Gait and Contralateral Limb Effects when Ambulating with a Total Contact Cast

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Introduction

Diabetes mellitus is a diagnosis with increasing prevalence worldwide. The contributory effects of diabetes on the development of a diabetic foot ulcer (DFU) are well documented. The International Working Group on the Diabetic Foot (IWDGF) recommends total contact casts (TCC) as a preferred, first-line offloading treatment for a neuropathic plantar ulcer.[1] The TCC consists of a below-knee plaster cast applied with minimal to no padding. It is designed to have a precise fit on the lower extremity.[2] The TCC-EZ®, utilized in this study, has been shown to be a viable alternative to the TCC and takes advantage of a more streamlined application.[3] The TCC reduces pressure to the plantar foot and decreases shearing forces to increase healing of a DFU. When a patient is utilizing a TCC, their gait is affected. The application of the cast and boot locks the ankle joint at 90 degrees eliminating the propulsive phase of gait. Additionally, the TCC with a walking boot creates an average limb length discrepancy (LLD) of 1-2 cm, causing the affected limb to be longer than the contralateral side. This iatrogenic limb length discrepancy increases plantar forces on the non-treated limb.

This LLD will affect speed, single support time, stride length and ground reaction forces (GRF). The Computer Assisted Rehabilitation Environment (CAREN) is an advanced biomechanical lab that was utilized in this study. The CAREN system operates with a dual belt treadmill to accurately document speed, single support time, stride length and GRF for each limb.[2] This study measured the above factors for bilateral limbs, compared the unaffected limb to the limb with the TCC-EZ as well as the accommodated LLD with a heel lift and a full-length shoe lift on the uncasted limb.

This study accommodates the LLD with a heel lift and a full-length lift utilizing the CAREN system to evaluate the change in biomechanics of the short uncasted limb. Other studies have shown the offloading of plantar pressures after applying TCC.[4] However, there is little known about the contralateral limb despite its potential for ulceration due to the bilateral nature of diabetic neuropathy and the development of subsequent neuropathic ulcers. Studying the potential increased pressures of the contralateral limb is critical, as individuals utilizing TCC face a systemic risk of DFUs on the side that is not protected by TCC. This investigation explores the impact of TCC-EZ® on the contralateral limb and various strategies to mitigate the development of potential undesirable outcomes.

Table 2: Summary statistics of each trial

Trial	1 (N=30) Athletic Shoes Only	2 (N=30) TCC-EZ® & Athletic Shoe	3 (N=30) TCC-EZ® & Athletic Shoe + Heel Lift	4 (N=30) TCC-EZ® & Athletic Shoe + Shoe Lift	Total (N=120)
Left Peak Combined GRF					
Mean (SD)	750.118 (140.702)	796.174* (150.885)	810.105* (157.698)	799.892 (152.996)	789.072 (150.578)
Range	525.550 - 1071.050	579.370 - 1131.520	578.030 - 1197.900	574.120 - 1112.520	525.550 - 1197.900
Left Peak Vertical GRF					
Mean (SD)	744.296 (138.770)	791.299* (149.341)	803.956* (155.408)	795.092 (150.301)	783.661 (148.530)
Range	523.070 - 1058.000	577.670 - 1117.000	576.400 - 1182.410	569.850 - 1100.950	523.070 - 1182.410

Table 3: Paired t-test comparing trial 2 TTC-EZ® & Athletic Shoe vs. trial 3 TTC-EZ® & Athletic Shoe +Heel Lift

	T-Value	DF	95% Confidence Interval	P-value	Mean Difference
Left Peak Combined GRF	-2.66	29	(-24.65, -3.21)	0.013	-13.93
Left Peak Vertical GRF	-2.96	29	(-21.40, -3.91)	0.006	-12.66

Table 4: Paired t-test comparing trial 2 TTC-EZ® & Athletic Shoe vs. trial 4 TTC-EZ ® & Athletic Shoe +Shoe Lift

	T-Value	DF	95% Confidence Interval	P-value	Mean Difference
Left Peak Combined GRF	-0.51	29	(-18.64, 11.20)	0.61	-3.72
Left Peak Vertical GRF	-0.63	29	(-16.15, 8.56)	0.535	-3.79

