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Enhanced rehabilitation for unstable pelvic tile C fractures: integrating mechanotherapy and early intervention

Khan Akhtar Ali[1†], LingXiao He[1†], Weikai Zhang[1], Chengyan Xia[1*], Hui Huang[1*] and Hui Huang Emails[1]

Abstract

Background and Objectives This study aimed to enhance the rehabilitation process for patients with unstable pelvic Tile C fractures resulting from polytrauma by integrating mechanotherapy using the Hocoma Lokomat robotic device with conventional rehabilitation methods. The goal was to improve functional recovery outcomes and minimize pain levels following surgical intervention.

Methods A total of 74 participants, aged 21 to 65 years, with severe unstable pelvic Tile C fractures were enrolled at Tongji Hospital's Department of Rehabilitation from 2022 to 2024. They were randomly divided into two groups: Group A (34 patients) received comprehensive rehabilitation including mechanotherapy with the Hocoma Lokomat, while Group B (40 patients) underwent only conventional therapeutic exercises. Functional outcomes were assessed using the Majeed pelvic score, and pain were monitored over time.

Results Group A demonstrated significantly better pelvic function scores compared to Group B throughout the rehabilitation period(91.53 ± 4.10vs. 88.17 ± 5.15). Additionally, at the six-month follow-up, Group A showed superior pain control benefits attributed to mechanotherapy(2.09 ± 1.10vs2.29 ± 1.12).

Conclusion Integrating the Hocoma Lokomat into rehab for unstable pelvic Tile C fractures improves function and pain control versus conventional care. The study supports robotic-assisted therapy's benefits for polytrauma patients, advocating innovative rehab approaches.

Keywords Rehabilitation, Pelvic tile C fractures, Mechanotherapy, Hocoma Lokomat

Introduction

Pelvic ring injuries, comprising 27–34% of polytrauma cases, pose significant clinical challenges due to their association with high mortality (6.1–8.5%) and long-term morbidity, with 15–20% of patients experiencing poor functional outcomes and 65% at risk of permanent disability without timely intervention [1]. These injuries, often resulting from high-energy trauma, disrupt pelvic stability and frequently require surgical stabilization to restore structural integrity. Despite advancements in trauma surgery, residual impairments in mobility, pain, and quality of life remain common, underscoring the

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critical role of postoperative rehabilitation in optimizing recovery [2]. Unstable pelvic Tile C fractures, characterized by both rotational and vertical instability, demand comprehensive management to address mechanical dysfunction and associated soft-tissue injuries. Chronic pelvic pain (CPP), a prevalent complication, arises from residual malalignment, muscle imbalances, or nerve irritation, impacting gait, posture, and daily activities [3]. Physical therapy is central to mitigating these issues, focusing on restoring pelvic stability, improving range of motion, and enhancing muscle strength. However, traditional rehabilitation approaches often lack the precision to address gait abnormalities and neuroplastic adaptations required for functional recovery, particularly in polytrauma patients with complex injury profiles [4]. Robotic-assisted devices like the Hocoma Lokomat® have emerged as promising tools in post-traumatic rehabilitation, offering structured gait training to stimulate neuroplasticity and improve lower limb function [5][5]. Unlike conventional therapy, which relies on manual guidance and static exercises, mechanotherapy provides dynamic, weight-bearing support, enabling early mobilization while minimizing mechanical stress on healing fractures [6]. This technology is particularly relevant for pelvic fracture patients, as it addresses gait dysfunction caused by pelvic malunion or soft-tissue contractures, which are known to perpetuate pain and mobility limitations [7]. While prior studies highlight the benefits of robotic gait training in stroke or spinal cord injury populations [8, 9], its application in unstable pelvic Tile C fractures—where pelvic biomechanics directly influence lower limb kinematics remains under investigated. A recent literature update by Piccione et al. [10] emphasized the need for innovative rehabilitative strategies to address the unique challenges of pelvic trauma, noting that traditional methods may insufficiently restore functional independence in patients with complex injuries. The Lokomat®'s ability to modulate gait parameters (e.g., step length, joint angles) offers a tailored approach to address these deficits, potentially reducing pain and enhancing mobility through improved mechanical alignment and muscle activation [11].The Lokomat provides a safe walking training environment for individuals with various injuries potentially stimulating neuroplastic changes and improving bowel and bladder function especially in severe spinal cord injury patients and it also offers a challenging exercise regimen for those with some walking ability by applying resistance at different gait cycle phases to enhance muscle activation and cortical plasticity [8, 9, 11, 12].The Lokomat provides objective and reliable measurements of patient performance to track training effects. The L FORCE assessment evaluates isometric muscle strength and demonstrates strong reliability and sensitivity to changes over time [13]. The Lokomat excels in gait training by allowing for greater training intensity, which has been linked to improved patient outcomes and enhanced neural plasticity, even in chronic injuries. Research shows that more intense training leads to better results [14–16].The aim of this study is to improve rehabilitation outcomes for patients with unstable pelvic Tile C fractures through the integration of mechanotherapy using the Hocoma Lokomat®. We hypothesized that integrating mechanotherapy with the Hocoma Lokomat® into the rehabilitation protocol for patients with unstable pelvic Tile C fractures would lead to significantly improved functional outcomes (as measured by the Majeed Pelvic Score) and reduced pain levels (via Visual Analog Scale) compared to conventional rehabilitation alone. This intervention was expected to leverage robotic-assisted gait training to enhance muscle strength, gait efficiency, and neuroplastic adaptation, thereby addressing the unmet rehabilitative needs of this vulnerable population.

