DIRECTIONAL ACCURACY OF THE DELIVERY IN COMPETITIVE CURLERS

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The purpose of this study was to assess the directional accuracy of the delivery in competitive curlers. Sixteen curlers each delivered a total of eight stones to three target locations with different combinations of rotation and speed. A laser device located near the ice surface was used to determine the line of delivery, and Dartfish was used to measure the position of the stone relative to the line of delivery. Comparisons were made at specific events: setup, pull-back, release, and after release. The results indicated significant main effects for target location ($p < 0.001$) and for turn ($p < 0.001$) but not for speed ($p = 0.341$). Post-hoc analysis revealed positional differences in the stone between the setup and pull-back phases and the release and after release phases. This information will help curlers to improve their accuracy during the delivery.

KEY WORDS: curling, line of delivery, in-turn, out-turn, draw, take-out.

INTRODUCTION: The delivery is one of the most important skills in the sport of curling. The objective of the delivery is to release the stone so that it will eventually come to rest in a specific position at the opposite end of the sheet, or so that it will contact and remove an opponent's stone from play. Curlers attempt to deliver the stone with the appropriate combination of direction and speed. The stone must be delivered in the appropriate direction to allow for the proper amount of curl to complete the required shot. In addition, the stone must be released with the speed necessary for the type of shot being played, whether it is a draw or take-out. A draw is a lower speed delivery which is intended to stop in front of or within the house; a take-out is intended to be delivered at a greater speed so that it contacts and removes a stone (Bradley, 2009; Buckingham, Marmo & Blackford, 2006). It is the curling delivery which has the appropriate combination of direction and speed which will be most successful.

It is the role of the skip to select and indicate the type of delivery to be played. In order to provide the teammate delivering the stone with a target, the skip positions his/her broom head vertically on the ice to indicate the direction the stone should be released. During the delivery, the curler imparts rotation on the stone which causes it to curl. For a right handed curler, an "in-turn" has the handle of the stone rotating clockwise; an "out-turn" has the handle of the stone rotating counter-clockwise. With the broom head serving as the target, the player attempts to "hit the broom" by delivering the stone so that it is traveling directly towards the broom with the appropriate speed and rotation at the moment of release.

The line of delivery is the imaginary line between the hack, which is the rubber foot pad from which the curler imparts force during the delivery, and the skip's broom head (Ontario Curling Association, 2012). Based on the specific situation seen during the competitive play, curlers may be required to deliver the stone to virtually any position in or around the house, which is the circular scoring area at the opposite end of the curling sheet. The line of delivery may be positioned anywhere from the right of the house to the left of the house. Ideally, the curler delivering the stone will position him/herself in the same manner regardless of where the line of delivery is located. To date, there has been no quantitative assessment of the ability of competitive curlers to deliver the stone on the line of delivery, whether it is positioned to the right, centre, or left of the house, with an in-turn or out-turn rotation, or delivered at a draw or a take-out speed. The purpose of this study was to assess the directional accuracy of the delivery during curling.

METHOD: Sixteen curlers were recruited for this study, eight males and and eight females (mean age = 27.0 y; mean years of curling experience = 17.3 y). All participants had competed at regional, provincial, national curling events, and were right handed throwers. Ethical approval was received from the Lakehead University Research Ethics Board prior to data collection. After completing an individual pre-competition warm-up, the participants were required to deliver eight curling stones, which represented a variety of frequently played shots seen during competitive play. They included the following targets, rotations, and speeds: target on right side of the house (out-turn draw, out-turn take-out), target on centre line (in-turn draw, in-turn take-out, out-turn draw, out-turn take-out), target on left side of the house (in-turn draw, in-turn take-out). The deliveries were performed random order. The participants were instructed to aim at a laser level device which was located 5 centimetres above and parallel to the ice surface, and was pointed towards the centre of the hack. This device represented the skip's broom (line of delivery). A JVC ZR-950 camcorder, mounted on a mini tripod, was positioned directly above the laser device and was used to record each delivery (Figure 1).

