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**CASE REPORT**

# NOVEL APPLICATION OF LOWER BODY POSITIVE-PRESSURE IN THE REHABILITATION OF AN INDIVIDUAL WITH MULTIPLE LOWER EXTREMITY FRACTURES

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***Objective:*** **Lower extremity fractures, if not treated appropriately, can increase the risk of morbidity. Partial weight-bearing after surgical repair is recommended; however, current methods of partial weight-bearing may cause excessive loads through the lower extremity. A new rehabilitation tool that uses lower body positive-pressure is described, that may allow partial weight-bearing while preventing excessive loads, thereby improving functional outcomes.**
***Methods:*** **A patient with multiple lower extremity fractures underwent a 6-month rehabilitation programme using bodyweight support technology 3 times per week, post-surgery.**
***Results:*** **The patient experienced a reduction in pain and an improvement in ankle range of motion ($p=0.002$), walking speed ($p>0.05$) and physical function ($p=0.004$), as assessed by the Foot and Ankle Module of the American Academy of Orthopaedic Surgeons Lower Limb Outcomes Assessment Instrument. Training did not appear to affect fracture healing, as was evident on radiograph. The effect of lower body positive-pressure on effusion, which has not previously been reported in the literature, was also investigated. No significant difference in effusion of the foot and ankle when using lower body positive-pressure was found.**
***Conclusion:*** **Initial results suggest that this new technology may be a useful rehabilitation tool that allows partial weight-bearing during the treatment of lower extremity injuries.**

*Key words:* fracture healing; weight-bearing; pain; case reports.

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## INTRODUCTION

Lower extremity fracture rehabilitation is important to reduce the risk of morbidity. Fractures, in particular those below the knee, have a strong impact on functional recovery (1, 2), and optimizing the rehabilitation of these fractures can significantly improve patient quality of life. Partial weight-bearing, along with active range of motion exercises, have been recommended for various surgically repaired lower extremity fractures (2–6). However, current methods of partial weight-bearing, such as crutches and canes, may not adequately reduce lower extremity loads, and require the modification of gait patterns. Research has shown that patients with lower extremity fractures consistently bear loads much greater than recommended when ambulating under partial weight-bearing conditions (6). This excessive amount of loading can increase the risk of fracture complications and morbidity (6). A new technology has been developed to support the rehabilitation of ambulation through bodyweight unloading. This tool may help to optimize functional recovery in patients with lower extremity fractures by allowing weight-bearing at reduced loads. Bodyweight unloading may also reduce pain in patients with lower extremity fractures; the presence of pain has been correlated with worse functional outcomes (7). This report describes the use of this emerging technology in the rehabilitation of an individual with multiple lower extremity fractures.

## METHODS

The patient was a 42-year-old man with multiple lower extremity fractures. The patient had an avulsion fracture of the right medial malleolus, comminuted fracture of the left talus, and fractures of the left proximal and distal tibia and fibula due to a mountain climbing accident. He was airlifted and initially treated at a local hospital, before being transferred to a regional trauma centre. At the regional trauma centre he underwent open reduction internal fixation of the talus fracture, but developed stiffness in his left hindfoot, varus deformity and a loss of dorsiflexion to 0º. In addition, he developed medial knee pain along the joint line of the left leg. After surgery, the patient attended physical therapy and progressed from a wheelchair to a cane with a significantly asymmetrical gait. The patient experienced pain and little functional improvement with therapy and the traditional treadmill walking programme could not provide enough remediation to compensate for the patient's lower extremity dysfunction. Six months after the trauma, the traditional physical therapy walking programme results were deemed unsatisfactory and he started our partial weight-bearing rehabilitation programme. This study was approved by the local health research ethics board, and written approval was provided by the participant.