Materials and methods

Study design and ethical considerations

This prospective, randomized controlled trial was conducted at Tongji Hospital's Department of Rehabilitation between 2022 and 2024 (ethics approval: TJ-IRB20230440), evaluating the efficacy of Hocoma Lokomat®-assisted mechanotherapy versus conventional rehabilitation in 74 adults (21–65 years) with severe unstable pelvic Tile C fractures from polytrauma. The protocol adhered to CONSORT guidelines and included written informed consent from all participants.

Eligibility required

1. Radiological Confirmation: Unstable pelvic Tile C fractures (AO/OTA classification) diagnosed via pelvic X-rays and computed tomography (CT), demonstrating displacement, comminution, or pelvic ring instability.
2. Clinical Validation: Post-surgical stability following standardized fixation (open reduction internal fixation [ORIF] with plates/screws or closed reduction percutaneous sacroiliac screws [SIS] fixation, determined by fracture morphology), assessed by a multidisciplinary team (orthopedic surgeons, radiologists, rehabilitation specialists). Exclusion criteria included pre-existing severe lower limb disability, cognitive impairment, or contraindications to robotic therapy.

Blinding procedures outcome measures

"Functional outcomes were assessed by a physical therapist blinded to group assignments. However, due to the visible differences between mechanotherapy (Lokomat®) and conventional therapy, participants and treating

therapists were not blinded. To minimize bias, self-reported pain (VAS) and functional scores (MPS) were supplemented with objective measures (L FORCE muscle strength). Blinded assessors conducted all evaluations to ensure impartiality."

Sample size and randomization

A target sample size of 74 (34 in mechanotherapy group, 40 in conventional group) was determined using G*Power 3.1 to detect a 10-point between-group difference in the Majeed Pelvic Score (MPS), assuming 80% power ($\alpha = 0.05$, effect size = 0.8). Patients were randomized 1:1 via computer-generated sequences, stratified by age and Injury Severity Score (ISS) to balance baseline characteristics. Allocation was concealed in sealed, opaque envelopes managed by an independent research assistant.

Operator training and protocol adherence interventions

"All Lokomat® operators underwent standardized training certified by Hocoma, including 20 hours of hands-on practice and competency assessments. Training emphasized consistent adjustment of gait parameters (speed, assistance levels) and force settings. Protocol adherence was monitored via monthly audits, with corrective feedback provided to ensure uniformity across sessions.

Table 1 Baseline demographic and clinical characteristics

	Group A Hocoma Lokomat *n* = 33	Group B Conventional *n* = 40	t/X2	*P*
Age	47.36 ± 10.63	51.61 ± 12.50	1.018	0.317
Gender			0.088	0.767
Male	19	25		
Female	14	16		
BMI	22.13 ± 2.07	22.63 ± 2.31	0.337	0.966
ISS	9.58 ± 3.43	10.44 ± 3.19	1.117	0.268
Mechanism of injury			0.036	0.850
Car accident	24	29		
Fall injury	9	12		
Basic diseases				
Heart disease	2	3		
Diabetic	2	2		
Smoke	3	5		
Collateral damage				
Head trauma	0	2		
Abdominal injury	2	5		
Chest injury	1	0		
Multisystem injury	4	4		

