



## OPEN Effect of early weight bearing on rehabilitation in ankle fractures with syndesmotic injuries

Kai Tang<sup>1,2</sup>, Ling Huang<sup>1,2</sup>, Xuping Lin<sup>1,2</sup>, Ying Cao<sup>1</sup>, Danhong Liang<sup>1</sup>, Dongchen Chen<sup>1</sup> & Jiejie Lin<sup>1</sup>✉

To explore the effect of different weight-bearing timings on the rehabilitation of ankle fractures with syndesmotic injuries. Based on different postoperative rehabilitation protocols, the patients were divided into early weight-bearing groups (EWB groups) and late weight-bearing groups (LWB groups). The Olerud-Molander Ankle Score (OMAS), Visual Analog Scale (VAS) pain score, range of motion (ROM), time to return to work, time to return to sports, wound complications, and fracture fixation complications were recorded and compared between the groups. A total of 81 patients completed the follow-up, with an overall follow-up period of 12 months. At 6 weeks post-surgery, the EWB group had significantly higher OMAS scores than the LWB group ( $P < 0.01$ ). The EWB group also had lower VAS pain scores at 6 weeks compared to the LWB group ( $P < 0.01$ ). At 6 and 12 weeks, the EWB group exhibited significantly higher ROM than the LWB group (both  $P < 0.01$ ). The EWB group returned to work and sports significantly earlier than the LWB group ( $P = 0.01, 0.04$ ). This study shows that early weight bearing initiated 2 weeks post-surgery is safe and feasible in patients sustaining ankle fractures with syndesmotic injuries.

**Keywords** Ankle fracture, Syndesmotic injuries, Postoperative rehabilitation, Early Weight-Bearing, Functional recovery

The ankle joint is the primary weight-bearing connection between the body and the ground. It plays a critical role in transmitting load and maintaining balance during walking, running, and jumping. This anatomical feature makes the ankle one of the most vulnerable parts of the musculoskeletal system. The syndesmotic constitutes a sophisticated osteoligamentous complex comprising the distal tibia, distal fibula, and four interconnected ligamentous structures<sup>1</sup>. This functional ensemble ensures anatomical congruity of the distal tibiofibular articulation, thereby playing a pivotal role in maintaining ankle joint integrity. Particularly under weight-bearing conditions, the syndesmotic indicates essential biomechanical competence in dissipating shear forces and rotational stresses across the ankle mortise<sup>2</sup>. Clinical evidence has firmly established that syndesmotic injuries lead to significant mechanical destabilization of the ankle complex. Current orthopedic literature underscores that inadequate management of these injuries can result in progressive joint degeneration, clinically presenting as chronic pain syndromes and post-traumatic osteoarthritis. Therefore, early anatomical restoration and stabilization are crucial to preventing long-term sequelae in affected patients<sup>3</sup>.

Contemporary epidemiological studies reveal significant pathological involvement of the syndesmotic in ankle trauma, with injury prevalence demonstrating notable variation across clinical populations. Analysis of multicenter trauma registries indicates that 5–10% of general ankle injury cases present with concomitant syndesmotic damage. This incidence escalates to 11–20% among surgically managed ankle fractures, particularly in rotational injury patterns involving Weber type C fractures or Lauge-Hansen supination-external rotation injuries<sup>4,5</sup>. The current gold-standard surgical protocol for managing combined fractures and syndesmotic injuries involves anatomical reduction and internal fixation (ARIF) of fractures, in conjunction with trans-syndesmotic screw fixation. However, postoperative weight-bearing protocols remain a topic of debate in orthopedic practice. Current orthopedic guidelines recommend staged rehabilitation protocols based on intraoperative stability assessments, with biomechanical studies demonstrating a 40–60% reduction in syndesmotic displacement through screw stabilization<sup>6</sup>.

Conventional rehabilitation protocols typically advocate 6-week below-knee cast immobilization followed by phased weight-bearing progression, predicated on biomechanical models suggesting premature loading cycles may induce deleterious stress concentrations (0.8–1.2 MPa) at the bone-implant interface<sup>6,7</sup>. However, prolonged

<sup>1</sup>Department of Spine Surgery, Longyan First Affiliated Hospital of Fujian Medical University, Longyan 364000, China.

<sup>2</sup>These authors jointly supervised this work: Kai Tang, Ling Huang and Xuping Lin. ✉email: 17757040318@163.com

immobilization often causes complications like joint stiffness, limited motion, and muscle atrophy<sup>8–10</sup>. These complications delay patients' return to work and daily life, creating a significant socioeconomic burden<sup>11</sup>. Recent evidence from evidence-based medicine has demonstrated the safety of early rehabilitation following ankle fractures, such as weight-bearing within two weeks post-surgery. A systematic review of randomized controlled trials revealed no statistically significant differences between the early weight-bearing group and the control group in terms of rates of fixation failure, delayed healing, and infection<sup>12</sup>. Recent biomechanical studies have further confirmed that early weight-bearing does not lead to implant failure or loss of reduction<sup>13</sup>. Meta-analyses indicate that initiating partial weight-bearing at 2 weeks postoperatively for ankle fractures does not increase complication rates when fixation stability is adequate<sup>14–16</sup>. Recent studies<sup>17</sup> further suggest that early weight-bearing at 2 weeks is feasible for ankle fractures combined with syndesmotic injuries under specific conditions, provided fixation strength and syndesmotic stability are ensured. Biomechanical evidence<sup>13,18</sup> supports the safety of this protocol, demonstrating positive effects on joint stability and functional recovery. These additions provide a mechanistic and clinical context for our protocol, affirming that 2-week weight-bearing initiation is biomechanically sound and clinically justified for patients with stable fixation.

Nonetheless, research on early weight-bearing after surgery in patients with ankle fractures complicated by syndesmotic injuries remains limited, and no consensus has been reached in clinical practice. This study aims to explore the potential benefits and outcomes of early weight-bearing in such patients by retrospectively analyzing the effects of different weight-bearing timelines on postoperative functional recovery. The anticipated results are expected to provide evidence supporting the clinical value of early weight-bearing protocols in accelerating functional recovery and shortening rehabilitation periods.

## Methods

### Inclusion criteria

Closed ankle fractures complicated by syndesmotic injuries require surgical treatment.

Age between 18 and 60 years;

Time from injury to surgery  $\leq 14$  days;

Imaging (ankle X-rays and CT) and intraoperative findings meeting the diagnostic criteria for syndesmotic separation, with a positive Hook test (intraoperative confirmation of damage to the anterior or posterior inferior tibiofibular ligament).

### Exclusion criteria

Open fractures or concomitant significant neurovascular injuries;

Previous history of ankle fractures or ligament injuries;

Severe osteoporosis (bone mineral density T-score  $\leq -2.5$ ).

