THE EFFECT OF VISUAL GAZE LOCATION ON BLOCK-START BIOMECHANICS

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This study investigated the effects of varying visual gaze location (VGL), by means of externally-focused instruction, during the block-start "set" phase with the intention of optimizing block-start biomechanics for faster starts in an athlete-specific manner. Nine collegiate sprinters performed a series of block-starts while directing their VGL to their personal baselines, and at 0.5m, 1m, 2m and 3m from the start line. Twelve infrared opto-reflective cameras and one force plate were utilized to assess trunk, hip, knee and centre of mass kinematics, and blocks push-phase kinetics. An eyetracker was used to determine participants' VGL. Some postural changes observed were a significant decrease in pelvic height in the "set" position, and more upright trunk postures at toe-off from the blocks, when participants gazed further at 2m and 3m. Gazing at 1m was effective in eliciting changes to pelvic horizontal velocity. These results suggest that manipulating VGL could help certain athletes to optimize their block-start biomechanics for faster starts. Coaches can consider redirecting VGL in addition to usual instructional methods to improve the block-start performances of athletes.

KEYWORDS: block-start, gaze location, coaching cues

INTRODUCTION: Poor technique off the starting blocks could cascade into a slow acceleration phase, later peak velocity, and consequently longer race time in athletics. Rear leg knee flexion-extension angles and pelvic height in the "set" position (the crouched stance just prior to initiation of push-off), trunk and lower limb flexion-extension angles, and pelvic horizontal velocity and impulse during block clearance can affect block-start performance (Bergamini et al., 2013; Mero, Luhtanen, & Komi, 1983; Milanese, Bertucco, & Zancanaro, 2014). Pelvic horizontal velocity at toe-off is a direct representation of the effectiveness of block push-off mechanics (Atwater, 1982). Perfecting the block-start technique takes time, more so when a coach is unable to clearly articulate technically implicit instructions. The use of externally-focused instructions has been suggested to improve movement efficiency and decrease cognitive demand (Marchant, 2011). The aforementioned, explored together with an understanding of perception-action whereby movement is regulated by visual information (Warren, 1990), may improve athletes' block-start performance. Getting athletes to vary their VGL in their respective "set" positions could result in biomechanical changes that are more optimal than their baselines. For example, by gazing further than baseline location, an athlete may push off the blocks more forcefully in order to reach the further location.

This study investigated the effects of varying VGL during the "set" phase on block-start biomechanics. It was anticipated that varying an athlete's VGL from their baseline in "set" position would result in more optimal block-start biomechanics for some, such as increased pelvic horizontal velocity. The anticipated findings may present sprint coaches with new insight into how redirecting VGL during the block-start could be a simple way of eliciting desired technique changes in their athletes compared to solely using verbal instructions.

METHODS: Nine collegiate level sprinters, 8 males and 1 female (23 ± 2 years old; 65.5 ± 6.2 kg; 173 ± 5 cm; 8 ± 5 years of experience; 11.8 ± 0.9s 100m personal best), performed a series of fifteen block-starts during "set" position while gazing at different locations that were demarcated by tape on the ground (baseline, 0.5m, 1m, 2m, and 3m from start line). Thirty-six retro-reflective markers were affixed to the trunk and lower limb in accordance to the University of Western Australia lower limb model (Besier, Sturnieks, Alderson, & Lloyd, 2003) prior to warm up. A 12-camera VICON MX 3D motion analysis system (VICON PEAK, Oxford, United Kingdom) sampling at 250 Hz and one 0.6 m by 0.9 m Kistler force plate (Kistler Holding AG, Winterthur, Switzerland) sampling at 1000 Hz were used to examine the lower limb and trunk kinematics and kinetics during the block-start performance. A Dikablis eyetracker (Ergoneers Gmbh, Manching, Germany) sampling at 25 Hz was used to ascertain the participants' gaze locations.

After a self-selected warm up and familiarization, participants performed 15 block-starts, with 60 seconds rest between trials; three trials while gazing at one of the five locations each time, with the prescribed location randomized. Participants pushed off the blocks with maximal effort upon a clap and accelerated for 5 steps before slowing down into a soft mat.

Eyetracker data revealed that all participants had a baseline VGL that was the start line. Raw marker trajectory data was labelled, with gaps filled, using the VICON Nexus software. A residual analysis was performed on each marker using a customized MATLAB software (The Mathworks, Natick, Massachusetts, USA) before determining the optimal filtering cut-off frequency for all markers. All marker trajectories and ground reaction force data were filtered using a fourth-order, 11 Hz zero-lag low-pass Butterworth filter. Kinematic and kinetic outputs were obtained using a customized model (Besier et al. 2003) in the VICON Nexus pipeline. Pelvic height from the ground was obtained when participants were in the "set" position. Trunk, hip, and knee flexion-extension angles, and pelvic horizontal velocity were obtained at the instance of front foot toe-off from the blocks. Average horizontal impulse during the block push phase was calculated by taking the average propulsive force from instance of force application till front-foot toe leaving the blocks multiplied by total time taken during this entire phase, and normalized to body mass. Eyetracker data was inspected to confirm that participants were gazing at the correct VGLs as instructed.