BMI: Body Mass Index; ISS: Injury Severity Data are presented as mean ± standard deviation (SD) for continuous variables or number (%) for categorical variables. Group differences were evaluated using independent *t*-tests (continuous variables) or chi-squared tests (categorical variables). No significant baseline disparities were observed (all $p > 0.05$). BMI = body mass index; ISS = Injury Severity Score. Score

Group A (Mechanotherapy + Conventional Rehabilitation): Received 12 weeks of robotic-assisted treadmill training (Hocoma Lokomat®; 30–60 min/session, 3 times/week), combined with personalized conventional physiotherapy (strength, flexibility, and range-of-motion exercises).

Group B (Conventional Rehabilitation): Underwent identical conventional therapy without mechanotherapy, including manual therapy, stretching, and strengthening exercises, matched for session duration and frequency.

Baseline characteristics and statistical adjustments

Demographic and clinical baseline data, including age, gender, Injury Severity Score (ISS), and surgical approach, were systematically collected to ensure group comparability (Table 1). Although the mean age differed marginally between Group A (47.36 ± 10.63 years) and Group B (51.61 ± 12.50 years, $p = 0.317$), no significant differences were observed in surgical intervention distribution (open reduction internal fixation [ORIF] vs. closed reduction sacroiliac screw [SIS] fixation, $p > 0.05$) or other key baseline variables (gender, BMI, ISS, injury mechanisms). To address potential age-related confounding in outcome analyses, age was incorporated as a covariate in regression models evaluating functional recovery (Majeed Pelvic Score [MPS]) and pain severity (Visual Analog Scale [VAS]), ensuring statistical adjustment for any residual effects on rehabilitation trajectories.The Majeed scoring system, widely used for chronic sacroiliac joint pain assessment, demonstrated acceptable reliability and validity in this study, though high floor effects in pain, work, sitting, and sexual function highlighted the need for refined measures specific to sacroiliac dysfunction [17, 18]. The ISS, calculated using the Abbreviated Injury Scale (AIS), effectively captured injury severity by summing the squares of the highest AIS scores from the three most injured regions [19, 20].

Patient selection & baseline characteristics

Seventy-four patients with polytrauma-related severe unstable pelvic Tile C fractures were enrolled, with detailed documentation of concomitant injuries (e.g., head, abdominal, chest trauma, or multisystem involvement) at baseline (Table 1). While Group A (mechanotherapy) and Group B (conventional rehabilitation) showed minor heterogeneity in concomitant injury distribution (7 vs. 11 patients with head/abdominal/chest trauma, respectively), between-group comparisons revealed no significant differences ($p > 0.05$ for all injury categories). Rehabilitation protocols were customized to accommodate common concomitant injuries: patients with chest/abdominal trauma received pain-modulated range-of-motion exercises to avoid exacerbating injury sites, and those with head injuries

underwent pre-treatment cognitive screening to ensure safe participation in robotic-assisted training. For lower limb injuries, the Hocoma Lokomat® mechanotherapy was individualized through adjustable gait assistance levels, aligning with each patient's functional tolerance. This standardized, adaptive approach minimized bias from heterogeneous concomitant injuries, ensuring both groups received targeted care for secondary injuries while maintaining focus on primary rehabilitation.

Group allocation The patients were randomly divided into two groups based on the type of rehabilitation method employed: Group A (Main Group): This group consisted of 34 patients (average age 47.36 ± 10.63 years) who received a comprehensive rehabilitation program that included conventional physiotherapy exercises combined with mechanotherapy using the Hocoma Lokomat® device. Group B (Comparison Group): This group included 40 patients (average age 22.63 ± 2.31 years) who only received standard conventional rehabilitation therapy without the use of mechanotherapy.

Assessment of injury severity To ensure comparability between the two groups in terms of injury severity, participants were evaluated using the Injury Severity Score (ISS) upon admission. The ISS is a widely used scoring system that quantifies the severity of injuries in trauma patients, providing a comprehensive assessment of the overall physical condition of each participant. The Injury Severity Score (ISS) quantifies multi-injury severity using the Abbreviated Injury Scale (AIS), which rates six body regions (head/neck, face, chest, abdomen/pelvis, extremities/pelvic girdle, external) on a 0–6 scale (6 = critical). ISS sums the squares of the highest AIS scores from the three most injured regions, ranging from 3 to 75. An AIS 6 in any region sets ISS to 75, indicating maximal severity [17].

