# COMPARISON OF GROUND REACTION FORCES IN TWO RUNNING-SPECIFIC PROSTHESES (SPRINTER 1E90 AND CHEETAH XTREME): A CASE STUDY

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The purpose of this study was to describe the difference in ground reaction forces (GRF) between two different running-specific prostheses (RSPs) during maximal sprinting in a transfemoral amputee. One male sprinter performed maximal sprinting with two types of RSP (Sprinter 1E90 and Xtreme) on over 40 m runway with 7 force plates located halfway. Sprint velocity was found to be greater in the trials performed with Sprinter 1E90 than with Xtreme. The peak vGRF, zero fore-aft shear and impulse of the anterior-posterior component of the GRF with PST limb differed among the two RSPs. These results suggest that the participant in this study would show the differences in variables influencing on the sprint velocity between two types of RSPs.

**KEY WORDS:** biomechanics, prosthetic sprinting, transfemoral amputation.

**INTRODUCTION:** Since sprint kinematics in transfemoral amputees (TFAs) are quite different from those of able-bodied sprinters and transtibial amputees, improving sprint performance of this population can be a very complex task (Buckley, 1999). Ground reaction force (GRF)-time histories, which reflect the acceleration pattern of the center of gravity of body, form a part of the descriptive data that characterized the mechanics of running gait (Munro et al., 1987). In the sagittal plane of motion, peak vertical GRF (peak vGRF) and impulse of the anterior-posterior component of the GRF (apGRF) are thought to be the major factors influencing on of the sprint velocity (Hunter et al., 2005; McGowan et al., 2012; Morin et al., 2015). Despite the fact that sprint velocity in transtibial amputees could be affected by prosthetic foot shape (Nolan, 2008), little is known about those of TFAs. Therefore, the purpose of this study was to describe the difference in GRF between two different running-specific prostheses (RSPs) during maximal sprinting in a TFA.

**METHODS:** One male sprinter (body height: 1.67 m, body mass: 62.0 kg, 100-m personal record: 12.61 s) with unilateral transfemoral amputation participated in this study. One prosthetic knee (3S80; Ottobock, Germany) and two RSPs (Sprinter 1E90, category 3, 595 g; Ottobock, Germany and Cheetah® Xtreme™, category 5, 947 g; Össur, Iceland) were used during the trials. These two RSPs were used by most prosthetic sprinters who participated in the final for the Men's and Wemen's 100m-sprint in T42, T43 and T44 classes during the 2015 IPC Athletics World Championships. Participant was asked to perform maximal sprinting on over 40 m runway with 7 AMTI force plates (sampled at 2000 Hz) located in the center of the runway with Sprinter 1E90 at first, then Xtreme and given adequate rest between trials. Ten and six trials for Sprinter 1E90 and Xtreme were performed, respectively. Three-dimensional coordinate data of a reflective marker attached to sacral was captured by optical motion capture system (VICON MX+, sampled at 200 Hz). Sprint velocity was calculated from the position of sacral marker during passing over the 7 force plates. Three successful steps from each limb were analyzed. Magnitude of the peak vGRF and impulse of the apGRF of each limb were also computed. Additionally zero fore-aft shear and braking / propulsive impulse ratio were also calculated. Zero fore-aft shear defined as the timing at which fore-aft shear changed direction from braking to propulsion by Munro et al. (1987) In these variables, the relative differences between two RSPs in both intact (INT) and prosthetic

(PST) limbs were expressed in percentage of Sprinter 1E90's values. Variables calculated from GRF were normalized by subject's body weight.

**RESULTS:** Sprint velocity was found to be greater in the trials performed with Sprinter 1E90 than with Xtreme (Sprinter 1E90: 7.11±0.13 m/s, Xtreme: 6.60±0.13 m/s, mean±SD). Figure 1 depicts GRF-time histories in each component with different prostheses. Although the peak vGRF with Sprinter 1E90 was greater than that of Xtreme in PST limb, we observed a greater peak vGRF with Xtreme than with Sprinter 1E90 in INT limb. The difference of zero fore-aft shear between two prostheses were larger in PST limb than in INT limb (Figure- 1 C and D). As shown in Table1 and 2, there were -7.15% and -3.70% difference in the stance time between prostheses on PST and INT limb, respectively. For the impulse in anterior-posterior direction of PST limb, the impulse generated by Sprinter 1E90 was of smaller braking and larger propulsive impulses as compared to Xtreme. On the other hand, impulse of the apGRF on INT limb in trials with Xtreme was lager with Sprinter 1E90. Earlier zero fore-aft shear and greater propulsive / braking impulse ratio on PST limb were showed in trials with Sprinter 1E90. However, on INT limb, Xtreme had earlier zero fore-aft shear and greater braking / propulsive impulse ratio.

