GAZE AND STEP CONTROLS OF AN ELITE ATHLETE DURING APPROACHING DIFFERENT HURDLE HEIGHTS

Mitsuo Otsuka[1], Tadao Isaka[1], Desmond Boey[2] and Marcus Lee[2]

Faculty of Sport and Health Science, Ritsumeikan University, Kusatsu, Japan[1]
Singapore Sport Institute, Sport Singapore, Singapore, Singapore[2]

This study investigated the gaze and step controls of one elite male hurdler when approaching hurdles at different heights. Across a 16 m runway, the participant performed three normal sprinting trials, and three hurdle running trials to clear a low, medium and high hurdle respectively. Gaze behaviour was captured using a mobile eye tracker that was mounted on the participant's head and was filtered using a low-pass filter. In normal sprinting, the step length increased gradually from the first to eighth step. In the hurdle running trials, step length did not increase in the last step and fixations remained on the hurdle. The duration of fixations on the hurdle was lengthened by 21% and 44% in the middle and high hurdle trials, respectively, compared with the low hurdle trials. This pilot study provides foundational information on the interaction between gaze and hurdle running to clear hurdles of different heights that could potentially be optimized to improve performance in hurdling.

KEYWORDS: travel fixations, object fixations, mobile eye tracker, step length.

INTRODUCTION: In dynamic sporting activities that involve running, the visual field in front of the athlete changes as he/she moves in space. The athlete constantly has to coordinate what he/she sees in the visual field and his/her actions so as to navigate safely and perform the required skills of the sport. To the best of our knowledge, there is no previous research on gaze behaviour during running at maximal efforts and hurdle running.
A mobile eye tracker that is mounted on a participant's head can measure one's gaze behaviour in terms of fixation frequencies, durations and locations during physical activity. Fixations are defined as gazes on a particular object for more than 100 ms and within 3 degrees of visual angle that allows for conscious information processing (Vickers, 2007). Previous studies have investigated gaze behaviours during sporting tasks that do not involve explosive and repetitive movements such as side-stepping to intercept an opponent (Lee et al., 2013), bowling (Goh et al., 2018) and skating (Vickers, 2006). Unfortunately, an explosive and repetitive sporting task like sprinting involves excessive head motion that results in gaze data that contains high frequency noise that requires extensive low-pass filtering.
Hurdle running is a complex motion. The hurdler is required to not only run at maximal effort but also needs to adjust his/her steps as he/she approaches the hurdles and prepares to clear the hurdles. During normal locomotion and stepping over an obstacle, the obstacle is identified at least two steps, or about 300 ms, before reaching that obstacle (Hollands, Patla &Vickers, 2002; Patla & Vickers, 1997). The duration of object fixations was reported to increase when the height of obstacles increased (Vickers, 2007). Gaze information is used in a feed-forward or top-down manner and provides the locomotor system with the advance information needed to step over obstacles correctly.
The purpose of this pilot study was to investigate the gaze and step controls required during the approach run of an elite hurdler as he tried to clear hurdles of different heights, and how this differs from normal sprinting.

METHODS: One male hurdler (height, 182 cm; body mass, 72 kg) participated in the study. The participant was an international-level hurdler, who was a winner in the Asia Athletics Championships. His personal bests of 110-m and 400-m hurdles were 14.30 s and 49.03 s, respectively.
The experimental protocol was approved by the Research Ethics Committee Involving Living Human Subjects at Ritsumeikan University. The participant provided written informed consent before study participation.