Rehabilitation protocols

Group A (Hocoma Lokomat® Rehabilitation):

1. Conventional Physiotherapy: Patients participated in a personalized program targeting strength, flexibility, and range of motion to improve functional mobility and alleviate pain.
2. Mechanotherapy with Hocoma Lokomat®: This robotic-assisted rehabilitation involved treadmill walking with the Lokomat® (Fig. 1), a device designed to guide patients' legs through a predetermined gait cycle with adjustable speed and assistance levels. Sessions lasted 30–60 min, scheduled three times weekly for 12 weeks.

Group B (Conventional Rehabilitation):

Patients received standard physiotherapy, including manual therapy, stretching, and strengthening exercises, with identical session duration and frequency to Group A.

Outcome measures

Functional recovery, pain, and muscle strength were evaluated using validated, standardized instruments to ensure objective assessment of rehabilitation outcomes.

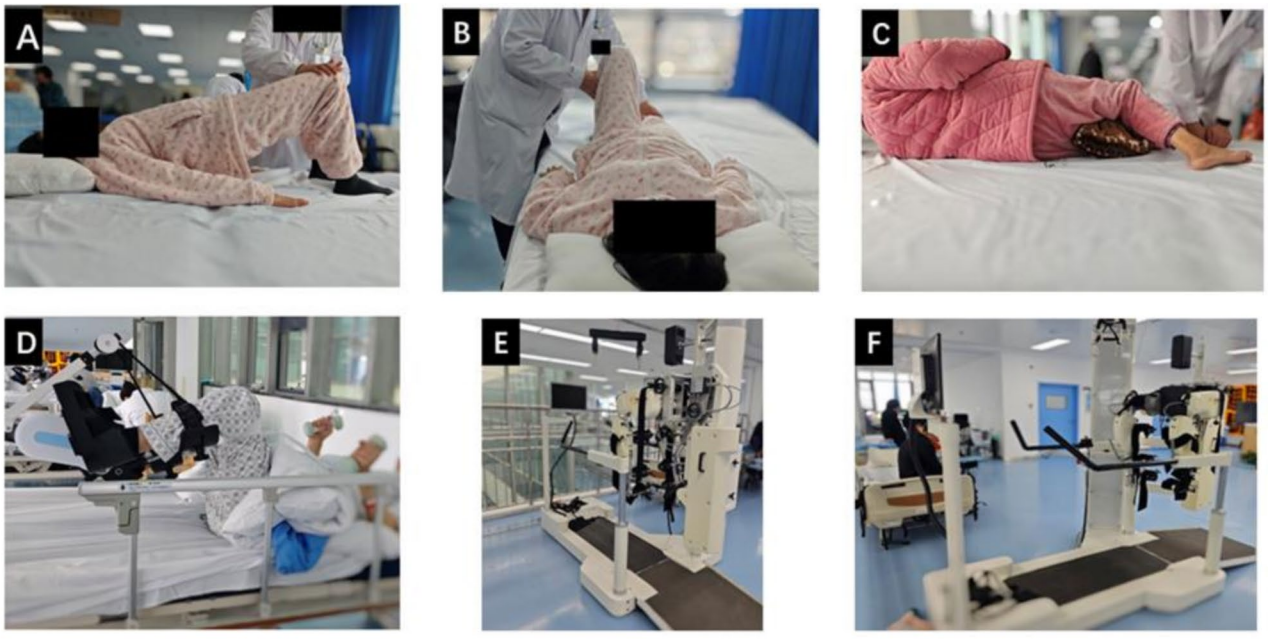

Fig. 1 Schematic representation of rehabilitation interventions rehabilitation with Conventional methods and Hocoma Lokomat

Table 2 Functional outcomes and pain scores over time

	MPS			VAS		
	3rd month	6th month	12th month	3rd month	6th month	12th month
Group A	76.94 ± 4.81	88.97 ± 4.29	91.53 ± 4.10	3.97 ± 1.33	2.79 ± 1.17	2.09 ± 1.10
Group B	78.00 ± 4.79	85.85 ± 5.91	88.17 ± 5.15	4.15 ± 1.47	3.49 ± 1.23	2.29 ± 1.12
t	0.939	2.508	2.958	0.542	2.493	0.775
p	0.974	0.015	0.004	0.590	0.015	0.440