This study included 84 patients who met the aforementioned criteria and were treated between December 2021 and December 2023. In- and exclusion criteria are shown in Fig. 1. Among them, 46 were male (54.8%) and 38 were female (45.2%). The age range was 19–60 years (mean age  $41.5 \pm 12.2$  years). According to the Danis-Weber classification, there were 36 patients with Type B fractures (42.9%) and 48 patients with Type C fractures (57.1%). All patients underwent ankle fracture internal fixation combined with inferior tibiofibular screw fixation. The study protocol was approved by the Institutional Review Board, and all patients provided written informed consent before surgery. The study adhered to the ethical guidelines outlined in the Declaration of Helsinki.

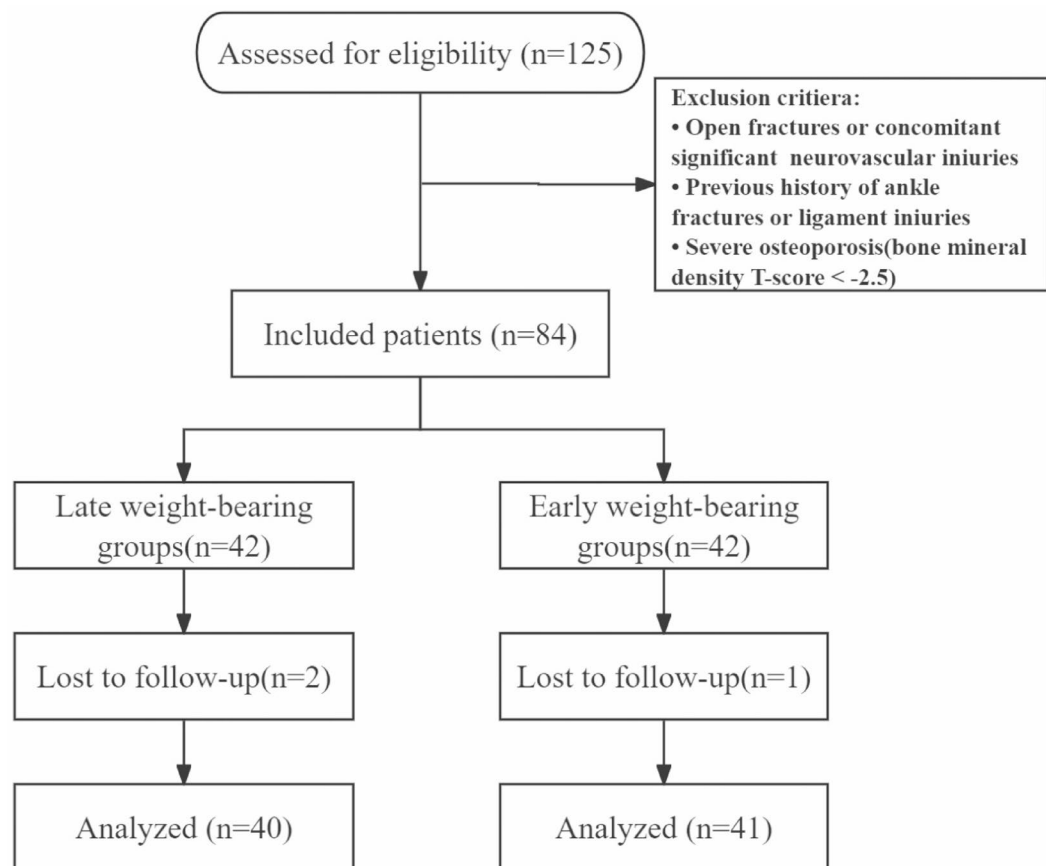
### Limitations of data collection

Due to the retrospective design of this study, data on several potential confounding variables—including preoperative functional status, occupational physical demands, and baseline activity level—were not routinely collected in the patient records and were therefore unavailable for analysis. The baseline characteristics that were compared between groups are limited to those presented in Table 1.

### Surgical plan

Before surgery, all patients received the same preoperative care, including admission and supervision by the attending surgeon, as well as management following standard care protocols. All patients with ankle fractures combined with syndesmotic injuries underwent surgery under continuous epidural anesthesia. Preoperative evaluation of the ankle soft tissue condition was performed; if severe blisters or swelling were present, temporary plaster external fixation or traction therapy was applied until the local soft tissue condition improved, after which surgery was performed. Depending on the type of fracture, fixation was performed using plates and screws; after reduction of the syndesmotic injuries, inferior tibiofibular screw fixation was used. After surgery, the surgical team applied a plaster cast to keep the ankle in a functional position. The same senior orthopedic surgeon, who had over 10 years of experience in trauma surgery, performed all operations using standard techniques.

Standardized steps included: (a) Anatomical reduction under fluoroscopy; (b) Lateral malleolar fixation: 1/3 tubular plates with  $\geq 6$  cortices; (c) Medial malleolar fixation: two 4.0-mm cannulated screws; (d) Syndesmotic fixation: 3.5-mm quadricortical screw (DePuy Synthes\*) at 2 cm proximal to plafond after positive hook test; (e) Intraoperative stress testing via external rotation and dorsiflexion to confirm stability. Intraoperative stability was quantitatively verified using intraoperative CT (O-arm\*) in all cases, requiring  $< 1$  mm syndesmotic displacement on axial views.



**Fig. 1.** Enrolment flow diagram.

	LWB Group (n=42)	EWB Group (n=42)	t/ $\chi^2$	P value
Sex (Female/male, %)	22(52.4%)/20(47.6%)	24(57.1%)/18(42.9%)	0.19	0.66
Age ( $\bar{x}\pm s$ , years)	44.14 $\pm$ 12.26	47.95 $\pm$ 11.91	1.43	0.16
BMI ( $\bar{x}\pm s$ , kg/m <sup>2</sup> )	23.38 $\pm$ 3.03	22.69 $\pm$ 2.66	1.11	0.27
Time from injury to surgery ( $\bar{x}\pm s$ , Days)	4.14 $\pm$ 1.79	4.02 $\pm$ 1.55	0.33	0.75
Smoking (Yes/No, %)	12(28.6%)/30(71.4%)	10(23.8%)/32(76.2%)	0.25	0.62
Diabetes (Yes/No, %)	5(11.9%)/37(88.1%)	6(14.3%)/36(85.7%)	0.11	0.75
Occupation (Clerk/Worker/Farmer/Unemployed, %)	11(26.2%)/11(26.2%)/13(30.1%)/7(16.7%)	9(21.4%)/13(30.1%)/12(28.6%)/8(19.0%)	0.47	0.93
Denis-Weber classification (B/C, %)	29(69.0%)/13(31.0%)	30(71.4%)/12(28.6%)	0.06	0.81

**Table 1.** Comparison of baseline Characteristics. Data presented as mean  $\pm$  standard deviation or percentages.  $P < 0.05$  was considered statistically significant.