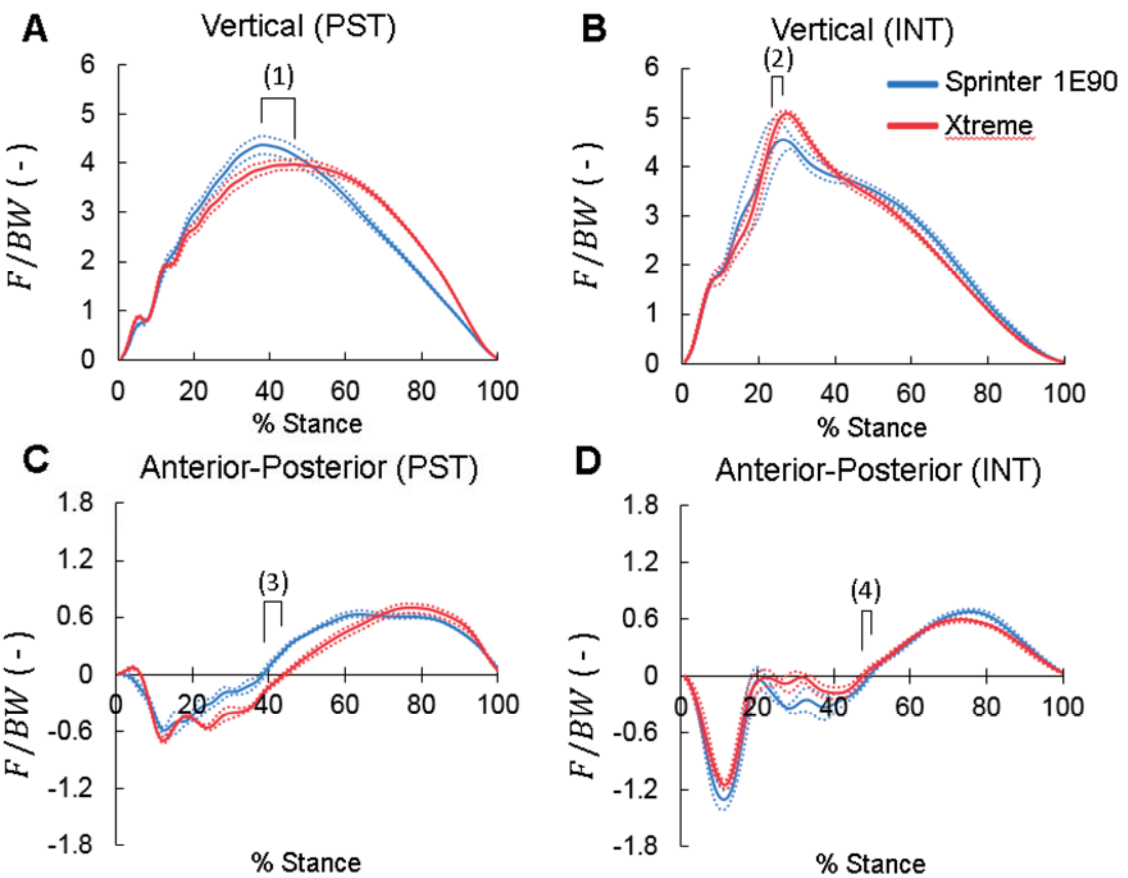


**Figure 1: Each component of GRFs (vertical: A&B, anterior-posterior: C&D) mean ± SD (dashed line) of force time profiles during the stance phase. A and C are GRF of PST limb. B and D are of INT limb. The numbers indicate the variables: (1) peak vGRF on PST limb, (2) peak vGRF on INT limb, (3) zero fore-aft shear on PST limb, (4) zero fore-aft shear on INT limb.**