MPS: Majeed Pelvic score; VAS: Visual Analogue Scale: Data are mean ± SD. MPS = Majeed Pelvic Score (0–100, higher = better function); VAS = Visual Analog Scale (pain intensity). Significant between-group differences at 6 and 12 months for MPS, and at 6 months for VAS ($p < 0.05$)

The Majeed Pelvic Score (MPS)—a 100-point scale—assessed five key domains of pelvic function: pain (30 points; 0 = severe pain, 30 = no pain), walking ability (30 points; 0 = unable to walk, 30 = normal gait), sitting tolerance (20 points; 0 = < 10 min, 20 = > 1 h), work capacity (10 points; 0 = unable to work, 10 = full capacity), and sexual function (10 points; 0 = severely impaired, 10 = normal). Conducted by a blinded physical therapist at baseline, 3-, 6-, and 12-months post-surgery, these assessments minimized observer bias and captured changes in daily activity, mobility, and quality of life. Pain intensity was quantified via the Visual Analog Scale (VAS), a self-reported 0–10 measure (10 = worst pain), recorded at rest and during weight-bearing activities to evaluate both baseline discomfort and pain triggered by functional tasks. For muscle strength, the L FORCE (Lower-Limb Force) evaluation utilized the Hocoma Lokomat®'s integrated force sensors to measure isometric strength of the hip and knee during static gait simulations (30° knee flexion, neutral hip position). Patients performed three 5-second maximal voluntary force trials per limb, with results averaged to ensure reliability. This method, validated in prior research, objectively quantified lower-extremity functional capacity, enabling precise tracking of strength gains over time and ensuring alignment with rehabilitation goals [18].Together, these measures provided a comprehensive profile of functional performance, pain control, and physiological improvement, facilitating robust evaluation of intervention efficacy.

Statistical analysis

Missing data were absent due to rigorous follow-up, with all 74 participants completing the 6-month assessment. Baseline demographics and injury characteristics were compared using Student's t-tests (continuous variables) and chi-squared tests (categorical variables), confirming group comparability (Table 1). Repeated-measures ANOVA with Bonferroni correction analyzed longitudinal changes in Majeed Pelvic Score (MPS) and Visual Analog Scale (VAS) pain scores, adjusting for age and Injury Severity Score (ISS) as covariates. Effect sizes (Cohen's d) quantified between-group differences, categorized as small (0.2), medium (0.5), or large (0.8). Analyses were performed in GraphPad Prism 9.0, with data reported as means ± standard deviation or counts. Statistical significance was defined as $p < 0.05$.

Results

Baseline characteristics and age confounder control

At baseline, Group A (mechanotherapy, $n = 34$) and Group B (conventional rehabilitation, $n = 40$) had mean ages of **47.36 ± 10.63 years** and **51.61 ± 12.50 years**, respectively. Independent *t*-tests confirmed no significant between-group age difference ($t = 1.117$, $p = 0.268$; Table 1), though age was included as a covariate in regression models for functional (Majeed Pelvic Score, MPS) and pain (Visual Analog Scale, VAS) outcomes to proactively address potential confounding from age-related variations in recovery trajectories, pain perception, or muscle regeneration.

While Group B had slightly more patients with head (2 vs. 0) or abdominal injuries (5 vs. 2), subgroup analyses revealed no significant interactions between injury type and outcomes ($p > 0.05$ for MPS, VAS, and L FORCE muscle strength). Rehabilitation protocols were adapted to accommodate concomitant injuries—for example, gentle, pain-modulated range-of-motion exercises for abdominal trauma patients—to ensure equivalent therapeutic intensity and safety across groups, minimizing bias from heterogeneous injury profiles.

Functional and strength outcomes with confidence intervals Majeed pelvic score

Both groups demonstrated significant improvements in MPS from baseline to 6 months (Table 2). Group A achieved a mean increase of 22.7 ± 8.2 points (95% confidence interval [CI]: 19.9–25.5), compared to 17.3 ± 7.1 points (95% CI: 14.9–19.7) in Group B, yielding a statistically significant between-group difference of 5.4 points (95% CI: 1.2–9.6, $p = 0.014$). The largest between-group disparities were observed in walking ability (Group A: +11.2 ± 4.1 vs. Group B: +8.3 ± 3.7, $p = 0.029$) and sitting tolerance (Group A: +8.5 ± 3.2 vs. Group B: +6.1 ± 2.8, $p = 0.035$), as illustrated in Table 1.