## Groupings and rehabilitation plan

The 84 patients included in the study were divided into two groups based on postoperative rehabilitation protocols: the late weight-bearing groups (LWB groups) and the early weight-bearing groups (EWB groups). A total of 42 patients were included in each group.

### LWB groups

Postoperative Weeks 0–6: A short leg cast was used to fix the ankle joint in a functional position, with strict non-weight-bearing precautions. Active movements of the metatarsophalangeal joint were performed daily (at least 5 sets/day, 10 repetitions/set) to prevent thrombosis.

Postoperative Weeks 6–12: After the cast was removed, patients gradually transitioned from partial weight-bearing (20% body weight) to full weight-bearing with the assistance of crutches. At the same time, isometric exercises for ankle dorsiflexion and plantarflexion were conducted (3 times/day, 15 min/session).

Internal Fixation: The inferior tibiofibular screw was removed at 12 weeks postoperatively. The ankle joint internal fixation device would be removed at 1 year based on fracture healing status.

## EWB groups

Postoperative Weeks 0–2: A short leg cast was used, with the same non-weight-bearing precautions as the LWB group.

Postoperative Weeks 2–12: After cast removal, patients immediately began progressive weight-bearing within their pain tolerance, starting with 10% of their body weight and increasing by 10%–15% weekly, using walking aids. Concurrently, active ankle flexion and extension exercises were performed (4 times/day, 20 min/session).

<sup>19</sup> The internal fixation treatment is consistent with the LWB group protocol.

The preoperative baseline data of patients were collected, including gender, age, body mass index (BMI), smoking status, occupation (employee, farmer, worker, or unemployed), time from injury to surgery, ankle fracture Denis-Weber classification, diabetes, and other preoperative basic information. Follow-up assessments were conducted at 6 weeks, 12 weeks, 6 months, and 12 months after surgery<sup>3</sup>.

## Rationale for load increments

The load increments in both protocols were designed to gradually stress the healing tissue while minimizing the risk of re-injury.

In the LWB protocol, weight-bearing was introduced at 20% of body weight at week 6, allowing the healing tissue to withstand controlled stress while avoiding early overloading. This initial loading is conservative, taking into account the potential for slower recovery in patients with more severe injuries. The EWB protocol allows for gradual progression of load by 10–15% weekly starting at week 2, reflecting the fact that early mobilization with cautious load progression may help stimulate bone healing, promote early functional recovery, and reduce muscle atrophy. The weekly increments in loading are based on clinical observations of patient tolerance and the evidence supporting gradual loading for enhancing bone regeneration without compromising healing<sup>3,19</sup>.

## Shoe type

Both protocols use a customized orthotic shoe to ensure controlled weight-bearing and provide adequate support to the injured area during the rehabilitation process. All patients used identical boots with: 15° dorsiflexion stop (prevents syndesmotom stress), Pneumatic compression system (controls edema), and Rocker-bottom sole (facilitates gait transition). The shoe design helps in redistributing body weight evenly across the foot, reducing strain on the injured region, and providing a stable base for progression in weight-bearing.

## Physiotherapy regimen

The physiotherapy regimen in both protocols was designed to promote joint mobility, muscle strengthening, and proprioception. In the LWB protocol, therapy focuses on early passive range of motion (ROM) exercises and isometric strengthening to avoid overloading the healing bone. As weight-bearing progresses, the therapy advances to more dynamic exercises, including active ROM and functional strengthening. In the EWB protocol, physiotherapy starts with gentle active exercises early on to encourage circulation and muscle activation, followed by progressive strengthening and functional rehabilitation as the load is increased. The overall goal of physiotherapy is to optimize functional recovery while ensuring safety and appropriate tissue healing<sup>20</sup>.

## Syndesmotom screws in both groups

Regarding the syndesmotom screws, we can confirm that the screws were retained in both groups until 12 weeks to provide adequate mechanical stability to the healing fracture site. After this period, the screws were removed based on clinical and radiographic assessments, indicating sufficient bone union and healing. This was consistent for both the LWB and EWB protocols, as early screw removal could risk destabilizing the fracture site before union was adequately achieved<sup>21,22</sup>.

## The primary outcome measure

The primary outcome measure was the functional recovery assessed using the Olerud-Molander Ankle Score (OMAS). This scale evaluates function through dimensions such as pain (45 points), joint stability (10 points), and ability to perform daily activities (45 points), with a total score ranging from 0 to 100 points (higher scores indicate better function)<sup>12,23</sup>. The anchor-based minimum clinically important difference (MCID) for the OMAS is 4.4 points at 6 to 12 weeks, 15.0 points at 3 to 6 months, and 9.5 points at 6 to 12 months<sup>24</sup>.

## The secondary outcome measures

Pain intensity (Visual Analog Scale, VAS, 0–10 points).

Ankle dorsiflexion-plantarflexion ROM: ROM was measured using a weight-bearing goniometer to assess joint motion in the sagittal plane. This method was chosen to ensure consistent and standardized measurements across all subjects. For the measurement process, the subject's foot was placed in a fixed position, and the goniometer was aligned to assess flexion and extension angles. To ensure consistency and accuracy, we assessed inter-rater reliability using intraclass correlation coefficients (ICC). The ICC value between two assessors was found to be 0.95, indicating excellent reliability between the raters.

## Time to return to social activities (return to work, sports)

Return-to-Sport Criteria:

Athletes were considered ready to return to sport when they met the following criteria:  
Achieving at least 90% of pre-injury ROM in the affected joint.

Strength recovery to at least 90% of the unaffected side, as measured by a standardized strength assessment protocol. No pain during sport-specific movements or exercises (rated  $\leq 2$  on the Visual Analog Scale for pain). No signs of instability during functional testing, including jumping and cutting movements.

Return-to-Work Criteria:

Individuals were considered fit to return to work when they showed:

Sufficient functional capacity to perform their job duties without discomfort or pain, as evaluated by a work simulation or functional assessment. A minimum of 80% recovery in strength and range of motion compared to pre-injury levels, ensuring that the individual could perform essential work tasks without risk of further injury. No significant limitations in daily activities or mobility, as assessed through a standardized questionnaire or interview.

Complications (wound dehiscence, infection, delayed healing; internal fixation failure, loss of reduction, reoperation). Among these, loss of reduction was defined as a displacement of the fracture ends  $\geq 2$  mm<sup>19</sup>.