**Table 1**
Comparison of the variables on PST limb between Sprinter and Xtreme

| | Sprinter 1E90 | Xtreme | Difference (%Sprinter 1E90) |
|---|---|---|---|
| stance time (s) | 0.119±0.002 | 0.127±0.002 | −7.15 |
| peak vGRF (N/BW) | 4.362±0.189 | 3.965±0.108 | 9.10 |
| braking impulse (Ns/BW) | −0.012±0.002 | −0.018±0.002 | −50.0 |
| proplusive impulse (Ns/BW) | 0.034±0.001 | 0.032±0.002 | 5.89 |
| impulse of apGRF (Ns/BW) | 0.022±0.003 | 0.015±0.003 | 31.8 |
| zero fore-aft shear (%) | 37.86±0.729 | 43.06±0.650 | −13.7 |
| P/B impulse ratio (-) | 2.824±0.539 | 1.835±0.237 | 35.1 |

**Table 2**
Comparison of the variables on INT limb between Sprinter and Xtreme

| | Sprinter 1E90 | Xtreme | Difference (%Sprinter 1E90) |
|---|---|---|---|
| stance time (s) | 0.108±0.002 | 0.112±0.001 | −3.70 |
| peak vGRF (N/BW) | 4.649±0.298 | 5.097±0.054 | −9.66 |
| braking impulse (Ns/BW) | −0.022±0.002 | −0.016±0.003 | 27.3 |
| proplusive impulse (Ns/BW) | 0.023±0.002 | 0.021±0.000 | 8.70 |
| impulse of apGRF (Ns/BW) | 0.001±0.003 | 0.006±0.003 | −500 |
| zero fore-aft shear (%) | 48.39±0.563 | 46.95±0.788 | 2.89 |
| P/B impulse ratio (-) | 1.065±0.157 | 1.416±0.318 | −34.0 |

**DISCUSSION:** The purpose of this study was to describe the difference in GRF between two different RSPs during maximal sprinting in a TFA. According to a previous study (McGowan et al., 2012), peak vGRF is a crucial parameter in achieving faster sprint velocity in both able-bodied and amputee sprinters. The participant in this study performed faster sprinting when he wore Sprinter 1E90 than Xtreme. Further, the peak vGRF with Sprinter 1E90 was greater than that of Xtreme in PST limb. Our results agree with a previous study which stated that sprint velocity could be affected by prosthetic foot shape (Nolan, 2008). However, we also observed a greater peak vGRF with Xtreme than with Sprinter 1E90 in INT limb. This result suggests that optimal selections for RSPs should be considered for PST limb rather than INT limb. Zero fore-aft shear shifted earlier on PST limb in trials with Sprinter 1E90 (37% stance) than with Xtreme (43% stance). But zero fore-aft shear on PST limb were generally earlier than those of INT limb in both RSPs in this study. Such results are also reflected in a previous finding which demonstrated that transtibial amputees has earlier shift of propulsive / braking GRF during stance phase (Baum, 2012). Early zero fore-aft shear induces an increase in time when propulsive force is applied to the body, which may result in greater impulse in the anterior component of the GRF in PST than INT limb. Compared with Xtreme, Sprinter 1E90 generated smaller braking and greater propulsive impulses on PST limb. Since impulse of the apGRF was the major factor influencing sprint velocity (Hunter et al., 2005; Morin et al., 2015), Sprinter 1E90 might be suitable for early acceleration of 100-m sprint in TFAs. There are certain considerations that must be acknowledged when interpreting the results of the current study. First, such results may not necessarily apply to a 100 m sprint as we only assessed 40 m runway. Second, there is only one participant in this study due to the limited number of TFAs who can sprint with several kinds of different prostheses. Clearly, the further study is needed to determine the factors which produce the difference on sprint velocity. Therefore, caution needs to be taken regarding the interpretation and generalization of these findings.

**CONCLUSION:** Sprint velocity was found to be greater in the trials performed with Sprinter than with Xtreme. This result suggests that the participant in this study would (1) reflect a difference between prostheses on the GRF-time histories and (2) show differences in the peak vGRF, zero fore-aft shear and the impulse of the apGRF with PST limb.

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