Pain visual analogue score (VAS)

Both groups reported reduced pain according to visual analogue score at 6 months, though no significant

between-group differences were detected in rest pain (Group A: −3.2 ± 1.5 vs. Group B: −2.8 ± 1.3, $p = 0.19$) or weight-bearing pain (Group A: −4.1 ± 1.8 vs. Group B: −3.7 ± 1.6, $p = 0.27$; Table 2).

Follow-Up timeline and data handling

Functional assessments were conducted at baseline, 3-, 6-, and 12-months post-surgery, consistent with the methodology described in the Methods section. All 74 patients (100%) completed follow-ups at all time points, with no missing data. Analyses were performed using a per-protocol approach, as no patients withdrew from the study or deviated from their assigned rehabilitation protocols. Outcome assessors remained blinded to group assignments throughout the study to minimize observer bias.

L FORCE muscle strength assessment

Group A exhibited superior gains in isometric hip and knee strength compared to Group B. Mean force production increased by 18.6 ± 6.3 Nm (95% CI: 16.1–21.1) in Group A versus 12.2 ± 5.1 Nm (95% CI: 10.0–14.4) in Group B, with a significant between-group difference of 6.4 Nm (95% CI: 3.1–9.7, $p = 0.002$). These strength improvements correlated positively with MPS changes ($r = 0.41$, $p < 0.001$), underscoring the relationship between muscle function and functional recovery.

In summary, the results of this study illustrate the significant advantages of utilizing mechanotherapy via the Hocoma Lokomat® for patients with unstable pelvic Tile C fractures. Participants in Group A not only reported higher functional outcomes and more effective pain control compared to those in Group B, but they also exhibited greater improvements in muscle strength. These findings suggest that integrating advanced rehabilitation technologies can greatly enhance recovery in patients with complex pelvic injuries, emphasizing the need for innovative approaches in postoperative care.

Discussion

The results of our study reinforce the importance of early integration of mechanotherapy with conventional rehabilitation methods for patients suffering from unstable pelvic Tile C fractures due to polytrauma. The observed reduction in pain at 6th month, increased MPS at 6th and 12th month, in the main group (Group A) align with findings from previous studies suggesting that early rehabilitation is pivotal for improving recovery outcomes after complex trauma. Several prior studies have shown that mechanotherapy, specifically using exoskeletal devices like the Hocoma Lokomat, significantly enhances the rehabilitation of patients with lower extremity injuries. For example, one study demonstrated that patients who engaged with robotic-assisted gait training exhibited marked improvements in walking ability and functional mobility, Hidler et al. [16]. This is consistent with our finding of a 14.1% increase in excellent and good outcomes as measured by the Majeed score in Group A, compared to Group B, which only received conventional rehabilitation. This study results echo the conclusions drawn by Wang Y et al. (2015), who reported that robotic-assisted therapy not only improved functional mobility but also encouraged greater engagement in therapeutic exercises [19].Furthermore, the timing of rehabilitation post-surgery is critical. Prior research has indicated that beginning rehabilitation within 2–3 days post-surgery can significantly impact recovery trajectories [20].Additionally, the fact that bowel function was normalized more rapidly in the main group (after 2–3 sessions of mechanotherapy) is noteworthy. Previous studies have indicated that mobilization and mechanotherapy can improve gastrointestinal function in a critical care setting [21]. This outcome highlights the multifaceted benefits of early mechanotherapy, extending beyond just orthopedic rehabilitation to overall patient well-being. While the findings suggest that mechanotherapy enhances functional recovery and muscle strength compared to conventional rehabilitation, Notable strengths include the study's rigorous methodology, featuring validated outcome measures (MPS, VAS, L FORCE), standardized rehabilitation protocols, and 100% follow-up completion, which ensure robust and reliable data collection. The use of objective muscle strength assessment via L FORCE—aligned with prior validation research—adds methodological rigor, particularly in quantifying the physiological mechanisms underlying functional gains. The findings contribute novel insights into robotic-assisted therapy for severe pelvic trauma, informing future investigations into dose-response relationships, long-term outcomes beyond 12 months, and cost-effectiveness analyses to guide clinical implementation. Overall, the study balances subjective and objective evaluations, providing a strong foundation for advancing rehabilitation strategies in polytrauma patients.