The participant performed 16-m hurdle running as he approached three different hurdle heights (low [76.2 cm], middle [91.4 cm] and high [106.7 cm] hurdle trails) and a 16-m dash (normal run trial). Each trial was performed three times from a standing start. The order of the experimental trials was 1) normal run, 2) low, 3) middle and 4) high hurdle trials. The experimental trials were performed in the laboratory after a sufficient warm-up involving several submaximal dashes wearing all measurement devices.
A mobile eye tracker (EMR-9, nac Image Technology Inc., Tokyo, Japan) was fixed on the participants' heads to capture gaze behaviour at 240 Hz. The eye camera recorded the participant's points of gaze from the dual eyes via the displacements of the pupil in relation to the cornea during vision while the scene camera captured his visual fields in the frontal plane at 30 Hz (a horizontal resolution of 640 pixels and a vertical resolution of 480 pixels). Data from both cameras were captured in a time-synchronized manner into a recording device that was placed in a pouch and worn around the trunk.
A fourth-order zero-lag Butterworth low-pass filter set at 1Hz was used to treat the high-frequency noises in the gaze data due to excessive motions of the head, eyeballs and cameras during data collection. The cut-off frequency of 1 Hz was determined through a baseline trial that required the hurdler to run 16-m at maximal effort while at all times, gazing at a 5-cm-radius yellow ball, which was fixed by a thin stick and was pointed at by a tester, till he stopped. The position of the yellow ball was same as the position of the hurdle bar, which was 13.72 m apart from the start line and was located at 1.0 m height from the floor. The most optimal cut-off frequency was determined using visual inspection from a range of 0.5 to 15.0 Hz (0.5 Hz intervals) to ensure that few errors were monitored between the target ball and the gaze point on screen. The duration of travel fixations was calculated from the instant at take-off of forefoot during the standing start to the initial instant whereby fixations was directed to the hurdle. The duration of object fixations was calculated from the initial instant whereby gaze was directed to any parts of the hurdle to gaze offset.
Three high speed cameras (GC-PX1, JVC Kenwood Holdings Inc., Kanagawa, Japan) were located at left side of the running pathway and captured the foot contact positions from the first to sixth step of the hurdler at 240 Hz. The digitized coordinates of the horizontal foot contact positions were converted to real coordinates using reference markers placed on left and right sides of the running pathway. The 24 high-speed infrared cameras (Raptor-E digital, Motion Analysis Corp., Santa Rosa, CA, US) were located around the hurdle and horizontal positions of the reflective marker attached on toes were captured at 250 Hz. These positions of reflective markers at foot contacts were used as the foot contact positions from the seventh to ninth steps.

RESULTS: In the normal run trial, the foot contact position of the eighth step from the start line was 10.96 ± 0.12 m. In contrast, the take-off positions for clearing the hurdle were 11.58 ± 0.03 m, 11.57 ± 0.07 m and 11.69 ± 0.15 m for the low, middle and high trials, respectively (Figure 1). As hurdle height increased, the standard deviation [SD] of foot contact position increased; for example, the largest were 0.08 cm during the fourth step in the low hurdle trial and 0.23 cm during the sixth step in the high hurdle trial, respectively. As hurdle height increased, the initial location for object fixations was shifted closer to the start line and the last location for object fixations was also shifted closer to the hurdle.
As hurdle height increased, the duration of travel fixations from start was shortened while the duration of object fixations after the initial travel fixations was lengthened (Figure 2). In the last two steps, fixations were on the hurdle, except fixation duration was lengthened by 21% and 44% in middle and high hurdle trials, respectively, compared with the low hurdle trials.
In the normal run trial, step length increased gradually from the first to eighth step (Figure 3). In the hurdle trials, step length did not change nor decrease in the last two steps, when fixations were on the hurdle with no change in location.

DISCUSSION: Object fixations are used to attend to objects even as the feet continues running. This study investigated the object fixations when approaching a hurdle.