Methods

Exclusion criteria: history of lower extremity surgery, condition, or injury that would affect gait

Inclusion criteria: ability to walk on the CAREN treadmill for 10 minutes with a TCC-EZ® applied to the right LE

Four trials ambulating on the CAREN treadmill:

1. Athletic shoes on bilateral feet
2. Athletic shoe on the left foot and a TCC-EZ® on the right lower extremity without any accommodations
3. Heel lift on the left (in athletic shoe) and TCC-EZ® on the right
4. Shoe lift on the left (on athletic shoe) and TCC-EZ® on the right

Table 1. Participant Demographics

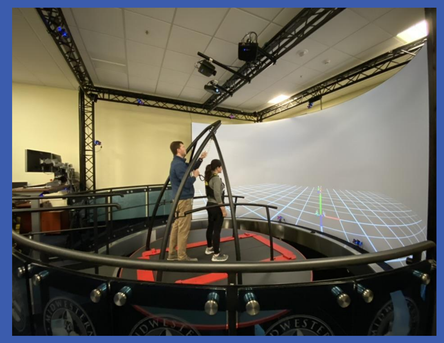
	Age (years)	Height (m)	Weight (kg)
Average	26.53	1.72	74.19
Range	24-34	1.55-1.85	52.16-165
Sex	16 females	14 males	
Total Participants	30		

Discussion

In this study, there was an increase in peak combined and peak vertical GRF of the contralateral limb when ambulating with a TCC (Table 2). The key finding of this study is that the addition of a heel lift reduced the peak combined and peak vertical GRF which was statistically significant for the contralateral limb (Table 3). These outcomes are consistent with the findings of Tirtashi, et al. which found that heel lifts improve gait dynamics in individuals with idiopathic LLD.[5] In our study, the use of a shoe lift did not significantly reduce the peak combined and peak vertical GRF. The use of a heel lift or shoe lift did not reduce forces to pre-TCC levels (Table 4).

Data evaluating the GRF on the untreated contralateral limb when utilizing a TCC is limited. This study is unique in that it is the first study evaluating the efficacy of a heel lift on the short limb utilizing the CAREN system, which provides objective data collection in a uniform environment.

Our study design of using healthy adults has strengths and weaknesses. Our subjects had no foot abnormalities enabling a pure single-factor analysis of the biomechanical influences of TCC-EZ® and potential mitigating factors. Isolating the impact TCC-EZ® as a variable enhances understanding. This also allowed us to utilize a participant's unique gait as the control; we then observed gait changes after TCC application and subsequent trials with heel and shoe lifts. Weaknesses of this design include the exclusion of individuals with diabetic foot ulcers or coexisting conditions that influence gait. Gait disturbances due to wounds, for example, would provide a more representative picture of the patients who benefit from TCC offloading. A clinical extrapolation would be needed to apply these results to a pathologic patient population who may have comorbidities, including peripheral neuropathy, that might influence the results. Additionally, there are gait changes in individuals walking on ground versus on a treadmill. Even in the CAREN setting, studies have shown that individuals have decreased step time and decreased step length.[6] This may not fully represent normal gait on ground. Further investigations exploring the impact of TCC-EZ® in patients with diabetic foot ulcers may be helpful. A larger sample might enable additional findings to be identified. An area for further research could include patient-reported feedback from heel and shoe lift applications when ambulating with a TCC.



Conclusion

Diabetes mellitus and its associated complications are on the rise. These complications include peripheral neuropathy and potential neuropathic ulcers due to shearing forces and plantar pressures on the weight-bearing surfaces of the foot. The important positive effects of offloading devices such as the TCC have been shown to decrease plantar pressures on the limb wearing the TCC.[7] The use of TCC as the gold standard for offloading plantar pressures of DFUs warrants research on its impact on gait and patient outcomes.

Ambulating with a TCC-EZ® creates an iatrogenic LLD and, therefore, increases contralateral foot peak GRF by approximately 6%. This increased GRF can be significantly reduced by the addition of a heel lift. These findings may suggest revising recommendations to consider a heel lift, matched to a patient's measured LLD after the application of TCC-EZ® to reduce gait changes and increased plantar pressures.

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