TEN REASONS WHY AN INTERVAL TIME MAY BE INACCURATE

THE TECHNICAL COACH SERIES

GLENN PAULLEY, ONTARIO CURLING COUNCIL

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7 OCTOBER 2024 **NO. 19**

In curling, an interval, or "split" time is the time it takes for a delivered stone to travel between either:

- the back-line to the near hog line, or
- the tee-line to the near hog line

in an attempt by the delivering team to estimate the velocity of the delivered stone, and with that knowledge determine either (a) for a guard or a draw, the eventual place that the stone will come to rest, or (b) for a hit-weight shot, whether the stone was thrown with the intended velocity.

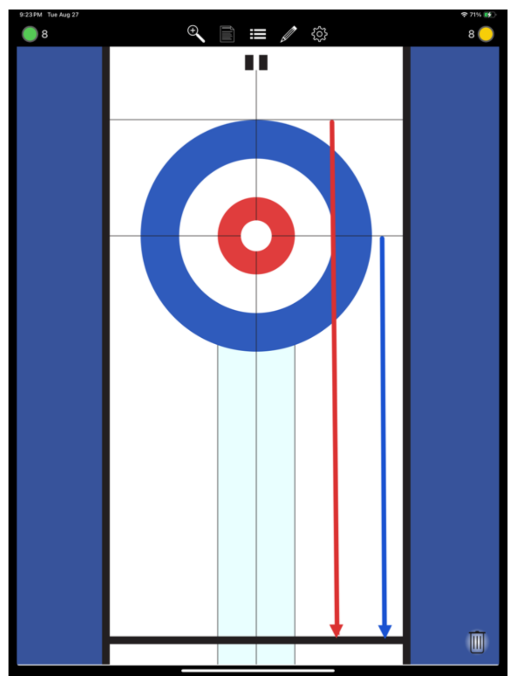

Figure 1 - Illustration of split times; back-line to hog in red, and tee-line to hog in blue.

Using intervals benefits the delivering team because the two brushers can utilize a split time to assist their weight judgement, and the delivering player can use a split time to assist their delivery with respect to weight control. However, relying on splits – either back-line to near hog line or, less commonly, tee-line to near hog line, can be complicated. One complication is that, to be more effective, the team must map split times into other timing systems, such as hog-to-hog times or hog-to-far tee-line times if they are to utilize the throws of the opposition team to help judge the speed of the ice.

However, that mapping of split times is by far not the only complication in their use. In this article we describe ten reasons why split times may be inaccurate. Many competitive teams will already be familiar with many of these reasons but we offer a detailed description to assist younger athletes or coaches with less experience.

To illustrate the problem, suppose a team takes a small sample of split times for two draw-weight shots during the first end of play, and determines that a back-line to hog-line split time of 4.1 seconds yields a stone that will stop, as desired, on the tee-line in the house at the far end of the sheet (see Figure 2 at right).

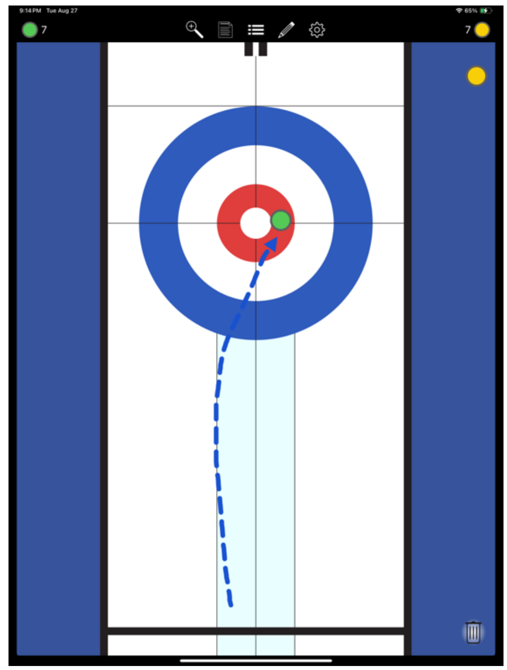

Figure 2 - Drawing the house with a 4.1 second split time, taken from the back-line to the near tee-line.