Radiographic Criteria for Union:

Radiographic union was defined as the presence of continuous cortical bone bridging across the fracture site in two orthogonal planes. Radiographic images were independently assessed by two blinded radiologists, and discrepancies between their assessments were resolved by a third senior radiologist.

## Statistical analysis

Statistical analysis was performed using SPSS 26.0 software. The Kolmogorov-Smirnov test was used to assess the normality of the data. For normally distributed continuous variables, the data were expressed as mean  $\pm$  standard deviation ( $\bar{x} \pm s$ ), and inter-group comparisons were conducted using the independent samples t-test. Categorical data were expressed as percentages, and inter-group comparisons were performed using the  $\chi^2$  test. All tests were two-sided, and a p-value of  $< 0.05$  was considered statistically significant. Data were analyzed using repeated-measures ANOVA (RM-ANOVA) with two factors: Group (between-subject factor) and Time (within-subject factor with four levels). When the assumption of sphericity was violated (Mauchly's test  $p < 0.05$ ), Greenhouse-Geisser correction was applied. Implemented Bonferroni adjustment for significant Group  $\times$  Time interactions (adjusted  $\alpha = 0.0125$  for 4 comparisons).

## Results

The study population consisted of two well-balanced cohorts: The LWB group included 42 patients (24 males, 57.1%) aged 19–60 years (mean  $44.14 \pm 12.26$ ), while the EWB group comprised 42 patients (22 males, 52.4%) aged 21–59 years (mean  $47.95 \pm 11.91$ ). Comparative analysis revealed no statistically significant intergroup differences ( $P > 0.05$ ) in key clinical baseline characteristics, including gender distribution, age, BMI, time from injury to surgical intervention, smoking history, diabetes status, occupational category, and fracture classification according to the Denis-Weber system. Detailed demographic and clinical characteristics are presented in Table 1.

## Clinical outcomes

All 84 enrolled patients completed the 12-month follow-up period. Three cases (2 in the LWB group and 1 in the EWB group) were lost to follow-up after 3 months due to postoperative reassessment at external medical institutions. Surgical site infections occurred in 1 case (2.4%) from each group, with no additional complications observed. At the final follow-up, radiographic evaluation confirmed complete osseous union in all patients, with no evidence of implant loosening, displacement, or hardware failure.

## OMAS comparison

The EWB group ( $58.29 \pm 4.38$ ), was significantly higher OMAS compared to the LWB group ( $52.62 \pm 3.98$ ), at 6 weeks postoperatively ( $P < 0.01$ , [95% CI 3.88 to 7.46]). No statistically significant intergroup differences were observed at subsequent follow-up intervals (12 weeks, 6 months, and 12 months;  $P > 0.05$ ). Temporal trends in functional recovery are systematically presented in Table 2 and visually summarized in Fig. 2.

## Comparison of VAS between the two groups

At 6 weeks postoperatively, the EWB group ( $1.66 \pm 0.70$ ) had significantly lower VAS scores than the LWB group ( $2.21 \pm 0.98$ ) ( $P < 0.01$ , [95% CI  $-0.78$  to  $-0.32$ ]). However, at 12 weeks, 6 months, and 12 months postoperatively, there were no statistically significant differences in VAS scores between the two groups (all  $P > 0.05$ ). See Table 3 and Fig. 3 for details.

Time Point	EWB Group (n = 41)	LWB Group (n = 41)	Mean Difference	P value	95% CI	Significance
6 weeks <sup>a</sup>	58.29 $\pm$ 4.38	52.62 $\pm$ 3.98	+ 5.67	< 0.01	[3.88, 7.46]	Yes
12 weeks <sup>a</sup>	66.87 $\pm$ 5.15	66.25 $\pm$ 5.04	+ 0.62	1.00	[-1.25, 2.49]	No
6 months <sup>a</sup>	75.13 $\pm$ 3.99	73.87 $\pm$ 4.35	+ 1.26	0.98	[-0.85, 3.37]	No
12 months <sup>a</sup>	85.12 $\pm$ 3.86	83.50 $\pm$ 3.32	+ 1.62	0.44	[-0.34, 3.58]	No

**Table 2.** Comparison of OMAS between groups (Points). Data presented as mean  $\pm$  standard deviation.  $P < 0.0125$  was considered statistically significant.

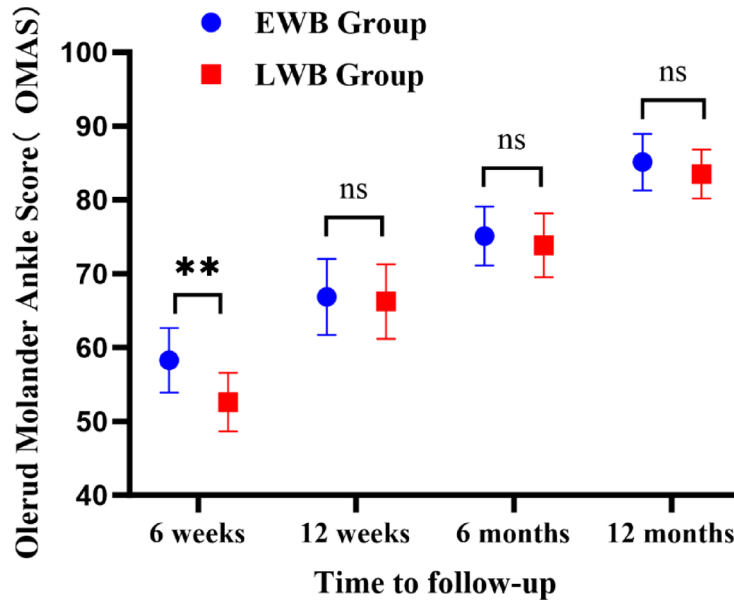


Fig. 2. Comparative Analysis of Olerud-Molander Ankle Scores (OMAS) Between EWB group and LWB groups.

Time Point	EWB Group (n = 41)	LWB Group (n = 41)	Mean Difference	P value	95% CI	Significance
6 weeks	1.66 ± 0.70	2.21 ± 0.98	-0.55	< 0.01	[-0.78, -0.32]	Yes
12 weeks	1.09 ± 0.58	1.37 ± 0.64	-0.28	0.05	[-0.49, -0.07]	No
6 months	0.71 ± 0.67	0.87 ± 0.68	-0.16	0.31	[-0.33, 0.01]	No

Table 3. Comparison of VAS between groups (Points). Data presented as mean ± standard deviation.  $P < 0.0125$  was considered statistically significant.

