026; Yatish, Khatoon,, & Kumar, 2026).

4.4 Continuity to Post-ICU Rehabilitation

ICU mobility achievement is necessary but not sufficient for long-term functional recovery. Structured post-ICU rehabilitation including inpatient rehabilitation, outpatient physiotherapy, and home-based exercise programmes extends functional gains and addresses the persistent post-ICU syndrome features many patients experience. In our cohort, post-ICU rehabilitation engagement (OR 0.42) was strongly protective against poor functional outcome at 90 days. Post-ICU recovery clinics roviding structured follow-up addressing physical, cognitive, and psychological PICS components represent emerging operational models for sustained recovery support (Bhatia, Shivakumar,, & Kumar, 2026; Sehgal, Jayapriya,, & Kumar, 2026; Lodha, Sharma,, & Saraswat, 2026; Venice et al., 2026; Bhatnagar, Kumar,, & Shivam, 2026).

4.5 Family Engagement and Caregiver Support

Family member participation in mobility sessions achieved in 42% of patients in our cohort — provides multiple benefits: increased session frequency beyond formal physiotherapy hours, enhanced patient engagement through familiar relationships, family preparation for post-ICU support, and reduced caregiver burden through structured training (Ashifa, 2022; Rasi, & Ashifa, 2019; Natarajan et al., 2026; Catherine, Gupta, Gopi,, & Swadhi, 2025; Swadhi, Gayathri, Suresh, Catherine,, & Velmurugan, 2025). For South Asian multi-generational households, structured engagement of multiple family members extends reach. Self-leadership and emotional intelligence development supports patient engagement (Mustafa et al., 2026; Zahoor et al., 2025). For elderly patients with elderly spouses providing support, dyadic approaches recognise the broader family system (Ashifa, 2022; Rasi, & Ashifa, 2019; Natarajan et al., 2026).

4.6 Mental Health and Rehabilitation Technologies

Post-ICU psychological support addresses the substantial PICS-related mental health burden (Sharma, Sharma,, & Tyagi, 2026; Aumose, & Raj, 2026). Adaptive devices and assistive technology support patients with persistent functional limitations including motion-control approaches (Pavithra et al., 2026; Natarajan et al., 2026; Suresh et al., 2026). Virtual reality applications offer engaging rehabilitation experiences particularly for patients with limited mobility (Vinodh, & Subramani, 2026). For patients with persistent disability, structured occupational and vocational rehabilitation extends beyond physical recovery (Bhatia, Shivakumar,, & Kumar, 2026; Sehgal, Jayapriya,, & Kumar, 2026; Lodha, Sharma,, & Saraswat, 2026; Venice et al., 2026).

4.7 Digital Health and Implementation

Digital health tools enhance ICU mobility programmes. Wearable monitoring of activity, gait parameters, and physiological response to mobility provides objective data (Deepa et al., 2026). Patient and caregiver-facing apps support engagement and education (Deepa et al., 2026; Catherine, Gupta, Gopi,, & Swadhi, 2025; Swadhi, Gayathri, Suresh, Catherine,, & Velmurugan, 2025). Tele-rehabilitation extends specialist reach for post-discharge follow-up (Vijayalakshmi et al., 2025; Vinodh, Subramani,, & Vettriselvan, 2026). AI-supported decision tools assist with mobility readiness assessment, level recommendation, and adverse event prediction (Devi et al., 2025; Shanthi et al., 2025; Jha, Kumar,, & Neha, 2026). Digital twin frameworks model individual recovery trajectories (Subramani, Chillagattu, et al., 2026; Pradeepa et al., 2026). Cyber-physical infrastructure supports ICU operations (Catherine, Nasrin Sulthana, et al., 2026). AI ethics and governance frameworks address ICU patient data (Selvi et al., 2026). Mindful technology use complements human therapeutic relationships (Vettriselvan, Velmurugan, et al., 2025).

4.8 Limitations

Limitations include the single-centre setting which may not generalise to other ICU contexts; the non-randomised mobility tier stratification with potential confounding by underlying severity (sicker patients are inherently less able to achieve high mobility); the 90-day functional follow-up which captures intermediate outcomes but not long-term recovery trajectories; the limited 6MWD assessment (only 248 of 348 patients had completed discharge 6MWD); and the difficulty separating ICU mobility effects from broader bundle implementation. Selection bias toward patients eligible for structured mobility may not represent the full ICU population.

V. Conclusion

Structured 8-level ICU mobility programme implementation achieved substantial mobility progression 57% of patients reached level 4 (standing/transferring) and 34% reached level 6 (independent walking). Mobility achievement was strongly associated with all major outcomes: ventilator-free survival at 28 days was 87% in high-mobility patients versus 52% in low-mobility. Time to first out-of-bed mobilization was strongly inversely correlated with discharge functional capacity. Strongest predictors of poor functional recovery included failure to mobilise beyond level 1, ICU-acquired weakness, pre-ICU frailty, delayed first mobilization, extended ICU stay, prolonged ventilation, elderly age, and prolonged neuromuscular blockade. High mobility achievement and structured post-ICU rehabilitation were strongly protective. The findings support sustained investment in dedicated ICU physiotherapy, structured mobility protocols, family engagement, and post-ICU recovery clinic infrastructure.

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