Now suppose the team begins the second end of the game, towards the glass at the home end, and continues to throw draw-weight shots with the same back-line to hog-line split time of 4.1 seconds. However, rather than the stone coming to rest at the far tee-line, the delivered stone either (a) comes to rest in front of the rings, or (b) comes to rest at the back of the house (see Figure 3 below). We consider ten potential reasons why either of these outcomes are possible, ranging from the obvious to the not-so-obvious. Before we begin, we define friction forces as the interaction forces between the ice surface and the running surface of the stone. Higher friction slows the stone more quickly, whereas lower friction allows it to decelerate more slowly. Brushing is a complicated phenomenon, but we will simply accept that it reduces friction forces in the context of this article.

TEN REASONS WHY A SPLIT TIME MAY BE INACCURATE

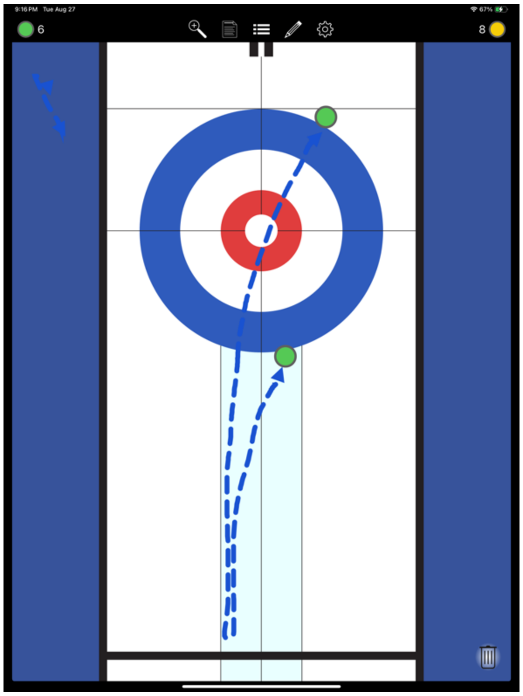

Figure 3 - Different shot outcomes for the same 4.1 second split.

We begin with some simple, even trivial, explanations for why the shot outcome differs despite the same split time captured by the delivering team. We follow these simple explanations with a discussion of more complex reasons why this might occur.

1. An obvious but infrequent reason for a stone to come up short is that the stone "picked", meaning that some debris became caught underneath the stone's running band and created significantly more friction at that point, leading immediately to a loss of velocity and corresponding momentum.

2. A second reason for a difference in the final position of the stone is that the stone's release – either the characteristics of the moment of rotation at release ("set" or "dump", to name two), or the release point before the hog line – is not the same. A stone released at some distance before the near hog line begins to decelerate sooner, even though the split time for that stone might be the same. Since the stone is released earlier it will also begin to curl sooner, taking a different path on the sheet which may, or may not, have characteristics similar to those of prior shots. Similarly, throwing a stone with a deliberate "extension" of the throwing arm, or other subtle differences in a stone's release, may increase the stone's initial velocity but that increase in forward speed may not be reflected in an interval time.

3. Changes to the brushing of the stone may, again obviously, impact the stone's final resting point. Even a stone that is brushed with minimal force (usually termed a "clean") may travel an additional 2-3 feet (0.61 m to 0.91 m). More interesting, however, is that if the players on the team have different force profiles, then differences in the vertical force applied through the brush may impact the stone's carry in different ways. In addition, the placement of the brush head in front of the stone's running band, the

angle of attack, and whether or not one brusher was used, or two, all can make significant differences in carry distance, lateral (curl) distance, or both, depending on the circumstances and the ice conditions that are present.

4. Elaborating on item (2) above, a different trajectory path for the stone may present a different coefficient of friction, and hence the frictional forces on the stone may differ from what is expected. Sometimes this phenomenon is termed "pathy" ice, and the path may be faster or it may be slower. Speed decrease may be due to pebble wear or frost; a speed increase may be because the path has been utilized (and/or brushed) previously, perhaps earlier in the end or even during the end before.

