Movement and Offloading strategies in Patients with Previous Foot Ulceration: A Case Series

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Introduction

People with a history of diabetic foot ulceration remain at high risk of recurrence, and reducing repetitive mechanical loading is central to maintaining remission. Current guidance recommends therapeutic footwear and insoles with a demonstrated pressure-relieving effect for people with a healed plantar ulcer (Bus et al., 2024). Insole design is important, with contoured, pressure-informed and appropriately cushioned insoles shown to reduce plantar loading, although the contribution of individual footwear and insole components can be difficult to separate (Collings et al., 2020). Pressure reduction alone does not describe how an intervention influences walking. More aggressive offloading strategies can alter push-off, centre-of-pressure (CoP) progression and gait symmetry (Bus et al., 2017). CoP trajectory provides additional information on how load progresses through the foot during stance and is influenced by footwear characteristics (Branthwaite et al., 2014). These pilot data form part of a wider prospective study of people with healed diabetic foot ulcers, examining biomechanical characteristics during remission and their relationship with time in remission. The present analysis evaluates pressure distribution, CoP progression and gait characteristics during barefoot walking and walking in standard accommodative footwear incorporating the diabetic insole.

Methods

Ten adults with diabetes and a diabetic foot ulcer healed within the previous year were included (**age 61.6 ± 10.1 years; diabetes duration 16.1 ± 12.5 years; 6 male, 4 female**).
Gait and pressure were assessed using a **Zebris FDM pressure platform** under two conditions:

- **Barefoot**
- **Standard accommodative diabetic footwear (Lucro, Schein) fitted with novel DiabetiX insoles (TalarMade)**

Participants walked at a self-selected speed. Outcomes included regional maximum pressure, spatiotemporal gait parameters and CoP measures. The main variables examined were forefoot maximum pressure, CoP gait-line length, single-limb-support CoP line, lateral symmetry, maximum gait-line velocity, stride length and walking velocity.
For foot-specific outcomes, analysis was based on the previously ulcerated foot. Participant-level gait measures, including stride length and walking velocity, were analysed at the participant level. Barefoot and footwear–insole conditions were compared within participants using paired two-sided t-tests.
The Zebris platform records pressure at the external support surface. Therefore, the shod measurements represent pressure recorded beneath the shoe rather than direct pressure at the foot–insole interface. The platform approach allowed pressure redistribution, CoP progression and gait characteristics to be assessed within the same measurement system.

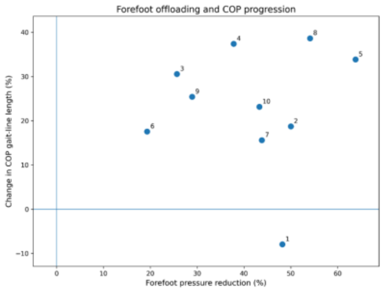
Results

The footwear–insole condition produced a marked reduction in forefoot pressure in the previously ulcerated foot. Maximum forefoot pressure decreased from **60.2 ± 21.5 N/cm^2 barefoot to 32.9 ± 5.7 N/cm^2**, representing a **45.3% reduction ($p < 0.001$)**. This was accompanied by an increase in CoP progression in the previously ulcerated foot. CoP gait-line length increased from **219.1 ± 25.5 mm to 270.2 ± 41.3 mm**, an increase of **23.3% ($p < 0.001$)**. Stride length increased from **107.1 ± 15.8 cm to 118.4 ± 18.8 cm (+10.6%; $p < 0.001$)**, while walking velocity increased from **3.25 ± 0.80 km/h to 3.58 ± 0.81 km/h (+10.2%; $p < 0.001$)**. There was no significant change in CoP progression during single-limb support, lateral symmetry or maximum gait-line velocity.

