ASYMMETRY IN SPRINT RUNNING: STRENGTH AND PERFORMANCE INTERACTIONS

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Asymmetry in sprint running can influence performance and injury. The aim of this study was to investigate the interaction between asymmetry in sprint performance and lower-limb strength. Ground reaction force data were collected from eight sprint runners whilst performing maximal effort squat jumps. Asymmetry during jump tests was compared with asymmetry of step responses and kinetic variables collected during maximal velocity sprint running trials. Significant positive correlations were reported between net ankle work in sprinting and peak force (r = 0.895) and peak power (0.761) during strength diagnostic jump tests. Results indicated individual athlete asymmetry profiles for both performance and strength asymmetry, suggesting that bilateral strength imbalances do not entirely account for asymmetry in performance variables during sprint running.

KEY WORDS: squat jump, symmetry angle, kinetic asymmetry

INTRODUCTION: Maximal velocity sprint running is of particular interest in sports biomechanics due to athletes performing at the body's limits of performance. Explosive performance measures, such as peak power, have been identified as important methods of evaluating sprint-specific strength (Harman et al., 1991). During straight, flat sprint events (i.e. 60 & 100 m) athletes appear to run with a symmetrical, cyclical gait pattern. However, recent research has identified significant asymmetry to be present in step characteristic, kinematic and kinetic variables during maximal velocity sprinting (Exell et al., 2012a,b). Knowledge of asymmetry during sprint running can be beneficial to athletes, coaches and biomechanists and can influence performance, injury and data collection. Asymmetry during the late acceleration phase of sprint running has been associated with greater hamstring injury potential (Ciacci et al., 2013). Furthermore, Vagenas and Hoshizaki (1991) identified strength imbalances as a cause of performance asymmetry in submaximal running. From these previous studies, it appears that asymmetry identified during sprint running may increase injury potential of the lower limbs and be the result of lower-limb strength imbalances; however, this relationship between strength and performance asymmetry is not clear. Enhanced biomechanical understanding of this relationship may be beneficial to sprinters and coaches and has potential to impact sprint running performance and injury predisposition. Therefore, the aim of this study was to investigate the interaction between asymmetry during maximal velocity sprint performance and asymmetry of lower-limb strength. The purpose of the study was to inform sprinters and coaches about asymmetry of performance and strength, which may influence physical preparation of athletes.

METHODS: Prior to the study, ethical approval was obtained from the university research ethics committee and written informed consent given by all participants. Sprint performance and strength data were collected from eight sprint-trained athletes (age = 22±5 years, mass = 74.0±8.7 kg & stature = 1.79±0.07 m). Athletes performed 9-12 maximal 60 m sprint runs (mean velocity = 9.05 ± 0.37 $m \cdot s^{-1}$), during which synchronised three-dimensional positional and ground reaction force data were collected. Positional data were collected from an 8 m section of each run, centred on the 40 m mark, using an automated motion analysis system (CODA, Charnwood Dynamics, Leicester, UK) operating at 200 Hz. Twelve active cx1 markers were connected in pairs to 'twin-marker drive boxes' and attached to athletes lateral to the fifth metatarsal-phalangeal joint, lateral malleolus, lateral condyle of the tibia, greater trochanter, iliac crest and greater tubercle for both sides of the body. Two piezoelectric force plates (Kistler 9287BA) operating at 1000 Hz were used to collect ground reaction force data.

The force plates were mounted end to end along the direction of the running lane in recessed customised housings and covered with running track identical to that covering the rest of the lane. To measure explosive limb strength, athletes also performed five maximal effort squat jumps, during which each foot was placed on a separate force plate (Kistler 9287BA).
All data were filtered using a fourth-order Butterworth filter with optimal cut-off frequencies determined using the autocorrelation method (Challis, 1999). Strength data were analysed using the limb-specific ground reaction force profiles. Vertical velocity of the centre of mass (CM) was calculated from the total net force applied to both plates by dividing the cumulative impulse by the participant's mass, as described by Harman et al. (1991). Individual limb joint powers were calculated by multiplying CM vertical velocity by the vertical ground reaction force applied to each force plate. Peak and average power values were calculated for each limb in addition to net work performed by each limb, calculated by integrating the power-time profiles. Asymmetry was calculated for kinematic and kinetic performance variables associated with success in sprint running, as described in Exell et al. (2011). Briefly described, asymmetry between left and right limb values was calculated using the symmetry angle (θ_{SYM}) proposed by Zifchock et al. (2008). Significant asymmetry was then quantified based on t-test results ($p<0.05$) for each variable using the method of Exell et al. (2012a). Following tests for normality, relationships between strength and performance asymmetry across the group of athletes were tested for using Pearson's Product-Moment Correlation.

RESULTS: Strength asymmetry results for the eight athletes are presented in Table 1. Three athletes showed significant asymmetry for peak power (Athletes 1, 3 & 6) and peak vertical force (Athletes 3, 6 & 7), while one athlete demonstrated significant ($p<0.05$) asymmetry for net work (Athlete 1). Table 2 includes asymmetry of performance variables associated with sprint performance. Variables include step velocity, length and frequency (SV, SL and SF, respectively), maximum vertical ground reaction force (Fz_{MAX}) and net joint work performed at the ankle, knee and hip (WA_{NET}, WK_{NET} and WH_{NET}, respectively).