5. Each stone’s running band is slightly different. A stone's running band may be rougher (frequently, and incorrectly, called "sharper") so the stone will likely curl more during its travel, following a different and longer path and, depending upon the initial trajectory, finish its travel by curling away from the rings. Moreover, a rougher running band will change the frictional forces between the stone and the ice, increasing friction, which will cause greater deceleration of the stone as it moves down the sheet.

6. Speaking of different frictional forces, one must pay attention to the number of rotations the stone makes over its travel. In normal play with the number of rotations being less than, say, 4 rotations between the hog lines, a stone will come to rest when both (a) forward velocity drops to zero and (b) the stone stops rotating. A stone thrown with fewer rotations will tend to curl more, travelling on a different path (see #4 above) and may stop prematurely because of a lack of rotation at release.

7. During their delivery, the particular athlete performing the throw may decelerate more quickly than their teammates, so their initial speed out of the hack is much faster but falls off more quickly. In this case, it can be very difficult to tell from the stopwatch alone if the stone will be moving at the same velocity at release. On a four-player curling team, particularly younger teams, it is commonly the case that the different players on the team will have differing rates of deceleration during their deliveries, making player-to-player comparisons using split times exceedingly difficult. Another difficulty that results is the additional complexity of mapping hog-to-hog times with multiple splits depending on the individual player.

8. Another common cause of error is that the timer(s) wasn't accurate enough at either the back line, the hog line, or both, to get an accurate interval time. Experience in other

sports, particularly in track and field, is that it is very difficult to be accurate with a stopwatch with better than 0.05 seconds accuracy. Before the advent of laser timing systems and photo finish technology, track events at the world championships or at the Olympics were managed by large teams of individuals seated at the finish line to try to ensure the accuracy of the results, especially the top three finishers. In curling, the issue is that each split time involves two measures (start AND stop) and since both can be commonly off by 0.05 seconds, it is easy for any split time to be inaccurate by 0.1 seconds (1/10 second). But in curling, a back-line to hog-line split time that differs by 0.1 seconds on keen ice represents a difference of six feet of distance at draw weight. Hence, merely an inaccurate time may result in a stone that is under- or over-brushed, yielding a difference in the shot.

9. Occasionally athletes will discover that a sheet of ice is faster in one direction than it is in the other. While it is possible that the root cause is an unlevel floor, such that the ice at one end has considerably greater thickness than the other, a more common situation stems from a lack of insulation at the away end of the arena. In many clubs, the away end of the rink, which has an exterior wall, faces south or west and, in comparison to the home end of the ice where the arena is insulated by the viewing lounge, the far end wall has little insulation. In the warmer months of spring there can be both an air temperature and ice temperature difference at the warmer end of the rink. The nominal temperature for curling ice is approximately -4 C and with that temperature just below the freezing point, a poorly insulated ice shed may permit ambient heat to accumulate. That additional warmth may not be reflected in hog-to-hog times in the middle of the rink, but there may be a 1.0 or 1.5 second difference in near hog line to far tee-line draw times, which of course will have different split times, making the accurate mapping of splits to hog-to-hog times extremely difficult. An example of this was at the 2016 Canadian CIS University Championships held in Kelowna, BC. The Kelowna Curling Centre faces north, with the far end of the arena at the southern end, and hence is prone to additional warming with springtime temperatures. At this event, the near-hog-line to far tee-line draw times differed by more than a second for shots thrown towards the scoreboard versus shots thrown towards the glass.

10. Finally, the tenth reason a stone may not travel identically to a prior shot may be because the stones thrown by the team differ in their mass. Since curling stones are natural objects that are ground and shaped to suit, the Rules of Curling permit a range of weights for a regulation curling stone: between 38.5 lbs and 44 lbs, with a nominal weight of 42 lbs (19.09 kg). The Normal Force on a stone is gravity; it is friction force that determines the deceleration of a curling stone, and hence the stopping distance.

