COMPARISONS OF SPATIOTEMPORAL PARAMETERS OF 100-M SPRINT AMONG ELITE-, SUB-ELITE AND NON-ELITE AMPUTEE SPRINTERS

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We investigated differences of the spatiotemporal parameters in a 100-m sprint among elite, sub-elite, and non-elite sprinters with a unilateral transtibial amputation. Using publicly available Internet broadcasts, we analyzed 125, 19, and 33 records from 30 elite, 12 sub-elite, and 22 non-elite sprinters, respectively. Average speed, step frequency, and step length were calculated Average speed was greatest in elite sprinters, followed by the sub-elite and non-elite groups. Although there was no significant differences in average step frequency, the average step length was longest in elite sprinters, followed by the sub-elite and non-elite groups. These results suggest that the differences in sprint performance between the three groups is mainly due to the average step length rather than step frequency.

KEY WORDS: prosthetic sprinting, running-specific prostheses, Paralympic games.

INTRODUCTION: Running-specific prostheses (RSPs) with energy storing capabilities have allowed amputee runners to compete at levels achieved never before (Hobara, Kobayashi and Mochimaru, 2015; Nolan, 2008). Theoretically, the average speed during a 100-m sprint is the product of the average step frequency and average step length. Although both parameters are inversely correlated, an increase in one factor will result in an improvement in sprint velocity, as long as the other factor does not undergo a proportionately similar or larger decrease. Because spatiotemporal parameters are modifiable by sprint training sessions (Bezodis Salo and Kerwin, 2008), identifying factors affecting these parameters of 100-m sprints in unilateral transtibial amputees will provide coaches and practitioners with a basis for better evaluation of sprint performance and aid in the development of more effective training methods for amputee sprinters.

On the other hand, despite the fact that examining sprint performance among different levels of sprinters is useful for training-conditioning programs and the design of effective talent development, less research attention has been given to examining differences in biomechanical characteristics in amputee sprinters using RSPs. In a previous study, Gajer Thepaut-Mathieu and Lehenaff (1999) compared sprint performance between faster and slower groups in able-bodied athletes. The authors found that the faster group had a longer stride length during the entire 100-m race than the slower group. However, it is unknown if this longer stride length of elite group can be observed in amputee sprinters using RSPs.

The aim of this study was to investigate the differences in the spatiotemporal parameters of a 100-m sprint among elite, sub-elite, and non-elite sprinters with a unilateral transtibial amputation. We hypothesized that the differences in sprint performance between the three groups would mainly be due to the average step length rather than step frequency.

METHODS: We analysed 177 races of 64 sprinters with lower extremity amputations from publicly available Internet broadcasts. Based on the classification system created by the International Paralympic Committee (IPC; http://www.paralympic.org/), we included the Men's T44 class (defined as any athlete with lower limb impairment/s that meets the minimum disability criteria for lower limb deficiency, impaired lower limb passive range of motion, impaired lower limb muscle power, or leg length difference). These races included several Paralympics, the IPC Athletics World Championships, and other national- and international-level competitions from 2004 to 2015. Individual races were excluded from the analysis if the athlete did not complete the race or the athlete's body was not visible throughout the entire race. T44 sprinters who did not use RSPs were also excluded. A similar approach – analysing publicly available data from sport competitions for research purposes – has been performed by Salo, Bezodis, Batterham and Kerwin (2011) for sprint running using 52 able-bodied sprinters and by Hobara et al. (2015) for prosthetic sprinting using 36 able-bodied, 25 unilateral, and 17 bilateral amputee sprinters. Institutional review board approval was obtained prior to the study.

In the present study, we separated the whole population into three groups based on qualification standards. The elite group (EL) consisted of sprinters who satisfied the A-Qualification Standards of the Men's T44 class (12.20 s) in the analyzed races (London 2012 Paralympic Games Qualification Guide-Athletics, 2011). The sub-elite group (SEL) consisted of sprinters who could not reach the A-Qualification Standards, but satisfied B-Qualification Standards (12.50 s). The non-elite group (NEL) consisted of sprinters who could not reach the B-Qualification Standards. Consequently, the EL, SEL, and NEL groups consisted of 125 (30 sprinters), 19 (12 sprinters), and 33 (22 sprinters) data, respectively.