Limitations

The study has several important limitations that warrant consideration. First, the lack of blinding for patients and therapists may have introduced **performance bias**, particularly affecting self-reported outcomes like pain (VAS) and functional capacity (MPS), as awareness of group assignments could influence patient effort or therapist engagement. However, this risk was partially mitigated by using **blinded outcome assessors** for MPS and objective strength measurements (L FORCE), which are less susceptible to subjective bias. Second, while operators received standardized training on the Hocoma Lokomat®, individual differences in clinician familiarity

with the device—such as adjustments to gait parameters or troubleshooting during sessions—were not formally quantified. Future research could incorporate operator competency assessments to better isolate the device's direct effects from learning curve influences.

Third, although baseline age was statistically comparable ($p = 0.268$), residual age-related variations in musculoskeletal healing capacity or pain perception may have subtly affected results, despite statistical adjustments via covariates. Larger, multicenter studies with more diverse age distributions and broader inclusion of comorbidities would help validate these findings. Fourth, the single-center design and focus on severe unstable pelvic Tile C fractures limit generalizability to milder injuries, other fracture types (e.g., Tile A/B), or populations with complex comorbidities. Minor baseline imbalances in concomitant injuries (e.g., head/abdominal trauma) were addressed through protocol customization, though residual confounding from trauma heterogeneity cannot be entirely ruled out.

Additionally, the moderate sample size (74 participants), while adequate for detecting significant effects, could benefit from larger cohorts to further balance age distributions and minimize the influence of individual variability. Reliance on self-reported measures (MPS, VAS) introduces subjectivity, which could be enhanced by integrating objective biomechanical assessments (e.g., gait analysis, pelvic motion tracking) to provide a more comprehensive evaluation of functional recovery. Finally, external factors such as patient adherence to rehabilitation protocols, psychosocial stressors, or postoperative complications were not systematically controlled, potentially affecting individual outcomes.

Conclusion

In conclusion, integrating mechanotherapy with the Hocoma Lokomat into the rehabilitation of unstable pelvic Tile C fractures improves functional outcomes, reduces pain, and enhances muscle strength compared to conventional methods. The study highlights the benefits of robotic-assisted technologies in optimizing recovery for polytrauma patients. Future research should focus on larger multicenter trials and long-term follow-ups to further validate these findings and standardize such innovative rehabilitation approaches.

Future perspectives Future research should aim to address the limitations highlighted in this study while expanding upon its findings. Considerations for future studies include.

Larger, Multicenter Trials: Conducting studies across multiple centers could improve the robustness of the findings and allow for a more diverse patient population. It could also help determine if outcomes are consistent across different healthcare settings.

Longitudinal Studies: Implementing longer follow-up periods (beyond 6 months) would provide insights into the sustainability of recovery outcomes over time, helping to determine the long-term benefits of mechanotherapy.

Control for Covariates: Future studies should seek control for external factors that could affect rehabilitation outcomes, including patients' baseline physical activity levels, psychological factors, and adherence to rehabilitation protocols.

Incorporating Objective Measures: Utilizing objective assessments in addition to subjective outcomes can strengthen data interpretation. Instruments like 3D motion analysis or integrated biomechanical assessments could be implemented to assess actual gait improvements and muscle function comprehensively.

Training and Protocol Standardization: As the effectiveness of mechanotherapy may be influenced by clinician experience, establishing training protocols for the use of robotic systems like the Hocoma Lokomat could help standardize the delivery of care and enhance the reproducibility of results. By addressing these areas in future studies, researchers can further clarify the role of mechanotherapy in rehabilitation for pelvic injuries and potentially influence clinical guidelines and practices in physiotherapy.

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Not relevant to this study.

Author contributions
K.A.A collected the data and wrote the title, abstract, introduction, and discussion. L.X conducted the statistical analysis and wrote results. W.Z reviewed the study. C.X and H.H served as the corresponding authors.

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Data availability
No datasets were generated or analysed during the current study.

Declarations

Ethics approval and consent to participate
The ethics committees of Tongji Hospital Wuhan approved the study registration number (TJ-IRB20230440). Informed consent was obtained from all the patients. The authors declare that the methods carried out in this study were in accordance with the relevant guidelines and regulations.

Consent for publication
Not relevant to this study.

Competing interests
The authors declare no competing interests.

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