LOWER LIMB ASYMMETRY DURING THE SKELETON PUSH START

Mike Muckelt[1,2], Laurie Needham[1,3], Ezio Preatoni[1], Steffi Colyer[1,3]
Dept for Health, University of Bath, UK[1]
British Bobsleigh and Skeleton Association, UK[2]
Centre for the Analysis of Motion, Entertainment Research and Applications, University of Bath, UK[3]

The aim of this study was to identify the presence and performance implication of asymmetry within the skeleton push start. Motion data were captured on 13 international skeleton athletes, using a custom 9-camera computer vision system. 6 maximal effort pushes were captured allowing the reconstruction of a 0–15 m push. Intra-limb differences for spatiotemporal variables and the change in velocity (ΔV) across a step were analysed. A negative relationship existed between 5 – 15 m split time and ΔV across a stride. Athletes who maximise their velocity across a stride were more likely to perform well in the skeleton push start. Though athletes employed different strategies based on inside and outside leg ΔV to achieve their performance outcome.

KEYWORDS: step characteristics, winter sports, performance

INTRODUCTION: Skeleton is a Winter Olympic sport which requires athletes to maximally push a sled in a bent over position, before "loading" the sled after 20 – 30 m and assuming a prone driving position. A fast start is critical for success in skeleton, with faster start times showing significant correlation (ρ = 0.87) with faster finish times (Oguchi, Ae & Schwameder, 2021). Previous research has demonstrated that athletes who can express large forces rapidly, as with sprinting, tend to excel within skeleton (Colyer, Stokes, Bilzon, Cardinale & Salo, 2017). However, there is limited research regarding the kinematic factors which may influence skeleton start performance. Oguchi et al. (2021) suggested that international level skeleton athletes achieve faster start times through a greater running speed acquired by large step lengths. More recently using a novel markerless motion capture system Needham et al. (2021) identified large asymmetries between the inside (leg closest to the sled) and outside leg when pushing. The inside leg demonstrated significantly greater (p <0.001) step length (SL), step velocity (SV) and flight time (FT) than the outside. Whilst the outside leg had significantly greater (p <0.001) step frequency (SF); (Needham et al., 2021). No difference in ground contact time (GCT) was observed between limbs. However, it remains unclear as to how this asymmetry might affect performance during the push start. The aim of this study was to confirm the presence of lower limb asymmetry during the push start in a group of male and female international level athletes and identify its effect on push start performance.

METHODS: Thirteen (8 males, 5 females) international skeleton athletes participated in this study. The local research ethics committee provided ethical approval for this study and all athletes provided informed consent prior to participation. Athletes completed six maximal effort push starts as part of their regular training routine.

Motion data were captured using a custom 9-camera (HD resolution, 200 Hz, JAI sp5000c, JAI ltd, Denmark) computer vision system. The camera system was positioned to capture the push from the start block to 10 m mark for the first three pushes. For the subsequent three pushes the start block was moved 5 m back, therefore capturing 5 – 15 m phase of the push. The best push from both block positions were used to reconstruct a 0 – 15 m and used for analysis.

Calibrated videos (Needham et al., 2021) were annotated using a custom-built annotation tool which computed the 3D touch-down (first frame the foot was visibly in contact with the ground) and toe-off (first frame the foot had visibly left the ground) locations and timings, annotation took place on the tip of the toe. A custom written MATLAB (MathWorks, USA, 2021a) script was used to compute SL, SF, FT and GCT. SV was calculated from:

$$SV = SL \times SF$$

Change in velocity (ΔV) within steps for inside and outside leg were calculated and ΔV within a stride were calculated from:

$$\Delta V = SV_{final} - SV_{inital}$$

Characteristics for inside and outside leg were averaged across all steps in the 15 m capture volume. Between leg differences were identified using estimation statistics (Ho, Tumkaya, Aryal, Choi & Claridge-Chang, 2019) for SV, SL, SF, FT, GCT and ΔV. Paired Hedges' g effect sizes (trivial < 0.2, small 0.2 ≥ g ≤ 0.5, medium 0.5 ≥ g ≤ 0.8, large ≥ 0.8), and 95% bootstrap confidence intervals were created. P values were computed using a Permutation t-test. A linear regression model was fit to the 5 – 15 m split time and average change in stride velocity across all strides.