Discussion

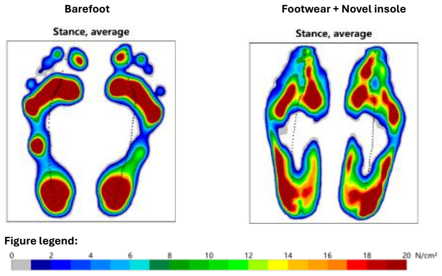
The main finding from this early analysis is that substantial forefoot offloading occurred alongside **increased rather than restricted overall CoP progression**. Participants also demonstrated longer strides and higher walking velocity in the shod condition. This is clinically relevant because pressure reduction does not necessarily indicate that normal progression through the foot has been maintained. Some more aggressive forefoot offloading strategies reduce pressure at the expense of push-off and proximal-to-distal CoP progression (Bus et al., 2017). The present findings suggest that considerable pressure redistribution can occur while allowing continued progression through stance. Previous research using different pressure measurement approaches has reported substantial pressure reductions with diabetic insoles and orthoses (Collings et al., 2020; El-Hilaly et al., 2013). The magnitude of the reduction observed here is therefore broadly consistent with previous biomechanical work, although absolute pressure values should not be compared directly between different measurement systems (Chockalingam et al., 2026).

Figure 1. Individual changes in forefoot maximum pressure and CoP gait-line length for the previously ulcerated foot between barefoot walking and standard accommodative footwear incorporating the novel diabetic insole. All participants demonstrated forefoot pressure reduction. CoP gait-line length increased in nine of ten participants, with one participant showing a modest reduction.



X-axis: Forefoot pressure reduction (%)
Y-axis: Change in CoP gait-line length (%)
Each point: one participant

Figure 2. Representative Zebris pressure and CoP output during barefoot walking and walking in standard accommodative footwear incorporating the novel diabetic insole. The example illustrates reduced forefoot loading together with increased overall CoP progression. Group-level effects are presented in Figure 1 and the results table.



Outcome	Barefoot	Footwear + insole	Change	p
Forefoot maximum pressure – previously ulcerated foot	60.2 ± 21.5 N/cm^2	32.9 ± 5.7 N/cm^2	−45.3%	<0.001
CoP gait-line length – previously ulcerated foot	219.1 ± 25.5 mm	270.2 ± 41.3 mm	+23.3%	<0.001
Single-limb-support CoP line – previously ulcerated foot	101.0 ± 21.9 mm	95.6 ± 32.7 mm	−5.4%	0.507
Stride length	107.1 ± 15.8 cm	118.4 ± 18.8 cm	+10.6%	<0.001
Walking velocity	3.25 ± 0.80 km/h	3.58 ± 0.81 km/h	+10.2%	<0.001

Interpretation

- The increase in **CoP gait-line length** indicates greater overall CoP progression through stance. Together with the increase in stride length and walking velocity, this suggests that forefoot offloading was achieved **without restricting forward progression during gait**.
- Single-limb-support CoP line, lateral symmetry and maximum CoP gait-line velocity did not change significantly, indicating that the main effect was on **overall progression rather than these secondary CoP measures**.
- These findings reflect the combined condition of **standard accommodative footwear with an appropriately designed diabetic insole**. Further work will help determine the specific contribution of the insole and its longer-term clinical relevance.

Clinical relevance

Offloading should not be considered separately from walking function.

In this pilot cohort, standard accommodative footwear incorporating a novel diabetic insole was associated with approximately **45% lower forefoot pressure**, while overall CoP progression, stride length and walking velocity increased.

Assessing **pressure redistribution together with CoP progression and gait** may provide a more complete biomechanical evaluation of diabetic insoles than pressure reduction alone.

Future work

These findings are part of an ongoing prospective study of people in remission following diabetic foot ulceration. The larger study will provide a more detailed characterisation of biomechanical function after ulcer healing and allow us to examine whether biomechanical characteristics and response to the insole are associated with **time in remission and subsequent ulcer recurrence**.

Further work will also:

- examine responses in a larger and more diverse cohort;
- investigate individual rather than only group-level biomechanical responses;
- include comprehensive movement analysis;
- separate the effects of the insole and footwear through a shoe-only comparator; and
- examine whether the biomechanical effects observed at baseline are maintained during longer-term use.

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