Statistical analyses were performed using IBM® SPSS® Statistics 21 (IBM Corporation, Armonk, NY, USA) and Microsoft Excel (Microsoft Office Home and Student 2016, Version 16.0.12527.20260). Two-tailed paired t-tests were conducted to determine, at a group level, any significant differences between various VGLs and baseline measures for the different dependent variables. This would indicate if, and which, changes in VGL were effective in altering block-start biomechanics, regardless of increase or decrease. Typical error in the form of coefficient of variation (CV) was used to determine if an individual's changes were meaningful; changes of larger magnitude than the CV indicate true changes not caused by measurement or biological errors (Hopkins, 2000). This provides greater insight as to how each participant's block-start biomechanics changed uniquely in response to changes in their VGL in the "set" position.

RESULTS: Table 1 reports the means and CV of the selected block-start biomechanical dependent variables that are elicited from the various VGLs. Table 2 reports the results from the two-tailed paired t-tests when examining differences between the various VGLs and baseline at the group level. Table 3 reports the number of participants displaying decreases or increases greater than the CV when comparing their own baselines to the various VGLs for each variable, and the total unique cases across all VGLs for each variable.

From Table 2 and 3, there were statistically significant differences ($p < 0.05$) in pelvic height when participants gazed at 1m, 2m and 3m from their baselines; there were meaningful decreases to pelvic heights greater than the CV. Pelvic horizontal velocity had a statistically significant change ($p = 0.03$) when participants gazed at 1m. The group's mean (Table 1) indicated a general decrease in velocity when gazing at 1m, within which, only 1 participant displayed a meaningful decrease greater than the CV. Changes to trunk angle approached statistical significance when participants gazed at 2m ($p = 0.08$) and 3m ($p = 0.07$). These two VGLs resulted in meaningful decreases in trunk flexion angle (more upright posture) greater than the CV.

Despite no significant change in impulse across all VGLs ($p > 0.05$), a small mix of participants, across the different VGLs, displayed increases or decreases greater than the CV.

Table 1. Means and CVs of selected block-start biomechanical dependent variables at the various VGLs.

		Baseline		0.5m		1m		2m		3m	
Time	Dependent Variable	Mean	CV	Mean	CV	Mean	CV	Mean	CV	Mean	CV
"Set"	Pelvic Height (cm)	82	2	82	1	81	1	79	1	78	1
Toe-off from blocks	Hip Flexion Angle (°)	8.1	1.2	9.3	3.3	8.7	5.6	8.3	4.2	7.8	3.4
	Knee Flexion Angle (°)	12.1	2.8	12.0	2.1	11.4	2.0	12.2	1.5	13.4	3.2
	Trunk Flexion Angle (°)	56.2	2.2	55.4	2.6	55.8	3.6	54.2	2.6	54.7	3.7
	Pelvic Hor. Velocity (m/s)	3.18	0.09	3.15	0.11	3.11	0.14	3.15	0.14	3.15	0.11
Push Phase	Avg Hor. Impulse (Ns/kg)	3.77	0.21	3.79	0.16	3.80	0.16	3.73	0.22	3.76	0.23

Table 2. Results of the two-tailed paired t-tests when examining differences between the various VGLs and baseline of selected block-start biomechanical dependent variables.

		Different VGL versus baseline (p-values)			
Time	Dependent Variable	0.5m	1m	2m	3m
"Set"	Pelvic Height	0.97	0.01†	< 0.01†	< 0.01†
Toe-off from blocks	Hip Flexion Angle	0.12	0.63	0.85	0.76
	Knee Flexion Angle	0.91	0.45	0.79	0.11
	Trunk Flexion Angle	0.44	0.69	0.08	0.07
	Pelvic Hor. Velocity	0.41	0.03†	0.41	0.47
Push Phase	Average Hor. Impulse	0.66	0.63	0.59	0.85

† Significant difference at the $p < 0.05$ level

Table 3. Number of participants displaying decreases versus increases greater than the CV for selected block-start biomechanical dependent variables when comparing their own baselines to the various VGLs, and total unique cases across all VGLs for each variable.

			Different VGL versus baseline			
Time	Dependent Variable	Unique Cases (#)	0.5m	1m	2m	3m
"Set"	Pelvic Height	9	1 v 0	1 v 0	9 v 0	8 v 0
Toe-off from blocks	Hip Flexion Angle	2	0 v 1	0 v 1	0 v 1	1 v 1
	Knee Flexion Angle	3	1 v 0	2 v 0	1 v 1	0 v 1
	Trunk Flexion Angle	5	1 v 0	2 v 1	4 v 0	1 v 0
	Pelvic Hor. Velocity	5	2 v 1	1 v 0	3 v 1	3 v 1
Push Phase	Average Hor. Impulse	6	0 v 1	2 v 2	1 v 2	1 v 2

DISCUSSION: This study investigated how changing VGL, by means of externally-focused instructions and an understanding of perception-action, during the block-start “set” phase could elicit postural adaptations that may contribute to more optimal block-start biomechanics and higher pelvic horizontal velocities. Key findings indicate changes towards more optimal block-start biomechanics despite a general decrease in pelvic horizontal velocity, and athlete-specific changes to average horizontal impulse as participants changed their VGL from baseline.