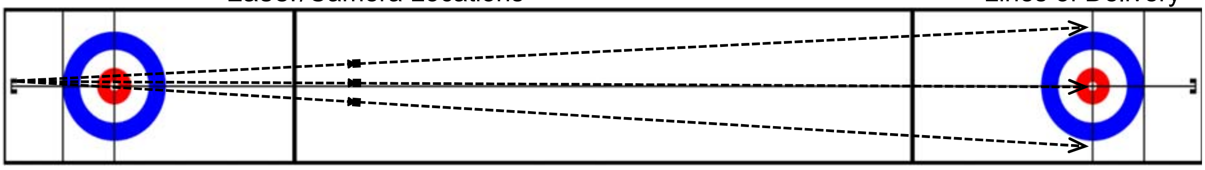

Figure 1: Set up for testing protocol, including the lines of delivery (right side of house, centre line, left side of house), and the location of the laser device and video camera for each.

The camera was zoomed in to ensure that the stone filled most of the the field of view, and then was zoomed out slowly as the stone was delivered towards the camera. The video was captured on a miniDV tape for subsequent analysis using Dartfish (software version 4.0.9). The software has a function which allows for distance measurements to be made based on a calibration scale. Using the diameter of the stone as the known distance, the location of the laser dot relative to the stone diameter was measured and used to determine the position of the stone relative to the line of delivery. A measurement directly on the line of delivery is represented by a value of zero. Positive numbers represent distances measured in which the stone is located to the right of the line of delivery, negative values indicate the stone is positioned to the left.

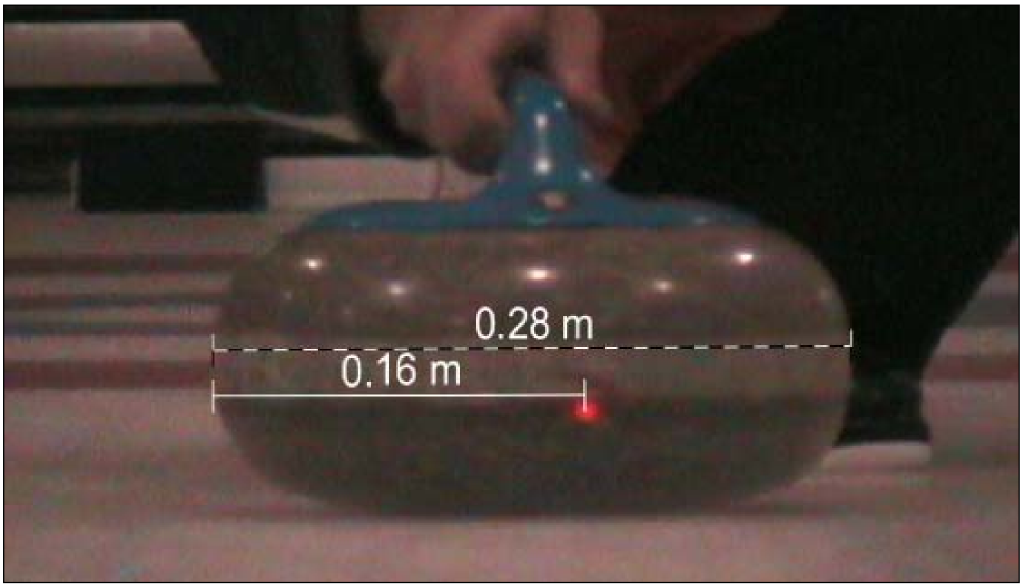

Figure 2: Screen capture outlining method used for measuring the position of stone relative to line of delivery. The diameter of the stone is 0.28m as measured from the left edge, which indicates the centre is located at 0.14m. Because the laser dot (line of delivery) is located 0.16m from the left edge, the stone is positioned 0.02m to the right of the line of delivery.

Measurements were taken in the position of the stone relative to the line of delivery at specific events during the delivery. They included the setup (the position of the curler in the hack prior to the initiation of movement), pull-back (the backward most position of the stone prior to the initiation of forward force application), release (the moment the stone left the

curler's hand), and after release (a measurement taken 5 video frames (0.17 seconds) after release to represent the path of the delivered stone).
Statistical analysis was completed using SPSS 18.0. Factorial repeated measures ANOVAs were used to evaluate the position of the curling stone relative to the line of delivery for the various delivery target locations (right, centre, left), speeds (draw, take-out), and turns (in-turn, out-turn) at the different phases of the delivery (setup, pull-back, release, after release). Significant main effects were further analyzed with Bonferroni adjusted pairwise comparisons to identify the specific differences among the delivery phases. Alpha was set at $p \leq 0.05$.