According to a previous study (Hobara et al., 2015), we determined the average speed (S_{100}) of each individual by dividing the race distance (100 m) by the official race times (t_{race}), which were obtained from each competition's official website; thus,

$$S_{100} = 100 / t_{race}. \qquad (1)$$

In the present study, we calculated average step frequency (F_{step}) as

$$F_{step} = N_{step} \ / \ t_{race}, \qquad (2)$$

where N_{step} is the number of steps, which was manually counted by the authors. Because S_{100} is the product of F_{step} and average step length (L_{step}), we calculated the L_{step} by

$$L_{step} = S_{100} / F_{step} \qquad (3).$$

Before the statistical analyses, Levene's test was performed to ensure that the assumptions of normality and homogeneity of variance were met. Since the assumptions were violated in our data, the Kruskal-Wallis test was used to compare S_{100}, F_{step}, and L_{step} among the EL, SEL, and NEL groups. We also calculated the effect size (ES) for the Kruskal-Wallis test using Cramer's V. From this effect size calculation, the results were interpreted as small (0.1 to 0.3), medium (0.3 to 0.5), or large (higher than 0.5). If a significant main effect was observed, the Mann-Whitney U test with a Bonferroni correction as post hoc multiple comparison was repeated for all combinations in each variables. Because there were three Mann-Whitney U tests in each variable, the alpha levels were set at 0.016 (0.05/3) and 0.003 (0.01/3). Statistical significance was set at $p < 0.05$. These statistical analyses were executed using SPSS version 19 (IBM SPSS Statistics Version 19, SPSS Inc., Chicago, IL).

RESULTS: Figure 1 shows the F_{step}–L_{step} plot for all the individuals in the three groups including the predicted time using respective F_{step} and L_{step} combinations. As shown in Figure 2-A, S_{100} exhibited a significant main effect on the groups (X^2 (2) = 112.66, $p < 0.01$, ES= 0.57). S_{100} was greatest in EL, followed by SEL and NEL ($p < 0.003$ for all comparisons). Statistical analyses revealed that F_{step} had a significant main effect on the groups (Figure 2-B; X^2 (2) = 13.184, $p < 0.01$), and F_{step} in EL was significantly higher than SEL ($p < 0.016$) but not NEL. However, the relative difference between EL and SEL was 3.1%, and the ES of the Kruskal-Wallis test was 0.19 (small). L_{step} also displayed a significant effect on the groups

(Figure 2-C; X^2 (2) = 72.58, $p < 0.01$, ES=0.45). Statistical analyses also revealed that L_{step} was longest in EL, followed by SEL and NEL ($p < 0.003$ for all comparisons).

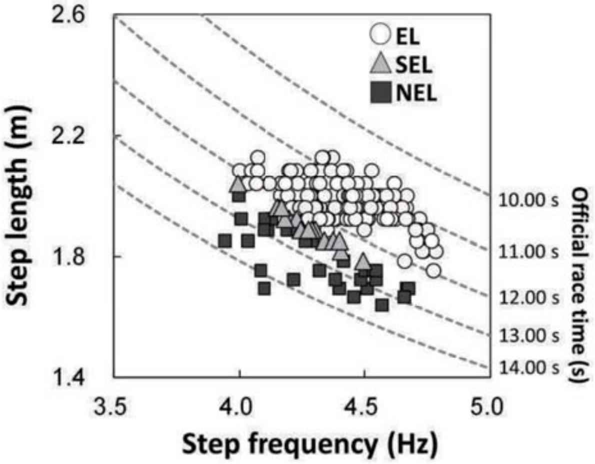

Figure 1: Relationship between step frequency and step length for the three groups. Unfilled circles, grey triangles, and filled squares indicate the data for elite (EL), sub-elite (SEL) and non-elite (NEL) groups, respectively. Dotted lines denote the official race times calculated using the combination of step frequency and step length.