RESULTS AND DISCUSSION: Step inter-limb asymmetries for the push are provided in Figure 1. A range of individual responses were observed between SV for inside and outside leg (Figure 1). This finding is in contrast to previous work (Needham et al., 2021) where the inside leg had significantly (P < 0.001) greater step velocity than the outside leg across the sample. These differences may lie in the observed individualised responses of athletes and the phase of the start analysed, since Needham et al. (2021) analysed steps between 5 – 15 m, whereas the current study observed steps from 0 – 15 m. It is therefore plausible that any asymmetry manifests more overtly later in the push. However, the inside leg displayed significantly greater (P <0.001, g = - 2.14) ΔV across a step than the outside leg. This suggests athletes can accelerate more effectively during an inside leg step. Aligning with previous research (Needham et al., 2021), the current study shows the inside leg to have significantly greater step length (P <0.001, g = 0.60) and significantly lower step frequency (P = 0.015, g = -0.77) when compared to the outside leg. No significant differences between inside and outside leg for ground contact time (P = 0.165, g = 0.25) and flight time (P = 0.057, g = 0.78) were observed. However, the moderate effect size for flight time (-0.78) is noteworthy, since previous research did identify a significant reduction in flight time for the outside leg (Needham et al., 2021).

The increase in step frequency for the outside leg was due to the decrease in FT, with limited difference in GCT between limbs. Since the support arm stays in contact with the sled, this limits the athlete's ability to move to a more upright position through the push, as seen in sprinting (Nagahara, Matsubayashi, Matsuo & Zushi, 2014). As such, during the swing recovery of the inside leg the athlete is limited by the position of the athlete's torso, resulting in a shortened step, leading to the decrease in SL and FT and increase in SF for the outside leg. The outside leg in contrast has more room to swing freely. Needham and colleagues (2021) suggested that the observed asymmetry may indicate a compromise in force production capability during outside leg contact. This suggestion was based on research in upright sprinting whereby a reduction in FT and SL indicates lower force production during ground contact (von Lieres Und Wilkau et al., 2020). In the context of skeleton, the differences may occur due to the transfer of energy into the sled. Since the outside leg applies force to the ground further away from the sled and at a greater angle to the point where the athlete and the sled connect. Kinematic and kinetic analysis of the push may be required to understand how these asymmetries in spatiotemporal variables are occurring.

