The Difference Between Urethane and Reactive Bowling Balls

BUS 450C

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Abstract

Bowling is a target sport that has been around since antiquity, but the modern history of the sport begins in the late 1800s. The primary material that bowling balls are composed of has changed throughout the years in order to produce better bowling balls. The evolution of bowling ball materials has led us to the point where bowlers primarily throw balls composed of either Urethane or Reactive materials. The purpose of this paper is to explain the differences in bowling ball materials, investigate the effects that these differences have, and to explore other variables that influence success in bowling.

Keywords: Ten-pin Bowling, Target Sports, Statistics

Introduction

In ten-pin bowling, bowlers have to make a choice on which ball they will throw for any given frame. There are three main materials that bowling balls are composed of: plastic, urethane, and reactive (Carubba, 2012). Each material offers a different set of strengths and weaknesses and knowing what these are can help a bowler make the best decision. Plastic bowling balls are mainly used to shoot spares as they allow for a straighter ball motion than the other two materials. Because plastic balls aren't used for strikes as often, this analysis will be focusing on reactive and urethane. This analysis will be focusing on a league bowler that bowls out of Starlite Lanes in Flagstaff, Arizona and also happens to be the author of this paper. He has been bowling for a total of around 4 years and wished to further his understanding of his bowling ball arsenal with this study.

Interdisciplinary Approach

Since bowling is a fairly complex sport, the differences in bowling ball materials are also fairly complex. There is not a simple answer to how urethane and reactive differ, but rather many different answers depending on what aspect is being looked at. Expectations don't always align with reality and results for one bowler may not hold true for other bowlers. For this analysis, an interdisciplinary approach was used in order to help the subject determine how reactive and urethane bowling balls differ for him.

There are multiple potential disciplines that are relevant to the topic, but the three most relevant are physics, statistics, and psychology. The discipline of physics can help understand what makes bowling ball materials differ and what the different effects will be. Statistics can give insight to the observed characteristics of different materials. Psychology can help explain other factors besides just material that effect success on a lane. There is a slight conflict between the statistics and physics disciplines as physics is looking to answer what is expected to happen while statistics is looking to answer what actually happened. Common ground can be found between these two by linking in the psychology discipline to help explain any contradictions between statistics and physics.

Literature Review

An analysis of 5-pin league bowlers in Canada revealed that bowling scores were approximately Normally distributed when applying the natural log transformation (Chen & Swartz, 1994). This is very interesting since despite individual throws being independent from one another, the scores still ultimately end up Normally distributed. Because the scores are approximately Normally distributed, different assumptions and tests can be made, such as the probability that a bowler of a certain skill will beat another bowler of a certain skill. Chen also explains the compounding effect that strikes have on scores since games with consecutive strikes will have a higher score than games with the same number of strikes but not consecutively.

The history of bowling lends itself to antiquity, but it’s time in the Elizabethan era helped shape the modern characteristics of the sport (Davies, 2019). Davies goes into detail on the history of bowling in London during the mid-to-late-sixteenth-century and how it relates to the playhouse industry. The main objective of this journal is to explain the wider leisure ecology of London and how bowling alley construction was a major influence on playhouse development. However, this paper provides great insight into some of the earliest documented cases of ‘modern’ bowling and helps show how different, yet similar, the sport has become.

While bowling lanes may appear identical with the naked eye, the actual surface of the lane varies from lane to lane, this is due to the topography of the lane (Davis, 2021). Three main measurements are used when measuring the topography of a lane: crosswise tilt, crowns and depressions, and lengthwise level. The United States Bowling Congress has specifications in place for each of these measurements in order to keep lane surfaces as standardized as possible. Topography can affect the ball’s reaction on the lane in many ways and can be caused by weather, faulty installation, and regular use of the lane.