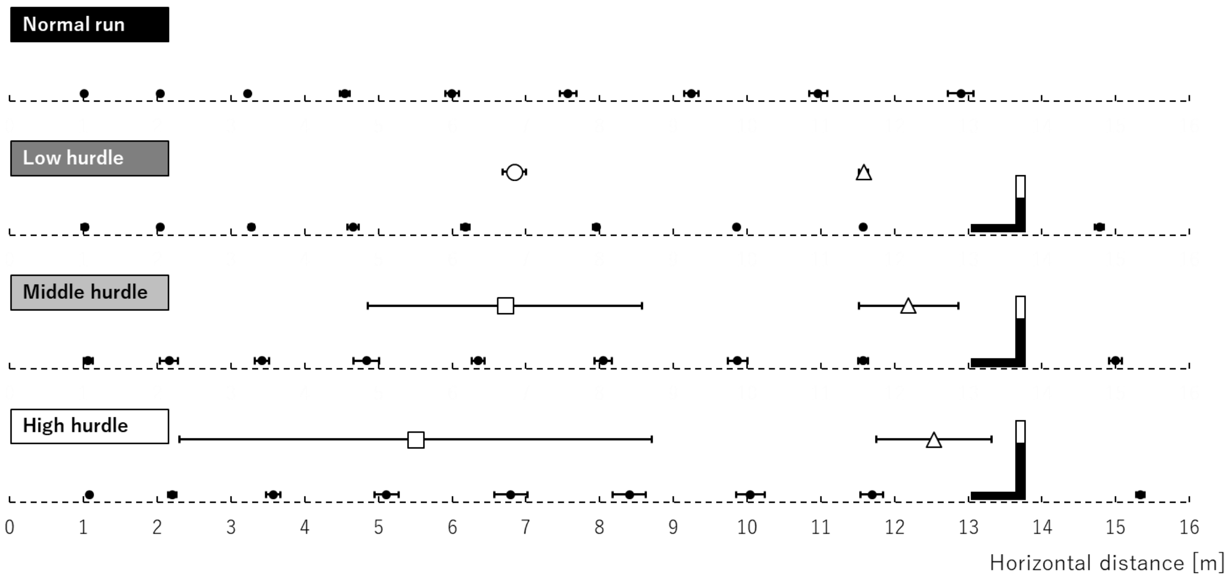

Figure 1: Foot contact positions from the first to ninth steps (filled circle), initial (open square) and last locations (open triangle) for the object fixations in normal run and different hurdle height trials (mean ± SD). The origin is the start line.

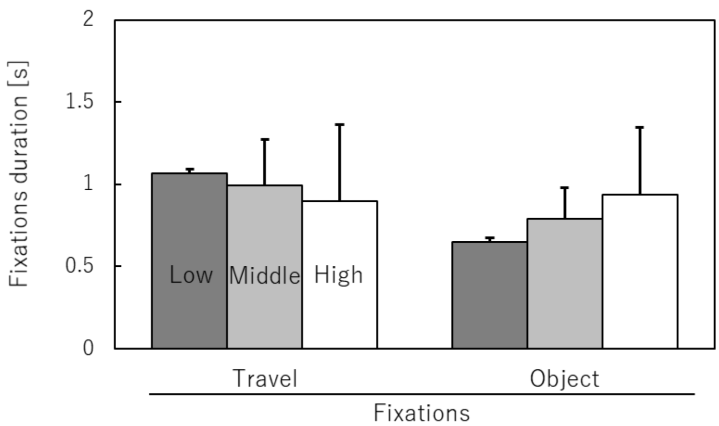

Figure 2: Duration of travel and object fixations in three hurdle height trials (mean ± SD).

So as to clear the hurdle from an optimal foot contact position with an optimal body position, the hurdler did not lengthened some step lengths during the second part of the approach run. When the hurdler adjusted his foot contact positions as he approached the hurdle, visual information from gazing at the hurdle was likely utilized. The duration of object fixations was lengthened as hurdle height was increased. This is supported by Vickers (2007) whereby fixation durations increased when participants had to step over higher obstacles when walking. In the high hurdle trial, the hurdler paid more attention to recognizing the hurdle position for a longer time so as to navigate safely.
Interestingly, the step lengths in the first and second steps, when the hurdler had not gazed at the hurdle yet, were larger in the middle and high hurdle trials than those in the normal run trial. Adjusting step lengths without object fixations may be due to the fact that the hurdler recognized the position of the hurdle immediately before starting the trial and had already used a feed-forward control from the beginning of the trial.