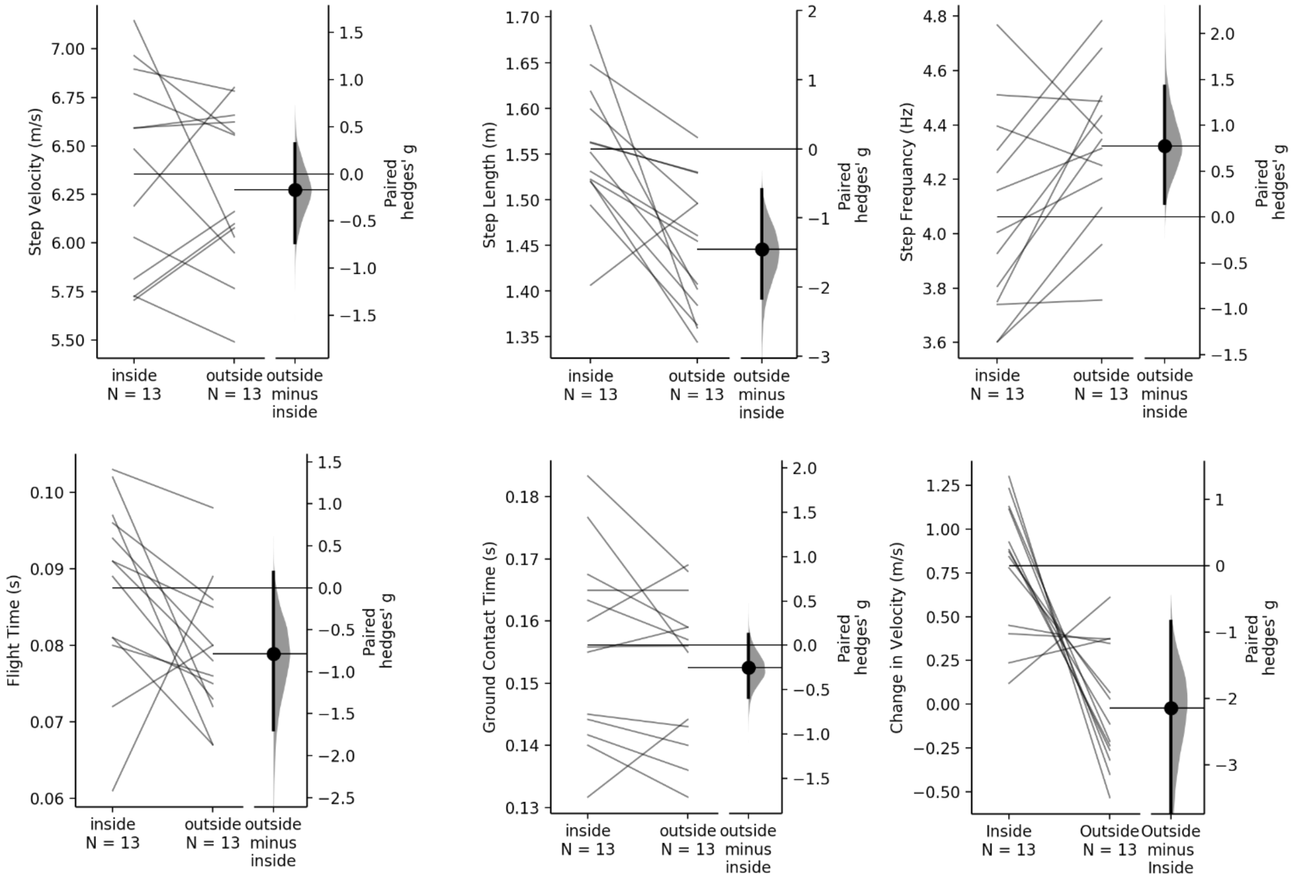

Figure 1: Paired averaged step characteristics for inside and outside leg (relative to the sled) during pushing. Each line represents the best trial for each participant. The paired hedges' g is plotted on a floating axis on the right as a bootstrap distribution. The hedges' g is depicted as a dot; the 95% confidence interval is indicated by the ends of the vertical error bar. Top left – SV, top centre – SL, top right – SF, bottom left – FT, bottom centre – GCT, bottom right – ΔV.

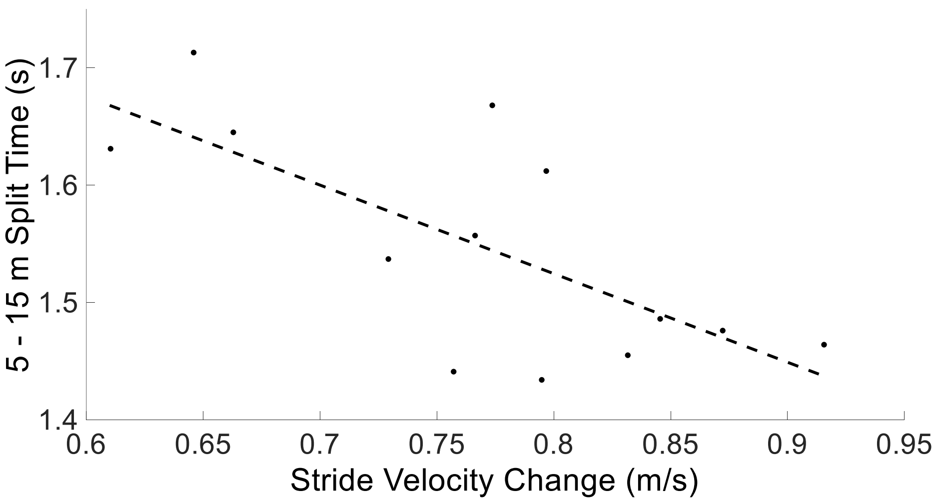

Figure 2: Relationship between ΔV change across a stride and 5 – 15 m split time. Dots represent the mean each participant (n = 13). Dashed blacked line represents outputs of the regression analysis (r^2 = 0.49, *P* = 0.007).

