EFFECT OF POWERED EXOSUIT TRAINING ON IMPULSE DURING GAIT

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INTRODUCTION

As exosuit technology develops, it is important to not only quantify the performance gains that they grant wearers, but also begin to attempt to maximize those gains by implementing training. Although research has been done on creating and refining exosuits themselves, few investigations have measured the effects of training. Developers recommend a varied amount of familiarization, however these recommendations are not always supported by quantitative data. Many studies include at least one initial familiarization session before testing [1,2,4,5], however few focus on the effects of repeated use of exosuit systems [3,6].

The primary purpose of this study was to quantify the effects of training with a powered soft exosuit. This work specifically investigated the braking and propulsive impulse between conditions and over multiple sessions. We hypothesized that braking and propulsive impulses would decrease over the course of a single session and between sessions during powered walking, as the wearer becomes better adapted to the exosuit. We also hypothesized that there would be significantly less braking and propulsive impulse during unpowered walking as compared to powered walking.

METHODS

Eight male United States Military Academy cadets (age: 20.6 ± 1.2 yr; height: 1.80 ± 0.09 m; weight: 78.6 ± 9.2 kg) participated in this study after providing IRB approved informed consent. The participants completed five sessions over 20 days, utilizing a backpack mounted soft exosuit, which provides assistance in hip extension during stance phase [7]. The exosuit mass was 5.4 kg and the backpack was loaded with an additional 20.4 kg. Each session consisted of 20 minutes of walking with the exosuit powered on, followed by 5 minutes of walking with the exosuit powered off. Multiple sessions were separated by at least 48 hours to reduce any impact from fatigue. Ground reaction force data was collected using an instrumented treadmill at 1000 Hz from the first two minutes of powered walking (condition A), the last two minutes of powered walking (condition B), and the last two minutes of walking with the exosuit powered off (condition C). Foot strikes from each two minute period were used in follow on calculations (94.6 ± 26.4 foot strikes per condition).

Braking and propulsive impulse were normalized by body mass and calculated during the right stance phase. Braking and propulsive impulse were found by taking the area under the posterior and anterior ground reaction force curves, respectively. Four different repeated-measure 2-way ANOVAs were used to identify statistical differences within and across sessions. Powered condition A was compared to powered condition B, for both braking and propulsive impulses separately. Powered condition B was compared to unpowered condition C, for braking and propulsive impulses separately. An alpha = 0.05 was chosen to represent a statistically significant difference between conditions and across sessions.

RESULTS AND DISCUSSION

Mean and standard deviation for braking and propulsive impulses across conditions and sessions are shown in Table 1. For braking, across conditions A and B, main effects were found for subject ($p<0.001$) and condition ($p<0.001$), but not for session ($p=0.416$). For propulsion, across conditions A and B, main effects were found for subject ($p<0.001$), condition ($p<0.001$), and session ($p=0.001$).

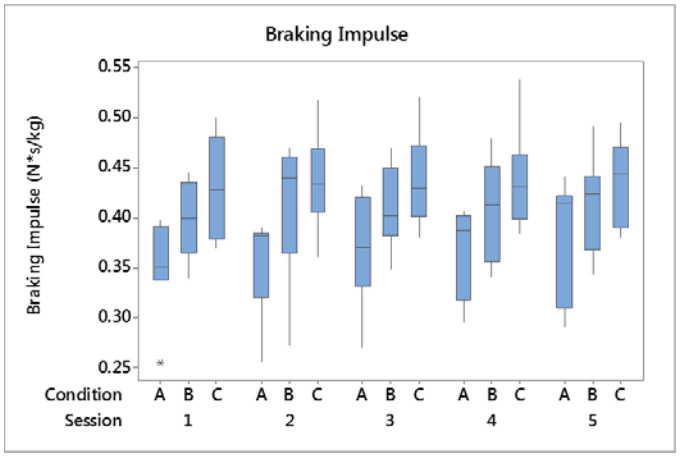

Figure 1: Boxplot of braking impulse for five sessions, conditions A, B, and C for each session.

For braking, across conditions B and C, main effects were found for subject ($p<0.001$), and condition ($p<0.001$), but not for session ($p=0.773$). For propulsion, across conditions B and C, main effects were found for subject ($p<0.001$), session ($p=0.001$), and condition ($p<0.001$).

These results indicate that successive training sessions using the exosuit changed how subjects applied propulsive impulse, but do not have significant effects on how they applied braking impulse. Between conditions A and B, from minutes 0-2 of powered walking to minutes 18-20 of powered walking, braking and propulsive impulse increased in magnitude. The highest magnitude of braking and propulsive impulse were recorded during condition C during minutes 23-25 of unpowered walking.

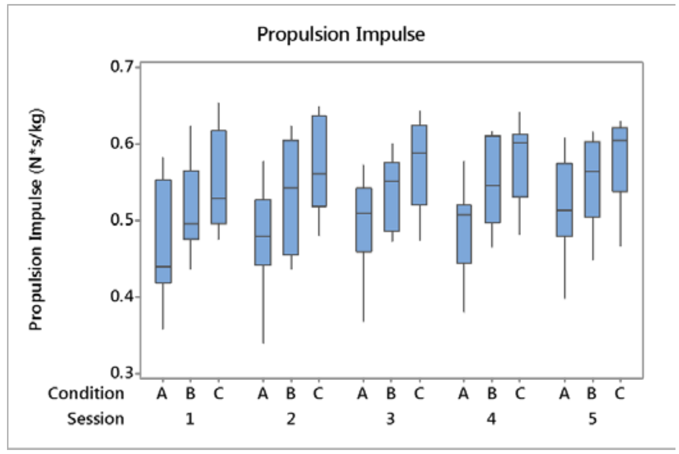

Figure 2: Boxplot of propulsive impulse for five sessions, conditions A, B, and C for each session.

CONCLUSIONS

We identified a significant difference in braking and propulsive impulses between powered and unpowered conditions. Propulsive impulse also changed significantly between multiple training sessions, while no difference was found in braking impulse across sessions. This data supports the notion that individuals may alter ground kinetics over time while using a powered exosuit. More research is required to identify how much training is necessary before steady state kinetics are obtained, and to identify the influence of fatigue and time on impulse.

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Table 1: Braking and propulsive impulses averaged across all eight subjects.

	Braking Impulse (N*s/kg)			**Propulsive Impulse (N*s/kg)**		
Condition	A	B	C	A	B	C
Session 1	0.35 ± 0.05	0.40 ± 0.04	0.43 ± 0.05	0.47 ± 0.08	0.51 ± 0.06	0.55 ± 0.07
Session 2	0.35 ± 0.05	0.41 ± 0.07	0.43 ± 0.05	0.47 ± 0.07	0.53 ± 0.07	0.57 ± 0.06
Session 3	0.37 ± 0.06	0.41 ± 0.04	0.44 ± 0.05	0.50 ± 0.06	0.54 ± 0.05	0.57 ± 0.06
Session 4	0.36 ± 0.04	0.41 ± 0.05	0.44 ± 0.05	0.49 ± 0.06	0.55 ± 0.06	0.58 ± 0.06
Session 5	0.38 ± 0.06	0.41 ± 0.05	0.44 ± 0.04	0.52 ± 0.07	0.55 ± 0.06	0.58 ± 0.06

Data are shown as mean and standard deviation. Conditions A, B, C are 0-2 minutes powered, 18-20 minutes powered, 23-25 unpowered respectively. Repeated measures 2-way ANOVAs were ran for condition (A vs. B and B vs. C) and session, p-values described in text.