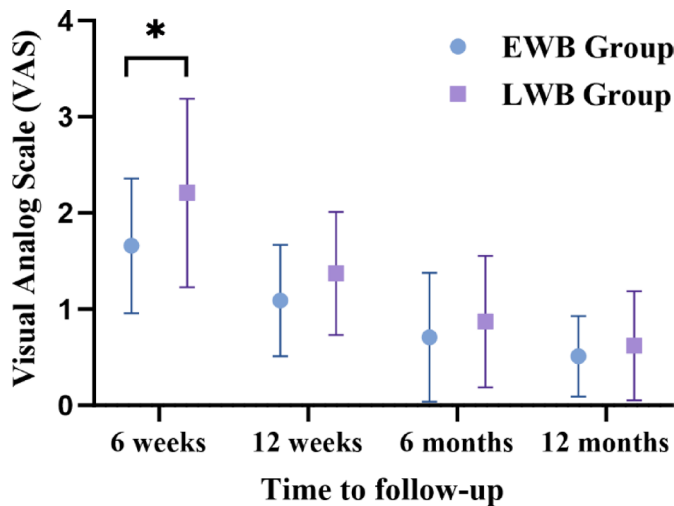


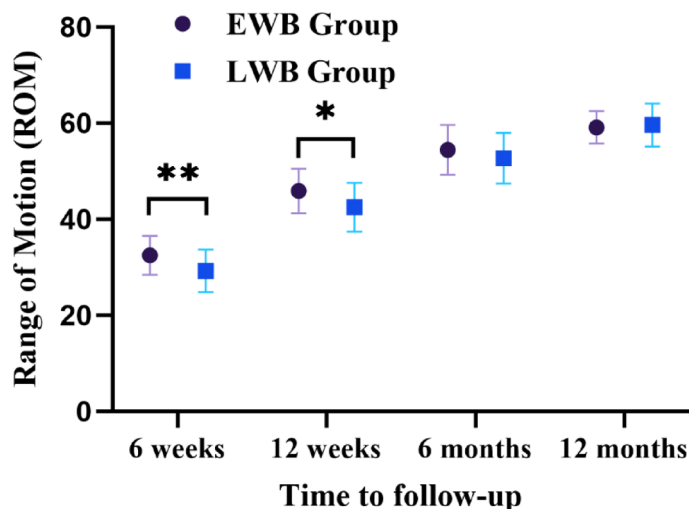
Fig. 3. Temporal Changes in Visual Analogue Scale (VAS) Pain Scores.

#### Comparison of ROM between the two groups

At 6 and 12 weeks postoperatively, the EWB group ( $32.49 \pm 4.06$ ,  $45.87 \pm 4.63$ ) had significantly higher ROM than the LWB group ( $29.25 \pm 4.42$ ,  $42.50 \pm 5.04$ ) (both  $P < 0.01$ , [95% CI 1.57 to 4.91, 1.38 to 5.36]). However, at 6 months and 12 months postoperatively, there were no statistically significant differences in ROM between the two groups ( $P > 0.05$ ). See Table 4; Fig. 4 for details.

Time Point	EWB Group (n = 41)	LWB Group (n = 41)	Mean Difference	P value	95% CI	Significance
6 weeks	32.49 ± 4.06	29.25 ± 4.42	+ 3.24	< 0.01	[1.57, 4.91]	Yes
12 weeks	45.87 ± 4.63	42.50 ± 5.04	+ 3.37	< 0.01	[1.38, 5.36]	Yes
6 months	54.42 ± 5.20	52.67 ± 5.27	+ 1.75	0.23	[-0.35, 3.85]	No
12 months	59.12 ± 3.35	59.65 ± 4.48	-0.53	1.00	[-2.10, 1.04]	No

**Table 4.** Comparison of ROM between groups (Degrees). Data presented as mean ± standard deviation.  $P < 0.0125$  was considered statistically significant.



**Fig. 4.** Comparative Analysis of Range of Motion (ROM) Between EWB group and LWB group.

Outcome	EWB Group (n = 41)	LWB Group (n = 41)	Mean Difference	P value	95% CI
Return to Work Time	4.87 ± 1.04	6.04 ± 1.12	-1.17	0.01	[-1.64, -0.70]
Return to Sports Time	9.54 ± 1.79	10.75 ± 2.17	-1.21	0.04	[-2.07, -0.35]

**Table 5.** Return-to-Function outcomes (Weeks). Data presented as mean ± standard deviation.  $P < 0.05$  was considered statistically significant.

#### Comparison of return to work and return to sports time between the two groups

The EWB group ( $4.87 \pm 1.04$ ,  $9.54 \pm 1.79$ ) had significantly shorter return to work and return to sports times compared to the LWB group ( $6.04 \pm 1.12$ ,  $10.75 \pm 2.17$ ) ( $P = 0.01$ ,  $0.04$ , [95% CI -1.64 to -0.70, -2.07 to -0.35]). However, there were no statistically significant differences in wound complications and fracture fixation complications between the two groups (both  $P > 0.05$ ). See Table 5 for details.

## Discussion

In recent years, early weight-bearing activity after ankle joint surgery has gained increasing attention, particularly in cases with concomitant syndesmotic injuries. While early mobilization benefits in isolated ankle fractures are established<sup>25</sup>, its application in syndesmosis-disrupted biomechanical environments remains contentious<sup>26</sup>. Recent studies suggest that early postoperative weight-bearing is relatively safe and does not significantly increase the risk of joint damage compared to later weight-bearing<sup>15</sup>. The same results were observed in this study, where patients in the EWB group began weight-bearing activities just 2 weeks post-surgery. Follow-up results showed that all patients achieved bone healing, with no instances of fixation loosening or displacement, and ankle joint function experienced rapid recovery. Notably, this is the first evidence demonstrating that early weight-bearing protocols—previously contraindicated in syndesmotic injuries—are feasible when combined with intraoperative stability verification.

This study corroborates the viability of partial weight-bearing initiation at 2 weeks postoperatively for ankle fractures with concomitant syndesmotic injuries. Crucially, we observed zero instances of reduction loss despite the inherent rotational vulnerability of syndesmotic complexes—an outcome attributable to the deployment of quadricortical syndesmotic screws that withstand early partial loading ( $\leq 20\%$  body weight). These findings confirm that early mobilization neither disrupts fracture healing nor compromises bone-implant integrity when

implemented under monitored conditions. An increasing number of studies on postoperative rehabilitation of ankle fractures suggest that, considering the convenience for patients, early functional improvement, and no increased risk of complications, early weight-bearing is widely recommended for ankle fracture patients who undergo surgical treatment<sup>19,26</sup>. Chen et al.'s study pointed out that early rehabilitation using a combination of standing beds and early anti-gravity treadmill training can reduce pain and improve ankle joint function. This method helps facilitate early mobilization and weight-bearing, which plays a key role in promoting recovery and improving the overall functional outcome of patients following ankle fractures<sup>27</sup>. In addition, Tan et al.'s study showed that early weight-bearing after ankle fracture surgery is biomechanically feasible and does not lead to fracture displacement or failure of internal fixation(26802427). This finding further supports the idea that early weight-bearing can be safely implemented in ankle fracture rehabilitation without compromising the healing process or the stability of the surgical fixation. We have reviewed recent studies, including the WAX non-inferiority trial published in *Lancet* in 2024<sup>17</sup>, which provides important context for the interpretation of our findings. The WAX trial indicated that while early interventions provide advantages in terms of functional recovery and pain reduction, these benefits may not persist in the long term. Our study supports this observation, where early advantages in recovery, such as improved mobility and strength, appear to dissipate by three months. We have now included a detailed discussion of the WAX trial to highlight how our findings align with or diverge from these results, particularly regarding the timing of recovery and the rate of healing.