The patient was scheduled for $3 \times 20$-min treadmill walking sessions per week (on Monday, Wednesday and Friday) for 6 months. He completed a total of 48 treatment sessions on the G-trainer (Alter-G, Menlo Park, CA, USA; Fig. 1), a novel rehabilitation device. The device utilizes a treadmill contained in a waist-high air-tight chamber, and small increases in chamber air pressure to produce a lower body positive-pressure (LBPP) that creates a lifting force approximately at the person's centre of mass (8, 9). Biomechanical research has demonstrated that LBPP can be used to significantly reduce ground reaction forces at the knee joint in a normal healthy population, while

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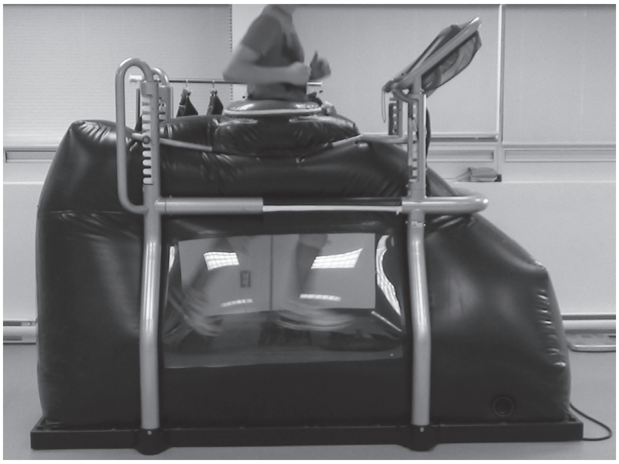

*Fig. 1.* The G-trainer anti-gravity treadmill.

maintaining typical patterns of muscle activation, joint motion, and cardiovascular function during walking and running (10, 11). The G-Trainer is believed to be superior to other methods of un-weighting that have been used previously by researchers to study gait mechanics of at-risk or pathology-specific populations (such as treadmill walking using an upper body harness or aquatic-based exercise), because it is the first known device that offers an ability to study un-weighted exercise in a user-friendly, kinematically correct manner (9). Through the use of the LBPP technology, the G-Trainer can create a lifting force of up to 80% of a user's bodyweight, providing a 4 kg reduction in joint load for every 1 kg of un-weighting (12). By avoiding the use of bulky and cumbersome "lifting" equipment, and facilitating the study of gait in an air medium, the G-Trainer can accurately mimic lower body kinetics (unlike in a water medium) (9). While this exercise equipment is currently more expensive than a regular treadmill and less widely available (see http://www.alter-g.com/ for more information), it may be useful in studying the biomechanical and physiological impact of a range of pathological conditions that impair lower extremity function and reduce functional autonomy, including multiple lower limb fractures, as seen in our patient.

The effects on injury healing and ambulation of this anti-gravity treadmill were assessed using the following: a visual analogue scale (VAS) to determine pain with ambulation, a lower limb specific survey (13) to determine foot and ankle pain and physical function, calf circumference, mid-foot circumference measures, range of motion (ROM) measures, and radiographs taken to assess bony healing. The VAS was administered every 5 min while the patient was ambulating. He was instructed to walk at a speed and LBPP level (bodyweight support, with lower percentages indicating less support) that maintained a level of pain $\leq 20$ on a VAS of 0–100 mm (0 representing no pain). The patient completed the Foot and Ankle Module of the American Academy of Orthopaedic Surgeons (AAOS) Lower Limb Outcomes Assessment Instruments (13) once per week. Calf and mid-foot circumference, to examine effusion, and plantarflexion and dorsiflexion ROM (Fig. 2) were measured before and after each treadmill walking session to assess changes over the rehabilitation period.