Table 1
Asymmetry of strength variables for eight athletes

Athlete	Fz_{MAX}	P_{MAX}	W_{NET}
1	1.69*	0.44	2.34*
2	-0.20	-1.01	-0.09
3	-0.70*	-1.55*	-0.29
4	-0.38	-0.85	-1.80
5	0.69	0.19	1.73
6	1.15*	1.44*	2.30
7	-1.30	-0.59*	-0.26
8	-2.27	-3.16	-0.87

* = significant difference between left and right limb values ($p<0.05$), positive value denotes R>L

Table 2
Asymmetry of performance variables

Athlete	SV	SL	SF	Fz_{MAX}	WA_{NET}[1,2]	WK_{NET}	WH_{NET}
1	-0.79*	-1.28*	1.13	2.14	42.95*	8.48	-5.47
2	-0.62*	1.16*	-1.68*	-0.38	11.64	-76.94*	11.28
3	-0.32*	0.79	-0.81	2.32	-6.07	-23.23	-21.63
4	-0.18	1.33*	-1.44*	3.01*	21.57*	42.67	-3.42
5	-0.22	-1.01	1.12	1.12	23.74	23.82*	24.25
6	-0.39*	1.04*	-1.38*	0.90	14.54*	22.86	13.83
7	0.25	-0.62	0.65	0.71	-41.25*	56.43	-66.43
8	-0.25	0.58	-0.65	4.33*	-93.23	-79.56	44.99*

* = significant difference between left and right limb values ($p<0.05$), positive value denotes R>L
[1] = significant correlation with Fz_{MAX} ($r = 0.895$) [2] = significant correlation with P_{MAX} ($r = 0.761$)

Significant correlations between strength and performance variables are highlighted in Table 2, with the only significant correlations found to exist between WA_{NET} and Fz_{MAX} (r = 0.895) and WA_{NET} and P_{MAX} (r = 0.761). Athlete-specific asymmetry profiles in performance variables were reported and no link between asymmetry and sprint performance was identified.

DISCUSSION: The aim of this study was to investigate the interaction between asymmetry during maximal velocity sprint performance and asymmetry of lower-limb strength with the purpose of informing sprinters and coaches about asymmetry of performance and strength variables. For the three strength variables calculated, four of the eight athletes showed significant asymmetry for at least one of the variables. When comparing strength and performance asymmetry the only significant relationships were found between WA_{NET} during sprinting and peak force and power values in the jump tests. This finding suggests that the ankle joint may play an important role in regulating asymmetry at the athlete-ground interface. Three athletes (Athletes 1, 3 & 6) demonstrated significant asymmetry for two of the three strength variables. However, conflicting findings were reported for Fz_{MAX} during sprint and jump trials, with Athletes 1, 3 and 6 demonstrated significant asymmetry in Fz_{MAX} during the squat jumps but not during sprint running trials. Conversely, Athletes 4 and 8 were significantly asymmetrical for Fz_{MAX} during sprint running, but not during the jump tests. A possible explanation for the disagreement in asymmetry results for Fz_{MAX} is the inclusion of a touchdown phase during a sprinting step that is not included during the propulsive phase of a squat jump.

Peak explosive power is often used as a sprint-specific strength diagnostic (Harman et al., 1991). During jump tests, significant asymmetry was reported for peak power for Athletes 3, 6 and 8; however, these athletes did not show a consistent link with asymmetry in step characteristic performance variables. Athlete 3 demonstrated significantly greater power for the left limb, with significantly larger step velocity also reported off of the left limb for this athlete. Conversely, Athlete 6 demonstrated significantly larger peak power for the right limb during the jump tests but with significantly larger step velocity from the left take-off during sprinting. An interesting observation for Athlete 6 was the significantly larger step length from right take-off whereas the opposite was reported for step frequency. The interaction between step characteristics is reportedly complex (Salo et al., 2011). The results for Athlete 6 indicate that the larger peak power generated by the right limb could lead to larger step length following right take-off; however, this step length asymmetry is not reflected in step velocity due to the larger asymmetry in the opposite direction for step frequency.

Only one athlete (Athlete 1) showed significant asymmetry for net vertical work during the jump tests, despite all athletes except one (Athlete 3) having significant asymmetry for net joint work at either the ankle, knee or hip during sprint trials. The absence of more athletes displaying significant asymmetry for vertical work during the jumps indicates that individual joint strength asymmetries may be compensated for, reducing overall asymmetry between limbs. This finding supports the notion of Vagenas and Hoshizaki (1991), that individual joint asymmetry may provide more insight than limb dominance when evaluating strength and performance.

Asymmetry in sprint running may have important implications on injury (Ciacci et al., 2013). For the strength variables presented in this study, asymmetry does not appear to be consistently linked with performance for the athletes analysed. However, links between strength and performance asymmetry were apparent for some variables (i.e. peak power and step length, Athlete 6). The lack of a consistent link between strength and performance asymmetry demonstrates that asymmetry in sprint running is not solely due to strength imbalances between limbs. Other possible contributors to asymmetry in sprint performance include structural differences and individual joint torque asymmetries. However, net strength asymmetry measures such as those presented could be used in athlete screening protocols to identify strength imbalances between limbs. A limitation of this study was the comparison of overall lower-limb strength during jump tests with individual joint asymmetry during sprint performance. Future work in this area should consider strength asymmetry at individual joints of the lower limb and bilateral structural differences.

CONCLUSION: Following recent work reporting asymmetry during sprint running, this study investigated the interaction between strength and performance asymmetry in sprinters. As with analyses of sprint running performance, asymmetry profiles for strength asymmetry were athlete-specific. However, there appears to be a link between asymmetry of lower-limb strength and net ankle work performed whilst sprinting. Individual links between overall limb strength asymmetry and asymmetry in performance variables were reported but the link was not consistent for all athletes. These findings highlight the individual nature of asymmetry in both performance and strength variables and indicate that performance asymmetry is influenced by more than just limb strength imbalance. Since asymmetry may lead to increased injury potential, these findings may be beneficial for athletes and coaches, providing unique insight into strength and performance asymmetry for a group of trained sprint runners.

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