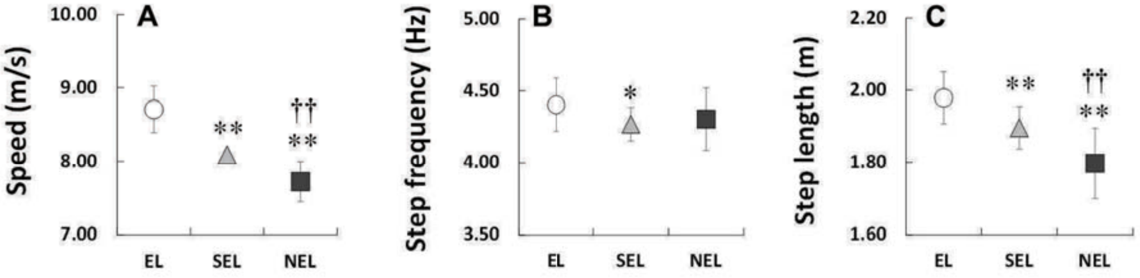

Figure 2: Comparisons of averaged speed (A), step frequency (B) and step length (C) among three groups. Asterisks (**) indicate significant differences with EL at $p < 0.01$. Daggers (††) indicate significant differences with SEL at $p < 0.01$.

DISCUSSION: The aim of this study was to investigate the differences in the spatiotemporal parameters of a 100-m sprint among elite, sub-elite, and non-elite sprinters with a unilateral transtibial amputation. In the present study, S_{100} was greatest in EL sprinters, followed by SEL and NEL (Fig 2-A). Although a statistically significant difference in F_{step} between the three groups was identified (Fig 2-B), the ES for this effect was small (0.19). On the other hand, L_{step} was the longest in EL, followed by SEL and NEL (ES = 0.45, medium). Therefore, the results of the present study support our initial hypothesis that the differences in sprint performance between the three groups would mainly be due to the L_{step} rather than the F_{step}.

In a previous study, Hunter, Marshall and McNair (2004) introduced a deterministic model for sprint running, especially for both the F_{step} and L_{step}. Based on the deterministic model, determinants of F_{step} and L_{step} could be partly explained by the relative horizontal and vertical ground reaction force impulse, segment positions, segment inertial parameters, and air resistance. For the ground reaction forces, Rabita, Dorel, Slawinski, Sàez-de-Villarreal, Couturier, Samozino et al. (2015) found that elite able-bodied sprinters in their study had a 9.7% greater force production capacity than sub-elite able-bodied sprinters. Furthermore, Fortier Basset, Mbourou, Favérial and Taesdale (2005) and Slawinski, Bonnefoy, Leveque, Ontanon, Riquet and Dumas et al. (2010) reported that elite able-bodied sprinters showed better force production capacity during the sprint start and subsequent steps than sub-elite able-bodied sprinters. Therefore, the differences in L_{step} among elite, sub-elite, and non-elite sprinters with a unilateral transtibial amputation in our study may be attributed to force production capacity during sprinting.

Although we calculated the average step length using the number of steps taken and the time of the whole race as data, not all the steps during a 100-m sprint have the same length and frequency. For example, step frequency and step length have been documented to change as a sprint progresses from the start in able-bodied sprinters (Nagahara, Naito, Morin and Zushi, 2014), indicating that these average values may not necessarily be representative of any particular part of the sprint. Thus, the current data should be recognized as an 'average' F_{step} and L_{step} during 100-m sprint.

CONCLUSION: In summary, we investigated differences in the spatiotemporal parameters of a 100-m sprint among elite, sub-elite, and non-elite sprinters with a unilateral transtibial amputation. The results of the present study suggest that the differences in sprint performance between the three groups is mainly due to the L_{step} rather than the F_{step}.

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