Pelvic height in “set” position decreased as participants gazed further. In order to gaze further without tilting the neck to uncomfortable degrees, while maintaining the “set” position, participants may have lowered their hips. A lowered pelvis is beneficial to almost all sprinters for pushing-off the blocks as a greater range of hip and knee extension is afforded for the generation of more impulse (Milanese et al., 2014). There is a trend toward a decrease in trunk flexion angle (more upright posture) at toe-off from the blocks, when gazing at 2m and 3m. When fixating on a further location during push-off, the athletes could have organized their bodies to reach towards that further location, which could explain the generally decreasing trunk flexion angle. The immediacy of change suggests the body's attempt to reorganize itself based on the visual stimulus. Biomechanically, this more upright posture that gets closer to the proposed ideal 45° as participants gazed further better aligns the line of action of force from foot through the trunk for more efficient transfer of force (Tellez & Doolittle, 1984).

Instructing an athlete to gaze at 1m was effective to change pelvic horizontal velocity, compared to the other gaze distances. Perhaps gazing at 2m and 3m was too much a change from baseline (all participants' baseline was the start line) for some, while gazing at 0.5m was too similar to baseline, resulting in no statistically significant differences when looking at the group as a whole. The group's mean suggested a decrease in velocity when gazing at 1m compared with baseline which was contrary to our hypothesis. The CV data revealed that 5 participants experienced a meaningful change in at least one condition within which 4 displayed a decrease while 1 displayed an increase in pelvic horizontal velocity. Despite the seemingly better postures when executing the block-start, unfamiliarity with these acute postural adaptations may have resulted in the dip in performance (pelvic horizontal velocity) in the short term. This, however, should not deter coaches as a better technique could eventually lead to faster times with practice. Future research should be conducted in a longitudinal manner to understand the long-term effects of training with VGL manipulation and whether these effects could help athletes improve their block-starts.

Although the kinetic variable of average horizontal impulse showed no statistically significant differences, the variation in VGL away from baseline was able to effect meaningful change in 6 out of the 9 participants, with some experiencing an increase while others a decrease. This reiterates the notion that VGL manipulation, though able to elicit meaningful changes to block-start biomechanics, remains highly-individualized.

CONCLUSION: This study showed that changes in block-start biomechanics can be achieved by simply instructing athletes to change their VGL while on the blocks. Some but not all athletes immediately achieved better block-start biomechanics based on the literature. Coaches could experiment with varying VGL for their athletes, to see which location elicits the optimal mechanics for the specific athlete, before training with this change for a prescribed timeframe in order to evaluate its impact to race performance. Manipulating VGL to elicit specific technique changes could serve as an alternative instructional method in addition to their usual practice.

REFERENCES

Atwater, A. E. (1982). Kinematic analyses of sprinting. *Track Field Q Review,* 82(2):12–6

Bergamini, E., Guillon, P., Camomilla, V., Pillet, H., Skalli, W., & Cappozzo, A. (2013). Trunk inclination estimate during the sprint start using an inertial measurement unit: A validation study. *Journal of Applied Biomechanics*. https://doi.org/10.1123/jab.29.5.622

Besier, T. F., Sturnieks, D. L., Alderson, J. A., & Lloyd, D. G. (2003). Repeatability of gait data using a functional hip joint centre and a mean helical knee axis. *Journal of Biomechanics*, *36*(8), 1159–1168. https://doi.org/10.1016/S0021-9290(03)00087-3

Hopkins, W. G. (2000). Measures of reliability in sports medicine and science. *Sports Medicine*. https://doi.org/10.2165/00007256-200030010-00001

Marchant, D. C. (2011). Attentional focusing instructions and force production. *Frontiers in Psychology*. https://doi.org/10.3389/fpsyg.2010.00210

Mero, A., Luhtanen, P., & Komi, P. V. (1983). A biomechanical study of the sprint start. *Scandinavian Journal of Sports Sciences*.

Milanese, C., Bertucco, M., & Zancanaro, C. (2014). The effects of three different rear knee angles on kinematics in the sprint start. *Biology of Sport*. https://doi.org/10.5604/20831862.1111848

Warren, W. H. (1990). The Perception-Action Coupling. In *Sensory-Motor Organizations and Development in Infancy and Early Childhood*. https://doi.org/10.1007/978-94-009-2071-2_2

Tellez, T., & Doolittle, D. (1984). Sprinting from start to finish. *Track Technique,* 88, 2802-2805