STEP CHARACTERISTICS DURING LONG JUMP APPROACH: RELIANCE AND ASYMMETRY CONSIDERATIONS

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This study's aim was to investigate step characteristic reliance and asymmetry during the long jump approach. Spatiotemporal data of the approach run were collected in national and international athletic competitions of 10 males (age 26.2 ± 4.1 yrs, height 1.84 ± 0.06 m, mass 72.77 ± 3.23 kg, PB 7.96 ± 0.30 m) and 9 females (26.3 ± 2.19 yrs, 1.73 ± 0.05 m, 55.75 ± 3.79 kg, 6.68 ± 0.20 m). Only two males showed step length reliance and only during late approach. Step frequency reliance was demonstrated during total, early and late approach, most prevalently during the latter (7/10 male & 3/9 female). Four males and females displayed step length asymmetry whilst three males and two females were asymmetrical for frequency. No athletes showed step velocity asymmetry. In conclusion, asymmetrical demands of take-off were not consistently reflected in step characteristics.

KEY WORDS: STRIDE, SPRINT, STEP FREQUENCY, STEP LENGTH, STEP VELOCITY

INTRODUCTION: Long jump approach running requires athletes to achieve high velocity to generate the required explosive strength at takeoff. It has been generally accepted (Hunter, Marshall & McNair, 2004; Salo, Bezodis, Batterham & Kerwin, 2011) that step velocity (SV) is the product of step length (SL) and step frequency (SF). Furthermore, in light of the conflicting demands of SL and SF it has been suggested that some athletes may be more reliant on one of these latter characteristics to develop SV (Salo et al., 2011). During late approach SV is well established as the most dominant factor for long jump performance (Hay, 1986). In the approach run, athletes must maximise SV but with the added constraint of placing their foot accurately at the point of take off. It has been reported that adjustments are made to step characteristics in order to achieve maximal SV with optimal foot placement (Bradshaw & Aisbett, 2006). Whilst step characteristics have been widely reported during acceleration and maximal velocity phases of sprint running, with the exception of the final steps preceding take off, there is little information available regarding these variables during the long jump approach run. Furthermore, due to the additional spatial constraints on foot placement, it is not known whether step characteristic reliance differs during running preceding a jump to straight line sprint running.

A further consideration when maximising SV whilst controlling foot placement is step characteristic asymmetry. Knowledge of asymmetry during running gait can be beneficial from performance, injury and methodological perspectives (Carpes, Mota & Faria, 2010; Exell, Irwin, Gittoes & Kerwin, 2012b). Due to the asymmetrical nature of the long jump take-off, and repeated explosive performance from one limb, athletes may achieve the required approach velocity through asymmetrical step characteristics, which could have implications on athlete training and injury potential. Exell, Gittoes, Irwin and Kerwin (2015) reported the asymmetry of lower-limb strength and step characteristics during sprint running. However, to the authors' knowledge, asymmetry of step characteristics has not been reported during the approach phase in horizontal jump events.

The aim of this study was to develop understanding of step characteristics in high level male and female long jumpers during the approach run. Subsequently, the objectives of the present study were to a) investigate the relative influence of SL and SF on SV of high level long jumpers during the total approach run and b) to quantify the direction and magnitude of asymmetry of these step characteristics.

METHODS: Ethical approval was gained from the university ethics committee prior to data collection. Step characteristic data were obtained for ten male (M; age 26.2 ± 4.1 yrs, height 1.84 ± 0.06 m, mass 72.77 ± 3.23 kg, PB 7.96 ± 0.30 m) and nine female (F; age 26.3 ± 2.19 yrs, height 1.73 ± 0.05 m, mass 55.75 ± 3.79 kg, PB 6.68 ± 0.20 m) athletes during the 2014 Greek Athletics Championship and the 2015 European Team Championships-First League. Data were collected using video (300 fps) and markers located on the approach runway, as detailed by Theodorou, Skordilis, Plainis, Panoutsakopoulos and Panteli (2013). Approach run phases were defined as the initial to the eleventh step from take off (early phase), the tenth to the third step from take off (late phase) and these phases combined (total approach). The last two steps of each run were excluded from analysis due to the changes of these steps in preparation for take off (Hay, 1986).

Individual athlete analyses were performed, due to previously reported individual differences in step characteristic reliance (Salo et al., 2011). To investigate step characteristic reliance (SV on SL or SF), a similar analysis as used by Salo et al. (2011) was performed, with athletes classified during three phases of the approach (early, late and total) as being reliant on SL, SF or neither. Briefly, this involved a bootstrapping technique (10 000 resamples, Matlab, R2015b) of the natural log transformed SL, SF and SV values. Differences in Pearson's (r) correlations between SL, SV and SF, SV were then calculated (r of SF, SV minus r of SL, SV) for each resample. Ninety percent confidence intervals (CI) were calculated for the correlation differences, which indicated SL or SF reliance. Athletes were SL reliant if the mean correlation difference was positive, with the 90% CI lower limit $\geq$ -0.1 and SF reliant if mean correlation difference was negative , with the upper limit of the CI $\leq$ 0.1.