The OMAS scale provides a comprehensive assessment of the functional recovery of patients after ankle fractures by evaluating multiple dimensions such as pain, joint stability, and walking ability. This allows for a more accurate understanding of the functional status of the ankle joint. A higher OMAS score typically indicates better functional recovery of the ankle joint, suggesting improved pain management, stability, and mobility, which are crucial for the patient's overall rehabilitation and quality of life<sup>19</sup>. Juul's study pointed out that compared to the current standard treatment (delayed weight-bearing), patients who engaged in early weight-bearing showed better outcomes on the OMAS<sup>17</sup>. Moreover, the early weight-bearing rehabilitation model was found to be as effective as other treatment strategies in clinical practice, and it might even offer better cost-effectiveness<sup>17,28</sup>. This suggests that early weight-bearing could be a viable alternative that not only improves functional recovery but also reduces healthcare costs in the long run<sup>29</sup>. The OMAS score results in this study showed that the EWB group had significantly higher scores than the LWB group, indicating that early weight-bearing has a positive effect on ankle joint function recovery. Critically, this difference exceeds the established Minimal Clinically Important Difference (MCID) of 4.4 points for the OMAS scale in ankle fracture populations<sup>24</sup>, confirming not only statistical significance but also clinical relevance. This indicates that early weight-bearing provides tangible functional benefits perceptible to patients during the critical initial recovery phase.

The author suggests that early mobilization allows patients to adapt to normal gait training sooner, thereby promoting the recovery of walking ability, ankle joint stability, and support capacity. Of course, during the rehabilitation process, it is essential to gradually increase weight-bearing according to the patient's safety and individual circumstances to ensure the effectiveness of the rehabilitation program. This approach ensures that patients can recover effectively while minimizing the risk of complications. At the same time, it is important to avoid excessive weight-bearing to prevent the loosening of the distal tibiofibular screw. Maintaining good joint stability and mobility is essential for promoting optimal recovery of ankle joint function. Gradual and controlled weight-bearing, along with careful monitoring, helps ensure that the healing process is not compromised while allowing the joint to regain its full range of motion and strength. Balancing the load on the joint is crucial for a successful rehabilitation outcome<sup>27,30</sup>.

Prolonged immobilization following an ankle fracture surgery can lead to adhesions of the surrounding soft tissues and functional impairment. To prevent such complications, it is crucial to initiate rehabilitation early, focusing on gentle mobilization and gradually restoring joint function to ensure better recovery outcomes and reduce the risk of long-term disability<sup>31</sup>. Therefore, early postoperative functional exercises are crucial to prevent adhesions, joint stiffness, and capsular contracture, thus maintaining muscle tone and improving the quality of life for patients with ankle fractures<sup>32,33</sup>. This study shows that, compared to the LWB group, the EWB group had lower VAS pain scores at 6 weeks postoperatively. Additionally, at both 6 and 12 weeks postoperatively, the EWB group showed greater dorsiflexion and plantarflexion range of motion in the ankle joint. This suggests that early weight-bearing helps reduce ankle joint pain and improve range of motion. The possible reason for these outcomes is that early weight-bearing allows for a gradual increase in the intensity and duration of load based on the patient's ankle joint movement. By progressively increasing the maximum load and range of motion of the ankle joint, it helps to enhance joint mobility and function, promoting better recovery and reducing long-term limitations. Related studies have also shown that early rehabilitation following ankle fracture surgery can effectively reduce ankle pain. This may be due to EWB activities promoting blood circulation, which helps decrease inflammatory mediators around the injury site. As a result, pain is alleviated, and adhesions in the surrounding tissues are minimized, ultimately leading to improved joint mobility<sup>27,34</sup>.

Ankle fracture patients often experience swelling, and in severe cases, even tension blisters, leading to ongoing concerns about potential wound complications. The follow-up results of this study indicate that no wound infections occurred, suggesting that postoperative wound issues are not the main barrier to early weight-bearing. Although weight-bearing was initiated as early as 2 weeks after ankle fracture surgery, resulting in some increase in pain and swelling, we did not observe wound infections, and no additional adverse events were reported. These findings are consistent with those of related studies<sup>20,35,36</sup>. In addition, early weight-bearing combined with personalized nursing rehabilitation following ankle fracture surgery can effectively reduce patients' stress responses and negative emotions. This approach helps to prevent issues such as decreased joint mobility, joint stiffness, and muscle weakness that can result from prolonged immobilization<sup>37</sup>. Another study conducted on lower limb fracture patients found that early weight-bearing activities did not increase complications but significantly shortened the recovery time<sup>19</sup>. Based on the results of this study, early weight-bearing starting two

weeks post-surgery for ankle fractures combined with syndesmotic injuries contributes to functional recovery. Additionally, the study found that patients who began early weight-bearing were able to return to work and physical activity sooner, reducing the impact of the fracture on their daily lives and allowing them to resume normal activities more quickly. The reason for this may be that early weight-bearing activities not only accelerate the recovery of ankle joint function but also help patients psychologically by reducing anxiety and fear. This, in turn, encourages patients to return to normal work and physical activity more quickly<sup>26</sup>.

The early benefits observed in our study, such as quicker recovery of ROM and strength, are likely attributed to the initial phase of rehabilitation when the body is more responsive to early movement and loading. However, as we observed in our results and as noted in other studies, these early advantages often dissipate by three months. This can be explained by the natural healing process, where early physiological responses such as muscle strength and joint mobility recover quickly but plateau as bone healing progresses more slowly. After the initial phase, patients may experience a gradual leveling off of functional improvements due to the slower maturation of tissue healing and the body's adaptation to the imposed load<sup>38,39</sup>. Although early advantages in recovery dissipate over time, we believe that the clinical relevance of these findings remains significant. Early interventions provide critical benefits, such as reducing the risk of complications (e.g., muscle atrophy, joint stiffness) and promoting faster functional independence, which are important for both patients and healthcare providers. The ability to resume activities earlier can improve psychosocial outcomes, such as patient satisfaction and quality of life, even if the long-term functional differences diminish by three months. Our study highlights that early interventions are still beneficial in the short term, especially for patients who wish to return to normal activities or work as soon as possible, and it provides valuable insights into how these early benefits may translate into improved outcomes over the first three months.