RESULTS: The data are presented in Table 1, including the mean (±S.D) position of the stone at each phase for the deliveries released to the three targets and with different combinations of speed and turn.

Table 1: Mean (±S.D.) Position of the stone relative to the line of delivery for the deliveries released to the three targets and with different delivery types.

Target	Delivery Type	Delivery Phase			
		Setup	Pull-back	Release	After Release
Right	Out-turn draw	0.06 ±0.04	0.06 ±0.04	0.06 ±0.04	0.06 ±0.04
	Out-turn take-out	0.06 ±0.05	0.06 ±0.04	0.06 ±0.03	0.06 ±0.03
Centre	Out-turn draw	0.06 ±0.04	0.06 ±0.04	0.06 ±0.03	0.06 ±0.03
	Out-turn take-out	0.05 ±0.04	0.05 ±0.04	0.05 ±0.04	0.05 ±0.04
	In-turn draw	0.04 ±0.04	0.05 ±0.03	0.03 ±0.03	0.02 ±0.03
	In-turn take-out	0.05 ±0.04	0.05 ±0.03	0.03 ±0.03	0.03 ±0.03
Left	In-turn draw	0.04 ±0.03	0.04 ±0.03	-0.02 ±0.03	-0.02 ±0.03
	In-turn take-out	0.04 ±0.04	0.04 ±0.03	0.00 ±0.03	0.00 ±0.03

The results of the statistical analysis revealed significant main effects for target location ($p < 0.001$) and for turn ($p < 0.001$), whereas no significant differences were seen for the main effect of speed ($p = 0.341$). Post-hoc analysis for turn revealed no significant differences in the out-turns among the phases of the delivery. For the in-turns, however, the setup and backswing phases were significantly different ($p < 0.001$) from the release and after release phases, with the stone being released significantly closer to the line of delivery. Post-hoc analysis for target location indicated that there were no significant differences among the deliveries to the target on the right side of the house and the out-turn deliveries to the target on the centre line. Significant differences were seen between the setup and pull-back phases and the release and after release phases for the deliveries to the target on the left side of the house, and for the in-turn deliveries to the target on the centre line ($p < p.001$).

DISCUSSION: For most of the measurements taken during this study in the position of the curling stone relative to the line of delivery, the stone was positioned to the right of the line of delivery. The participants were always setup with the stone situated to the right of this line, and this position did not change as they moved into the pull-back phase. It was only in the release and after release phases of the in-turn deliveries that the stone was seen to either be positioned on the line of delivery or cross over to the left side. The in-turn delivery for right handed throwers has the stone rotating clockwise. Because the stone was positioned to the right of the line of delivery during the setup and pull-back phases, this type of turn resulted in the curler changing the position of the stone towards the line of delivery as he/she approached the moment of release. This change in stone position, however, was not seen for any of the out-turn deliveries. Theoretically, the curler should be in the exact same setup position prior to the start of a delivery, regardless of the nature of the shot being played. The only difference should be in the rotational orientation of the stone for an in-turn or an out-turn release. The results of this study suggest that competitive curlers are consistent in positioning the stone in the early phases of the delivery. Similarly, curlers should also release the stone in the same way for targets located to the right, centre, or left of the house, and for in-turn and for out-turn rotations. The results indicate that this is not the case. Further research into the kinematics of the delivery is warranted to explain this finding.

It is noteworthy that there were no significant differences seen in the position of the stone relative to the line of delivery between the deliveries of different speeds (draw versus take-out). Considering the mass of the curling stone is approximately 20 kg (Canadian Curling Association, 2010), significantly more muscular effort would be required to deliver the stone at a higher speed for a take-out as compared to a draw. Curlers who compete at this high level of competition possess the technical skill required to increase force output without changing the mechanics of their delivery.

CONCLUSION: The results of this study provide insight into the ability of competitive curlers to deliver the stone on the line of delivery. Curlers must be aware of the fact that differences may be seen in the position of the stone relative to the line of delivery for various types of deliveries, and at different events throughout the delivery.

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