GAIT BIOMECHANICS COMPARISON ANALYSIS USING VARIOUS ANKLE-FOOT OFFLOADING DEVICES

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Introduction

Currently, crutches are the standard care for patients who cannot load their ankle or foot due to conditions such as diabetic foot ulcers, fractures, sprains, surgeries, etc. Crutch gait, however, limits the use of the upper extremities, reduces walking speed, and is energetically inefficient. Consequently, alternative devices that remove loading from the foot and ankle while walking have been proposed. This study investigates the biomechanical outcomes of using crutches (CR) and two alternative devices: iWalk (IW) and ZeroG (ZG), as shown in Figure 1.

Figure 1: Devices for ankle-foot offloading. From left to right: forearm crutches, iWalk, and ZeroG.

Methods

The experiments comprised of 20 healthy participants (9 male, 11 female, ages 20.8-39.1). Each participant walked at a self-selected speed with each device, as well as normal unassisted gait. A 16-camera Vicon motion capture system at 120 Hz using the Plug-In Gait Body model [1], two AMTI force plates, and Cosmed K5 metabolic system were used to measure spatiotemporal parameters, ground reaction force (GRF), foot center of pressure (COP), center of mass (COM), joint kinematics and kinetics, as well as the metabolic cost. Moreover, the users rated their perceived exertion (RPE), stability, comfort, and preferences, using questionnaires.

Repeated measures ANOVA was used to analyze the statistical significance of the differences between the different conditions, where the gait parameters of the weight-bearing leg were compared using each device relative to normal gait.

Results

All the devices changed the participants' walking patterns in comparison to their normal gait. The hip and knee angles obtained using the ZG were the most similar to normal gait, whereas no significant differences were found for the ankle. The medial-lateral fluctuations of the COM were largest for IW and smallest for CR. The GRF peaks were most pronounced for CR, whereas for ZG and IW the magnitudes were comparable to normal gait, but delayed, as illustrated in Figure 2. The stance phase was most significantly elongated using CR and the stride length was most significantly shortened using IW. All the devices caused a reduction in the cadence and walking speed. The normalized metabolic cost, measured during a 6-minute walking test, is summarized in Table 1. The questionnaires revealed that CR were least preferred by the participants, whereas IW and ZG were similarly preferred.

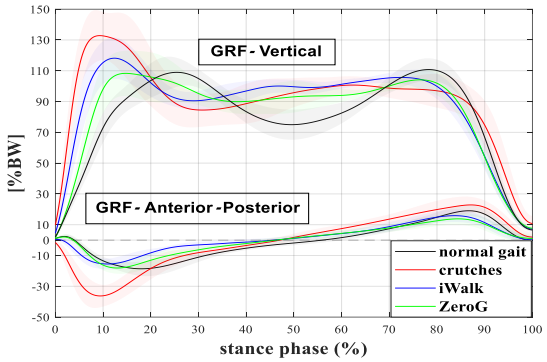

Figure 2: GRF components in the sagittal plane.

$\left[\frac{ml/min}{kg \cdot m/s}\right]$	CR	IW	ZG	Normal
Mean	11.56	8.51	5.35	3.19
STD	4.25	2.79	0.84	0.44

Table 1: Metabolic cost of all devices and normal gait.

Discussions

Overall, the ZG led to gait parameters that were most similar to normal gait, which may be linked to the lowest metabolic cost and highest user preference, together with IW. This suggests that it may be preferable as a replacement for CR. The small mediolateral COM fluctuation using CR may indicate improved balance, however, the user rated them as the most unstable. This suggests that the instability feeling of the subjects stemmed from a different parameter. The lower GRF peaks obtained using ZG and IW may be beneficial to limit the risk of injury on the weight-bearing leg. These results could inform clinicians' decisions regarding the prescription of such devices for patients with foot-ankle injuries and pathologies. Future research is planned to employ the results toward the design of new ambulatory devices that improve rehabilitation and patient care.

References

1. Fellinger, M., Passler, J. & Seggl, W. Plug-in Gait Reference Guide. *Hum. Nonhum. Bone Identif.* 27–46 (2010).