From Newton's laws of motion we know that momentum M is defined as the product of mass and velocity, so a stone thrown at the same velocity but with a different mass will have different momentum, and is likely to carry less, or further, down the sheet. The impact of stones with varying mass can be modelled mathematically, using Newton's formulas of motion.

From mechanics, for a curling stone to come to rest after it is thrown, the stone's kinetic energy at release must be completely offset by the "work" performed by the friction forces over the stone's travel distance. Hence, we have the following equation (1):

$$\frac{1}{2}mv_i^2 = Fd \quad (1)$$

where m is the mass of the stone, v_i is the stone's initial velocity at release, F is the friction force, and d is the travel distance.

Weight in lbs	Weight in kg	Normal Force (N)
44	20	196.2
43	19.55	191.74
42	19.09	187.3
41	18.63	182.82
40	18.18	178.36
39	17.72	173.90
38	17.27	169.45

Table 1 - Regulation curling stones, their mass, and Normal force.

For this comparison we are assuming that each stone is thrown with the same velocity. We don't know exactly what that velocity is – experiments indicate that a typical velocity of a curling stone at draw weight on keen ice is 2.2 m/sec – but the precise velocity is unimportant here. What matters is that we believe each stone's initial velocity v_i is the same because we assume that the interval time for each throw is identical.

Rewriting Equation (1), we specify m_c as the mass of our control stone, a stone with the nominal weight of 42 lbs., and its travel distance d_c, to get Equation (2) that solves for F:

$$F = \frac{m_c v_c^2/2}{d_c} \qquad (2)$$

We wish to solve for the stone's travel distance, d. We can rewrite Equation (1) again, this time using d_1 to denote the travel distance of another stone, say one weighing 39 lbs (so denoted by m_1) and thrown at velocity v_1. To repeat, note that $v_1 = v_c$. We have:

$$d_1 = \frac{m_1 v_1^2/2}{F} \qquad (3)$$

We can substitute Equation (2) above into Equation (3) since Equation (2) solves for F. This gives us Equation (4):

$$d_1 = \frac{m_1 v_1^2/2}{\frac{m_c v_c^2/2}{d_c}} \qquad (4)$$

Or more simply,

$$d_1 = \frac{m_1}{m_c} d_c \qquad (5)$$

In other words, the distance a stone of 39 lbs will travel is roughly the ratio of its mass to the mass of the control stone of 42 lbs. if thrown at the identical velocity. Equation (5) is an approximation because, to reiterate, the running band of every curling stone is different and hence their frictional coefficients are not identical. Nonetheless (5) is a useful guide. For example, if a 42 lb stone is thrown and stops on the far tee line, then another stone of 39 lbs thrown at the same velocity would travel $(39/42) \cdot 93$ feet, or 86.36 feet – just shy of the rings – all other things being equal. Conversely, a heavier stone of 44 lbs would travel $(44/42) \cdot 93$ feet, or 97.43 feet – the back 12-foot, rather than the tee-line.

It would be rare for a team to know the weights of the stones they are using during a game; figuring out the differences amongst the stones is part of the challenge of playing the sport. Moreover, in championship play significant differences amongst a set of stones would be uncommon. However, in club play we have, on occasion, experienced extreme differences in mass amongst a set of stones, and the difference in shot outcomes that occur as a result. Players will frequently call a lightweight stone a “pig” because it has less momentum than expected, but the “pig” connotation is somewhat inappropriate because the stone is lighter, not heavier, than the other stones in the set.

SUMMARY

Interval times offer a team a way to approximate the initial velocity of a curling stone by measuring the stone's travel time between two fixed sets of lines at the beginning of the throw. However, interval timing can be problematic and there are a variety of reasons why teams may introduce errors into their thinking if relying too heavily on split times. This is especially true if using near tee-line to near hog-line splits, since the magnitude of the error is greater because the timed distance is six feet shorter.

All this is not to say that interval times do not offer any value. However, teams would do better to rely on their judgement with all of their senses, including sound, when trying to estimate the velocity of a stone at release, rather than counting on their stopwatches solely for input.

QUESTIONS

We are pleased to provide whatever assistance we can to coaches and athletes. Our contact information is below.

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