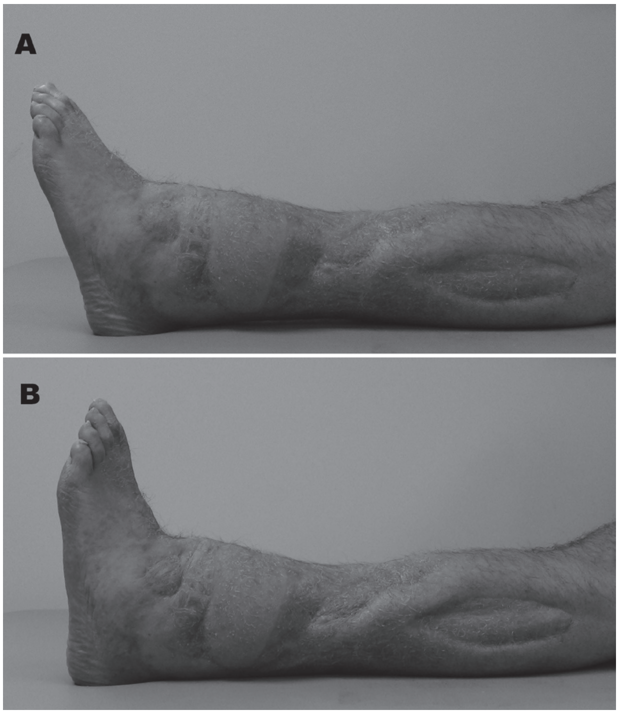

*Fig. 2.* (A) Plantarflexion and (B) dorsiflexion range of motion of the left leg at the start of the rehabilitation protocol.

## RESULTS

The baseline weight of the patient was 92.2 kg. Initial speed and LBPP on the treadmill were 0.67 m/s and 20% (representing approximately 20% unloading or 73.8 kg of weight-bearing) respectively. The patient progressed to a maximum speed of 0.98 m/s and a minimum LBPP of 10%, with no pain. A progression of rehabilitation parameters can be seen in Table I. LBPP ranged from 10% to 25%; speed ranged from 0.44 to 0.98 m/s; pain was maintained at $\leq 20$ on the VAS scale. During the course of treatment, LBPP decreased ($p < 0.05$), and although there was a trend towards increased speed and decreased pain, the difference was not significant. His AAOS physical function score was 89 at baseline and 73 after the programme. Higher scores indicate higher levels of dysfunction, with a minimum clinically significant difference of 8.8 (13). Scores ranged from 66 to 99 and improved significantly over the rehabilitation period ($p = 0.004$). ROM in the left ankle increased, with a significant improvement in plantarflexion, from 122º to 140º over the rehabilitation period ($p = 0.002$). Changes in dorsiflexion ROM, from 111º at baseline to 117º after the programme, were not significant. Calf circumfer-

Table I. *Rehabilitation progression over time. Mean maximum speed reached per session, minimum bodyweight support required (lower body positive-pressure; LBPP), maximum pain level experienced, and mean American Academy of Orthopaedic Surgeons (AAOS) score in 6-week intervals of the rehabilitation protocol*

| Time (6-week intervals) | Maximum speed per session, m/s Mean (SD) | Minimum LBPP, % unloading* Mean (SD) | Maximum pain 0–100 mm VAS Mean (SD) | Total AAOS scores* Mean (SD) |
|---|---|---|---|---|
| Baseline | 0.67 | 20 | 10 | 89.0 |
| 6 weeks | 0.78 (0.13) | 17.9 (2.87) | 5.0 (5.1) | 85.8 (7.5) |
| 12 weeks | 0.88 (0.23) | 14.5 (2.55) | 11.6 (8.3) | 76.6 (3.0) |
| 18 weeks | 0.89 (0.24) | 13.1 (4.47) | 19.0 (9.1) | 73.3 (6.4) |
| 24 weeks | 0.80 (0.08) | 18.1 (2.59) | 1.2 (3.5) | 73.0 (2.9) |

*Significant values.
VAS: visual analogue scale; SD: standard deviation.

ence at baseline was 30.5 cm prior to treadmill activity and 30.2 cm after treadmill activity. Calf circumference at the last session was 32.7 cm prior to ambulation and 32.6 cm post-ambulation. Mid-foot circumference at baseline was 27.5 cm prior to treadmill walking and 26.8 cm after treadmill walking. In the final week, mid-foot circumference was 23.0 cm pre-ambulation and 23.0 cm post-ambulation. These differences in circumference are not significant ($p > 0.05$). Training did not appear to adversely affect fracture healing, as observed on radiograph 10 months after injury; 4 months after the start of the rehabilitation programme (Fig. 3). After the rehabilitation period, the patient reported less pain and was able to participate in more activities of daily living including walking, housework, gardening, and family outings, many activities that he was unable to perform previously. The symmetry of his gait improved, and he relied less on his cane, being able to walk unaided for longer periods of time.