CONCLUSION: This pilot study used a low-pass filter for the gaze positions as one elite hurdler approached the different hurdle heights. It was concluded that gaze fixations on the hurdle is utilized for adjusting the foot contact positions and taking off at an optimal position based on the hurdle heights.

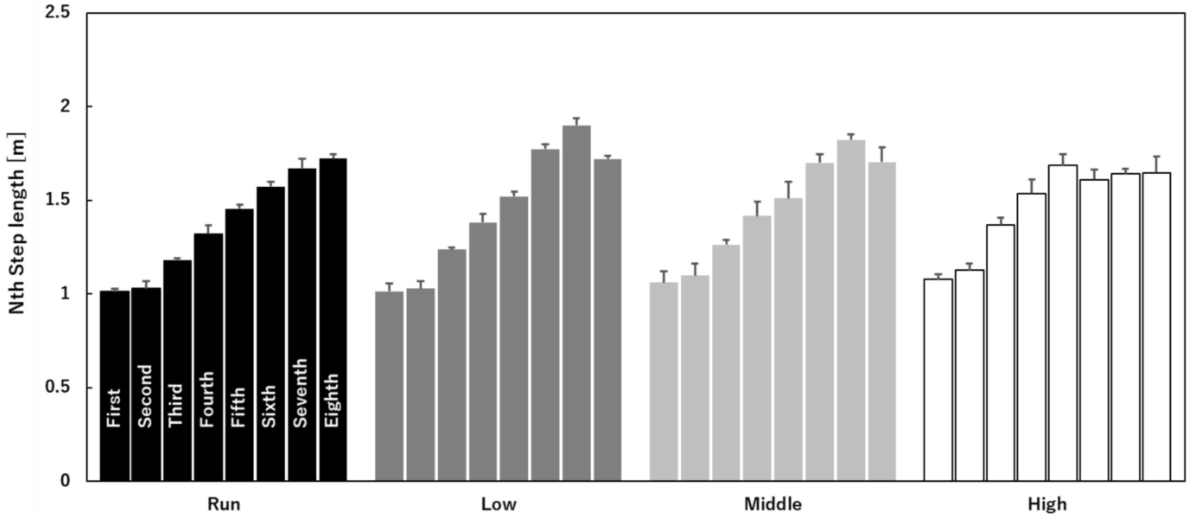

Figure 3: Changes of step length from the first to eighth steps in normal run and different hurdle height trials (mean ± SD).

REFERENCES

Goh, W.X., Lim, B.H.Y., Wylde, M.J., Macnaughton, M., Chow, J.Y. & Lee M.J.C. (2018). Pre-movement and during-movement visual search behaviours vary depending on expertise and anxiety levels in ten-pin bowling. *Journal of Sports Sciences*, 36, 2076-86.

Hollands, M.A., Patla, A.E., & Vickers, J.N. (2002). “Look where you’re going!”: gaze behaviour associated with maintaining and changing the direction of locomotion. *Experimental Brain Research*, 143, 221-30.

Lee, M.J.C. Tidman, S.J. Lay, B.S. Bourke, P.D. & Lloyd, D.G. (2013). Visual search differs but not reaction time when intercepting a 3D versus 2D video opponent. *Journal of Motor Behavior*, 45, 107-15.

Patla, A.E. & Vickers, J.N. (1997). Where and when do we look as we approach and step over an obstacle in the travel path? *NeuroReport*, 8, 3661-5.

Vickers, J.N. (2006). Gaze of Olympic speedskaters skating at full speed on a regulation oval: perception-action coupling in a dynamic performance environment. *Cognitive Processing*. 7, 102-105

Vickers, J.N. (2007). Making our way around and over obstacles. *Perception, cognition, and decision training*. (pp145-6). Champaign: Human Kinetics.

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