Step characteristic asymmetry was calculated based on the method of Exell, Gittoes, Irwin and Kerwin (2012a). Asymmetry magnitude was quantified between steps from the preferred (takeoff) and non-preferred limbs using the symmetry angle (θ_{SYM}) equation:

$$\theta_{SYM} = ((45 - X_P / X_{NP}) / 90) \times 100$$

where X_P and X_{NP} = preferred and non-preferred limb values, respectively.

Following tests for normality (Shapiro-Wilk), Mann-Whitney U tests between sides for each step characteristic determine whether the asymmetry for each variable was significant ($p < 0.05$) with respect to intra-limb variability (Exell, Irwin, Gittoes & Kerwin, 2012b).

RESULTS: During the competitions the investigated jumpers achieved 95.0 ± 2.5% of their PB performances. Male and female jump performance and step characteristic asymmetry results are presented in Tables 1 and 2, respectively. Similar trends are displayed for both sexes. Four male and four female athletes demonstrated asymmetry for SL with two male and three female athletes displaying larger values for the preferred limb. Three male and two female athletes displayed significant SF asymmetry with all but one (M7) showing larger values for the non-preferred side.

Table 1
Asymmetry of step characteristics (θ_{SYM}) between preferred (P) and non-preferred (NP) limbs for male athletes during total approach

Athlete & performance (m)		Step Length P (m)	NP (m)	θ_{SYM} (%)	Step Frequency P (Hz)	NP (Hz)	θ_{SYM} (%)	Step Velocity P (m/s)	NP (m/s)	θ_{SYM} (%)
M1	8.08	2.22	2.27	0.66	4.28	4.36	0.62	9.50	9.91	1.33
M2	7.88	2.29	2.29	0.10	3.95	4.07	0.93	9.06	9.33	0.93
M3	7.81	2.37	2.38	0.10	3.87	3.97	0.81	9.19	9.44	0.87
M4	7.76	2.12	2.20	1.10	4.51	4.57	0.42	9.58	10.03	1.47
M5	7.65	2.31	2.17	-1.95*	4.29	4.69	2.83*	9.90	10.16	0.84
M6	7.43	2.25	2.31	0.73	3.97	3.98	0.03	8.96	9.17	0.76
M7	7.43	2.20	2.40	2.73*	4.23	4.04	-1.49*	9.31	9.68	1.24
M8	7.23	2.24	2.33	1.33*	4.10	3.94	-1.24	9.17	9.19	0.06
M9	7.20	2.27	2.18	-1.41	3.76	4.18	3.42	8.54	9.09	1.97
M10	7.19	2.41	2.23	-2.51*	4.11	4.52	3.00*	9.91	10.06	0.49

* = significant asymmetry ($p < 0.05$). Positive θ_{SYM} = NP > P.

Table 2
Asymmetry of step characteristics (θ_{SYM}) between preferred (P) and non-preferred (NP) limbs for female athletes during total approach

Athlete & performance (m)		Step Length P (m)	Step Length NP (m)	Step Length θ_{SYM} (%)	Step Frequency P (Hz)	Step Frequency NP (Hz)	Step Frequency θ_{SYM} (%)	Step Velocity P (m/s)	Step Velocity NP (m/s)	Step Velocity θ_{SYM} (%)
F1	6.29	2.30	2.20	-1.51*	3.72	3.95	1.91	8.58	8.69	0.40
F2	6.22	2.24	2.13	-1.63*	3.75	4.08	2.70*	8.38	8.67	1.09
F3	6.06	2.29	2.00	-4.32*	3.67	4.18	4.12*	8.40	8.36	-0.18
F4	6.14	2.09	2.08	-0.13	3.95	4.02	0.55	8.27	8.37	0.39
F5	6.40	2.00	2.06	0.97	4.28	4.14	-1.00	8.54	8.55	0.04
F6	6.43	2.17	2.36	2.72*	4.02	3.78	-1.93	8.69	8.93	0.86
F7	6.38	2.16	2.24	1.17	3.91	3.81	-0.80	8.44	8.53	0.35
F8	6.34	2.21	2.26	0.63	3.77	3.74	-0.29	8.36	8.44	0.32
F9	6.53	2.01	2.11	1.66	3.97	3.84	-1.03	7.97	8.10	0.50

* = significant asymmetry ($p < 0.05$). Positive θ_{SYM} = NP > P.

Step characteristic reliance results are presented in Figure 1. Step length reliance was not demonstrated by many athletes with no male athletes reliant during the early and total phases of analysis and no female athletes SL reliant during any phase. For total approach, 4/10 male (M4, M5, M7 & M8) and 1/9 female (F2) athletes were SF reliant. During early approach, SF reliance was demonstrated by 3/10 male (M4, M5 & M7) and 2/9 female (F2 & F4) athletes. During the late approach phase 2/10 males (M1 & M7) demonstrated SL reliance and 7/10 (M2, M4-6 & M8-10) were SF reliant, whilst 3/9 (F1, F2 & F5) females were SF reliant and 6/9 demonstrated no reliance on either characteristic.