The relationship between ΔV across a stride and performance can be seen in Figure 2. The current study suggests that athletes who can increase their velocity effectively across a stride are more likely to perform well in the push phase of the skeleton push start. However, it is clear that athletes use different strategies to achieve their performance outcome (Figure 1). For example, some athletes have large increases in velocity from their inside leg, with reductions in velocity on their outside leg. While other athletes have a more balanced approach with similar increases in velocity from both inside and outside leg (Figure 1). The best performing athletes are likely those who employ a strategy which allows them to maximise their increase in velocity over a stride. As indicated by the relationship between performance and ΔV across a stride (Figure 2). Coaches should therefore seek to increase sled velocity across a stride with an understanding of potential athlete variation step to step strategy to maximise 15m Sled velocity. Future research should seek to understand why athletes adopt different strategies during the push start. Perhaps characterising athletes based on their individual strategy as utilised by Wild et al. (2021) might be appropriate to understand why athletes present a certain approach.

Conclusion: The aim of this study was to confirm the presence of lower limb asymmetry during the push start in a group of male and female international level athletes and identify its effect on push start performance. The inside leg demonstrated significantly greater SL, while the outside leg demonstrated significantly greater SF. There were however no differences between inside and outside leg for SV, FT and GCT. Athletes who maximise their velocity across a stride were more likely to perform well in the skeleton push start. Athletes employ individual strategies based on ΔV for the inside and outside leg to achieve their performance outcome. Future research should seek to understand why athletes adopt different strategies during the push start.

REFERENCES

Colyer, S. L., Stokes, K. A., Bilzon, J. L. J., Cardinale, M. & Salo, A. I. T. (2017). Physical predictors of elite skeleton start performance. *International Journal of Sports Physiology and Performance, 12***,** 81-89.

Ho, J., Tumkaya, T., Aryal, S., Choi, H. & Claridge-Chang, A. (2019). Moving beyond P values: data analysis with estimation graphics. *Nature methods, 16***,** 565-566.

Nagahara, R., Matsubayashi, T., Matsuo, A. & Zushi, K. (2014). Kinematics of transition during human accelerated sprinting. *Biology open, 3***,** 689-699.

Needham, L., Evans, M., Cosker, D. P. & Colyer, S. L. (2021). Development, evaluation and application of a novel markerless motion analysis system to understand push-start technique in elite skeleton athletes. *PloS one, 16***,** e0259624-e0259624.

Oguchi, T., Ae, M. & Schwameder, H. (2021). Step characteristics of international-level skeleton athletes in the starting phase of official races. *Sports biomechanics***,** 1-14.

von Lieres Und Wilkau, H. C., Bezodis, N. E., Morin, J.-B., Irwin, G., Simpson, S. & Bezodis, I. N. (2020). The importance of duration and magnitude of force application to sprint performance during the initial acceleration, transition and maximal velocity phases. *Journal of sports sciences, 38***,** 2359-2366.

Wild, J. J., Bezodis, I. N., North, J. S. & Bezodis, N. E. (2021). Characterising initial sprint acceleration strategies using a whole-body kinematics approach. *Journal of sports sciences***,** 1-12.

ACKNOWLEDGEMENTS: The authors thank Danny Holdcroft and all athletes who were involved in this study. This investigation was funded by the BBSA and the University of Bath, and was supported by CAMERA, the RCUK Centre for the Analysis of Motion, Entertainment Research and Applications EP/M023281/1 and EP/T014865/1.