This study is a retrospective analysis, which inherently carries certain limitations. A limitation of this study is that it is a single-center study with a relatively small sample size, which may reduce the statistical power of the study and limit the ability to detect subtle differences or trends. The absence of propensity-matched analysis due to sample size constraints may permit residual confounding. Additionally, although the two groups were well-balanced in terms of the available demographic and clinical variables we analyzed (Table 1), this study shares a common limitation of retrospective designs: the inability to account for unmeasured confounders. Importantly, data on preoperative functional status, occupational physical demands, and baseline activity level were not available. These factors could potentially influence both rehabilitation adherence and functional outcomes. Therefore, while our results are encouraging, they should be interpreted in light of these potential confounding factors. Future prospective, randomized controlled trials that systematically control for these variables are warranted to confirm our findings. Furthermore, the relatively short follow-up duration of this study restricts our ability to observe long-term complications that may develop over a longer period. Extended follow-up periods in future studies will be essential to capture these potential outcomes. Therefore, we plan to conduct future prospective, multi-center, large-scale studies with longer follow-up periods to provide more robust evidence.

## Conclusion

In summary, this study shows that weight-bearing rehabilitation two weeks after surgery for ankle fractures combined with syndesmotic injuries is feasible. It not only does not affect fracture healing or ankle joint stability but also promotes early functional recovery of the ankle joint, alleviates early pain, and helps patients return to work and normal life sooner.

## Data availability

The datasets used and/or analysed during the current study are available from the corresponding author upon reasonable request.

Received: 22 April 2025; Accepted: 4 September 2025

Published online: 07 October 2025

## References

1. Bejarano-Pineda, L. et al. The syndesmosis, part I: anatomy, injury mechanism, classification, and diagnosis. *Orthop. Clin. North Am.* **52** (4), 403–415 (2021).
2. Huber, T., Schmoelz, W. & Böldler, A. Motion of the fibula relative to the tibia and its alterations with syndesmosis screws: A cadaver study. *Foot Ankle Surg.* **18** (3), 203–209 (2012).
3. Vohra, R. et al. Instability of the distal tibiofibular syndesmosis. *J. Orthop. Surg. (Hong Kong)*. **31** (2), 10225536231182349 (2023).
4. Cornu, O. et al. Traumatic injuries of the distal tibiofibular syndesmosis. *Orthop. Traumatol. Surg. Res.* **107** (1S), 102778 (2021).
5. Marasco, D. et al. Static versus dynamic fixation of distal tibiofibular syndesmosis: a systematic review of overlapping meta-analyses. *Knee Surg. Sports Traumatol. Arthrosc.* **29** (11), 3534–3542 (2021).
6. Cardoso, D. V. et al. The effect of BMI on long-term outcomes after operatively treated ankle fractures: a study with up to 16 years of follow-up. *BMC Musculoskelet. Disord.* **23** (1), 317 (2022).
7. Ahl, T. et al. Early weight bearing of displaced ankle fractures. *Acta Orthop. Scand.* **58** (5), 535–538 (1987).
8. Lin, C-W-C. et al. Pain and dorsiflexion range of motion predict short- and medium-term activity limitation in people receiving physiotherapy intervention after ankle fracture: an observational study. *Aust J. Physiother.* **55** (1), 31–37 (2009).
9. Moseley, A. M. et al. Passive stretching does not enhance outcomes in patients with plantarflexion contracture after cast immobilization for ankle fracture: a randomized controlled trial. *Arch. Phys. Med. Rehabil.* **86** (6), 1118–1126 (2005).
10. Vandenborne, K. et al. Longitudinal study of skeletal muscle adaptations during immobilization and rehabilitation. *Muscle Nerve.* **21** (8), 1006–1012 (1998).
11. McPhail, S. M. et al. Life impact of ankle fractures: qualitative analysis of patient and clinician experiences. *BMC Musculoskelet. Disord.* **13**, 224 (2012).