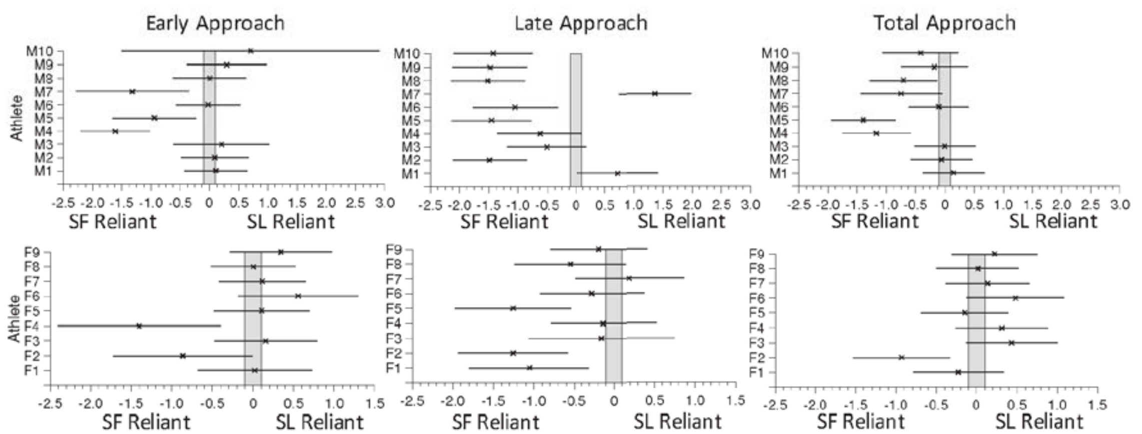

Figure 1: Step characteristic reliance for male (top) and female (bottom) athletes

DISCUSSION: This study aimed to facilitate understanding regarding the influence of SL and SF on SV in high level male and female long jumpers during the overall approach run. The step characteristic analyses revealed that step characteristic reliance varied between individual athletes but that there was a general trend for SF to have the greatest influence on SV, as displayed by more than half of all athletes during the late approach phase. The individual nature of step characteristic reliance has been previously reported during sprint running by Salo et al. (2011) but with both SL and SF being favoured by different athletes. The greater dependency on SF displayed by the male athletes in this study than reported during sprint running confirm the notion of Hay (1986) that an increase in stride frequency is the predominant method in which the long jumper can strive to increase late approach speed. However, the low proportion of women demonstrating SF reliance may indicate that the interaction between both step characteristics differ between male and female athletes (Debaere, Jonkers, & Delecluse, 2013).The prevalence of step characteristic asymmetry was similar in the current study to that previously reported during maximal velocity sprint running

(Exell et al., 2015); however, largest asymmetry magnitude values were higher in the current study (M = 3.00%, F = 4.32%) than those reported during sprint running (1.68%). Asymmetry analyses of step characteristics did not reveal a consistent trend across the athletes in this study. Eight athletes (4 male, 4 female) displayed significant asymmetry for SL and five athletes (3 male, 2 female) for SF. No athletes demonstrated significant asymmetry for SV, as previously reported in sprint running (Exell et al., 2015). An interesting finding is that the direction of asymmetry was not consistently related to the athletes' take-off limb, with five athletes (2 male, 3 female) displaying greater SL for the preferred limb and three (2 male, 1 female) for the non-preferred limb. These findings indicate that the asymmetrical explosive nature of the take-off event may not influence step characteristic asymmetry during the long jump approach run. A finding in this study that was consistent with previous asymmetry analyses of sprint running (Exell et al., 2015) was that the athletes in the current study that demonstrated significant asymmetry for SL and SF (M5, M7, M10, F2 & F3) favoured a different limb for each characteristic. This appears to be a fundamental characteristic of asymmetry in straight line sprint (Exell et al., 2015) and approach running, resulting in athletes demonstrating no significant asymmetry in SV. However, further research is required to identify whether it would be more beneficial for asymmetrical athletes to adapt their training to reduce step characteristic asymmetry or train the preferred and the non-preferred limbs differently to take advantage of the differing step characteristic reliance of each limb.

CONCLUSION: Based on the overall prominence of SF-reliant athletes, it is proposed that athletes and coaches should consider step characteristic reliance in their training, with SF-reliant athletes needing to keep their neural system ready for fast leg turnover and SL-reliant athletes requiring more concentration on maintaining strength levels (Salo et al., 2011). Five of the 19 athletes in this study demonstrated significant asymmetry of opposing direction for both SL and SF, which indicates that training to improve step characteristics may need to be tailored for each limb for these athletes, due to the conflicting demands of each limb.

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