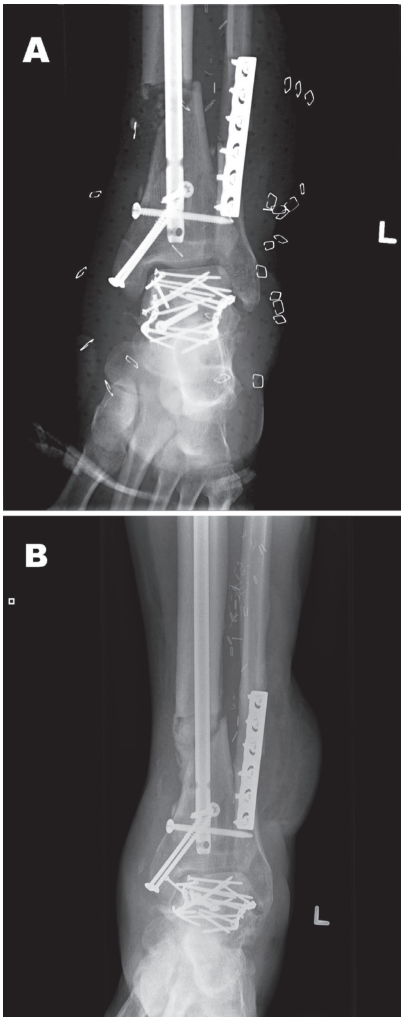


*Fig. 3.* (A) Initial radiograph 1 month after injury. (B) Radiographic evidence of healing 10 months post-injury.

## DISCUSSION

Bodyweight support has been shown to be a useful tool in the rehabilitation of gait in stroke patients and individuals with Down's syndrome, cerebral palsy, and spinal cord injury by "un-weighting" patients against gravity (14–16). This method is being explored in lower body orthopaedic patients after anterior cruciate ligament reconstruction and meniscetomy, as a means of graded rehabilitation and early partial weight-bearing through unloading of the lower extremities (8); however, the anatomical effects on healing are unknown. Beyond traditional walking aids, such as crutches and canes, previous systems for unloading have used harness-based systems or water immersion, but have been limited in their ability to accurately recreate the mechanics of ambulation (15, 17–19). Initial research on the G-trainer shows that this tool preserves many of the natural biomechanical patterns in ambulation, providing an advantage over previous systems. Research has demonstrated that LBPP can be used to significantly reduce ground reaction forces at the knee joint, while maintaining normal patterns of muscle activation, joint range of motion, limb swing mechanics and cardiovascular function during walking (8, 9, 11). This creates an ideal tool for early partial weight-bearing. The effect of LBPP on effusion has not been reported in the literature; our results indicate no change in calf or foot circumference, common areas of effusion in lower extremity orthopaedic patients, before and after treadmill activity ($p > 0.05$).

There are few studies using the G-trainer to assess the impact on injury rehabilitation (8, 20). Initial results suggest that the G-trainer may be a useful rehabilitation tool that allows accelerated partial weight-bearing during the treatment of lower extremity injuries, and our report supports these conclusions. Our rehabilitation protocol showed improvements in pain levels and physical functioning of a patient with lower extremity fractures. The rehabilitation programme used for this case appears to support anatomical healing and recovery after surgery; however, further study is needed. The psychological effects of chronic training using this technology are unknown. Anecdotal evidence from our case report suggests a false sense of confidence on the part of the patient with respect to ambulation and his ability to complete activities. After treadmill walking, he was more likely to participate in physically active tasks, such as home renovation, stating that he felt confident and motivated to be active. The resulting inflammation may have limited further advancement in his rehabilitation, and this merits further study. Future research should be directed at investigating lower extremity injuries using the G-trainer for partial weight-bearing in early rehabilitation, and establishing the limitations of this emerging technology in the treatment of musculoskeletal disorders of the lower extremity.

## ACKNOWLEDGEMENTS

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*Conflict of interest*

The authors declare no conflicts of interests in their authorship and publication of this contribution.

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