12. Matthews, P. A. et al. Early motion and directed exercise (EMADE) versus usual care post ankle fracture fixation: study protocol for a pragmatic randomised controlled trial. *Trials* **19** (1), 304 (2018).
13. Tan, E. W. et al. Early weightbearing after operatively treated ankle fractures: A Biomechanical analysis. *Foot Ankle Int.* **37** (6), 652–658 (2016).
14. Khojaly, R. et al. Weight-bearing allowed following internal fixation of ankle fractures, a systematic literature review and Meta-Analysis. *Foot Ankle Int.* **43** (9), 1143–1156 (2022).
15. Chen, B. et al. The effect of early weight-bearing and later weight-bearing rehabilitation interventions on outcomes after ankle fracture surgery: A systematic review and meta-analysis of randomised controlled trials. *J. Foot Ankle Res.* **17** (2), e12011 (2024).
16. Sharma, T. & Farrugia, P. Early versus late weight bearing & ankle mobilization in the postoperative management of ankle fractures: A systematic review and meta-analysis of randomized controlled trials. *Foot Ankle Surg.* **28** (7), 827–835 (2022).
17. Bretherton, C. P. et al. Early versus delayed weight-bearing following operatively treated ankle fracture (WAX): a non-inferiority, multicentre, randomised controlled trial. *Lancet* **403** (10446), 2787–2797 (2024).
18. Hollensteiner, M. et al. Biomechanics of osteoporotic fracture fixation. *Curr. Osteoporos. Rep.* **17** (6), 363–374 (2019).
19. Dehghan, N. et al. Early weightbearing and range of motion versus Non-Weightbearing and immobilization after open reduction and internal fixation of unstable ankle fractures: A randomized controlled trial. *J. Orthop. Trauma.* **30** (7), 345–352 (2016).
20. Schubert, J. et al. Effect on overall health status with weightbearing at 2 weeks vs 6 weeks after open reduction and internal fixation of ankle fractures. *Foot Ankle Int.* **41** (6), 658–665 (2020).
21. Walley, K. C. et al. Removal of hardware after syndesmotic screw fixation: A systematic literature review. *Foot Ankle Spec.* **10** (3), 252–257 (2017).
22. Van Heest, T. J. & Lafferty, P. M. Injuries to the ankle syndesmosis. *J. Bone Joint Surg. Am.* **96** (7), 603–613 (2014).
23. Nilsson, G. M., Eneroth, M. & Ekdahl, C. S. The Swedish version of OMAS is a reliable and valid outcome measure for patients with ankle fractures. *BMC Musculoskelet. Disord.* **14**, 109 (2013).
24. Spierings, J. F. et al. Cast versus removable orthosis for the management of stable type B ankle fractures: a systematic review and meta-analysis. *Eur. J. Trauma. Emerg. Surg.* **49** (5), 2085–2095 (2023).
25. Pyle, C. et al. Effect of early weightbearing following open reduction and internal fixation of unstable ankle fractures on wound complications or failures of fixation. *Foot Ankle Int.* **40** (12), 1397–1402 (2019).
26. Smeeing, D. P. J. et al. Weight-bearing or non-weight-bearing after surgical treatment of ankle fractures: a multicenter randomized controlled trial. *Eur. J. Trauma. Emerg. Surg.* **46** (1), 121–130 (2020).
27. Chen, J. et al. Rehabilitation effect of standing bed combined with early anti-gravity running table training on ankle fracture. *Sci. Rep.* **14** (1), 3582 (2024).
28. Mitrogiannis, L. et al. An early functional unsupervised rehabilitation protocol allows safe return to function after Achilles tendon repair. *Cureus* **16** (1), e52477 (2024).
29. Barlow, C., Duggleby, L. & Barton, T. Early weight bearing in elderly patients with ankle fractures reduces care needs and maintains independence. *Foot Ankle Surg.* **29** (1), 63–66 (2023).
30. Wu, W. et al. Comparative analysis of internal fixation modalities for PER type IV ankle fractures: a finite element study. *J. Orthop. Surg. Res.* **19** (1), 503 (2024).
31. Goost, H. et al. Fractures of the ankle joint: investigation and treatment options. *Dtsch. Arztebl. Int.* **111** (21), 377–388 (2014).
32. Chen, J., Wu, T. & Guo, Y. Nordic hamstring exercises in functional knee rehabilitation after anterior cruciate ligament reconstruction: a prospective, randomised, controlled study. *Sci. Rep.* **13** (1), 19039 (2023).
33. Painter, E. E. et al. Manual physical therapy following immobilization for stable ankle fracture: A case series. *J. Orthop. Sports Phys. Ther.* **45** (9), 665–674 (2015).
34. Jansen, H. et al. Active controlled motion in early rehabilitation improves outcome after ankle fractures: a randomized controlled trial. *Clin. Rehabil.* **32** (3), 312–318 (2018).
35. Gorczyca, J. T. & Early Rather than late, Weight-Bearing and Range-of-Motion exercise improved early function but not time to return to work after surgical fixation of unstable ankle fractures. *J. Bone Joint Surg. Am.* **99** (4), 350 (2017).
36. Smeeing, D. P. J. et al. Weight-bearing and mobilization in the postoperative care of ankle fractures: a systematic review and meta-analysis of randomized controlled trials and cohort studies. *PLoS One.* **10** (2), e0118320 (2015).
37. Heare, A. et al. Early versus late Weight-Bearing protocols for surgically managed posterior wall acetabular fractures. *Orthopedics* **40** (4), e652–e7 (2017).
38. Stassen, R. C. et al. Prospective randomized controlled trial: early weight bearing after Conservative treatment of Weber B ankle fractures (pancake trial). *Eur. J. Orthop. Surg. Traumatology: Orthopedie Traumatologie.* **34** (1), 591–598 (2024).
39. Kumar, M. D. et al. Evaluation of results of open distal femur fractures with primary fixation and antibiotic impregnated collagen. *Chin. J. Traumatol. = Zhonghua Chuang Shang Za Zhi.* **22** (6), 328–332 (2019).

## Author contributions

K.T., L.H. and J.J.L.: Conceptualization, data analysis, validation, writing. X.P.L. and Y.C.: data analysis, writing. D.H.L. and D.C.C.: writing and editing the manuscript. K.T. and J.J.L.: investigation, review and editing. All authors read and approved the final manuscript.

## Funding

This research did not receive any specific grant from funding agencies in the public, commercial, or not-for-profit sectors.

## Competing interests

The authors declare no competing interests.

## Contributions

K.T., L.H. and J.J.L.: Conceptualization, data analysis, validation, writing. X.P.L. and Y.C.: data analysis, writing. D.H.L. and D.C.C.: writing and editing the manuscript. K.T. and J.J.L.: investigation, review and editing. All authors read and approved the final manuscript.

## Ethics declarations

This study was approved by the Ethics Committee of Longyan First Hospital Affiliated to Fujian Medical University.

### Abbreviations

EWB Group, Early Weight-bearing Groups; LWB Group, Late Weight-bearing Groups; BMI, body mass index.

### Abbreviations

EWB Group, Early Weight-bearing Groups; LWB Group, Late Weight-bearing Groups; OMAS, Olerud-Molander Ankle Score; CI, confidence interval.

<sup>a</sup>Range 0 to 100, with higher scores indicating better function. The anchor-based MCID is 4.4 points at 6 to 12 weeks, 15.0 points at 3 to 6 months and 9.5 points at 6 to 12 months.

### Abbreviations

EWB Group, Early Weight-bearing Groups; LWB Group, Late Weight-bearing Groups; VAS, Visual Analog Scale Pain Score; CI, confidence interval.

### Abbreviations

EWB Group, Early Weight-bearing Groups; LWB Group, Late Weight-bearing Groups; ROM, Range of Motion; CI, confidence interval.

### Abbreviations

EWB Group, Early Weight-bearing Groups; LWB Group, Late Weight-bearing Groups; CI, confidence interval.

### Additional information

**Correspondence** and requests for materials should be addressed to J.L.

**Reprints and permissions information** is available at [www.nature.com/reprints](http://www.nature.com/reprints).

**Publisher's note** Springer Nature remains neutral with regard to jurisdictional claims in published maps and institutional affiliations.

**Open Access** This article is licensed under a Creative Commons Attribution-NonCommercial-NoDerivatives 4.0 International License, which permits any non-commercial use, sharing, distribution and reproduction in any medium or format, as long as you give appropriate credit to the original author(s) and the source, provide a link to the Creative Commons licence, and indicate if you modified the licensed material. You do not have permission under this licence to share adapted material derived from this article or parts of it. The images or other third party material in this article are included in the article's Creative Commons licence, unless indicated otherwise in a credit line to the material. If material is not included in the article's Creative Commons licence and your intended use is not permitted by statutory regulation or exceeds the permitted use, you will need to obtain permission directly from the copyright holder. To view a copy of this licence, visit <http://creativecommons.org/licenses/by-nc-nd/4.0/>.

© The Author(s) 2025