The case of a ‘hot hand’ has been a heated debate for years. Do athletes experience hot streaks where when they perform well, they heat up and begin to perform even better? Or is this just another form of the Gambler’s fallacy, the erroneous thinking that the results of events are more or less likely given the results of the previous event? Dorsey-Palmateer and Smith set out to see if there was any evidence for a hot hand in bowling, while also debunking a previous paper on the hot-hand in basketball. Despite being outdated and using a slightly skewed dataset, this journal does a great job explaining the process used for testing if shots in bowling are independent of the previous shot. This study concludes that the probability of striking is not independent on the previous shot, there is evidence for a hot hand in bowling (Dorsey-Palmateer & Smith, 2004).

Another test for the hot hand in bowling was conducted on a larger sample size across a larger pool of bowlers (Yaari & David, 2012). This study calls out the Dorsey-Palmateer article saying that they used a non-satisfactory test of independence. They then go on to conduct different tests for a hot hand, including one where games were randomly generated in order to compare observed games against generated games. This journal also concludes that there is evidence for a hot hand in bowling.

The ideal entry angle for a bowling ball into the pocket is around 5 degrees, which can only be replicated by hooking, curving, the ball (Frohlich, 2004). Bowling balls are able to hook due to friction between the ball and the surface of the lane. The factors that influence the amount of friction and the effect of the friction include weight distribution, radius of gyration, number of revolutions, surface of the ball, among many others. Frohlich also introduces the concept of flare, which is when a ball rolls down a lane it is also spinning every so slightly. This allows the lane to come into contact with a part of the ball that has not touched the lane. Since bowling balls pick up oil when they roll, flare allows the ball to roll over a dry part of the ball rather than a wet part.

Handicap is a system in league and tournament bowling where bowlers are given extra pins based on their average in order to level the playing field (Keogh & O'neill, 2012). This analysis on the fairness of handicap systems revealed that, like 5-pin bowling, scores in 10-pin bowling are approximately Normally distributed when applying the natural log transformation. Knowing this allows certain assumptions to be made allowing for other statistical tests to be conducted. Keogh concludes that the most commonly used handicap system is actually unfair to lower skill bowlers and suggested an alternative system. The author believes that the current system is in place in order to keep competitiveness and give bowlers reason to try to increase their average.

An analysis on Welsh basketball players revealed that confidence in one's ability directly correlated with probability of success (PARFITT & PATES, 1999). Players took self-assessments immediately before competing. Various measurements were recorded during competition and after running a regression analysis, the author concluded that anxiety was not very significant in predicting success, but self-confidence was extremely significant. With this conclusion, we can state that lower self-confidence results in lower probability of success and higher self-confidence results in higher probability of success.

A common misconception in bowling is that you need to be strong in order to throw the ball hard enough to strike. This is not true, bowling is much more a fines sport than it is a strength sport (Tan et al., 2000). While ball speed may have some effect on striking, this journal concluded that there was no correlation between bowling scores and grip strength, aerobic power index, lower body strength, or sit and reach distance. While there is plenty of athletic ability required to be good at bowling, one does not need to be strong to find success on the lanes.

Early bowling balls were made of wood or rubber until modern equipment was introduced in the 1950s (Carubba, 2012). Plastic bowling balls were first introduced in 1959 and provided more friction between the ball and the lane than rubber, leading to more hook potential. Plastic balls tended to skid instead of hooking, leading to the development of urethane in the late 1970s. Urethane offered an increased amount of friction between the ball and the lane which created a greater angle of entry into the pocket. Reactive was introduced in the 1990s and is composed of similar materials as urethane but includes more additives that create pores on the surface of the ball. More pores lead to a huge increase in friction between the ball and the lane, making reactive bowling balls extremely aggressive compared to urethane. Bowling ball cores also have an effect on ball motion. The way a ball is drilled in relation to the core can lead to different motions on the lane. The three components of a bowling throw are called the skid, hook, and roll phases.

About Bowling

Bowling is a target sport where players roll a ball down a wooden or synthetic lane in order to try and knock all ten pins over. Traces of sports similar to bowling have been found in ancient Egypt and early Germany, but the modern sport really began to take shape during the 1500s in London when it became an indoor activity (Davies, 2019). Lanes are 60 feet long and 41 inches wide with target markers at 6 and 15 feet. Pins are placed in a triangular fashion with 1 foot between pins.

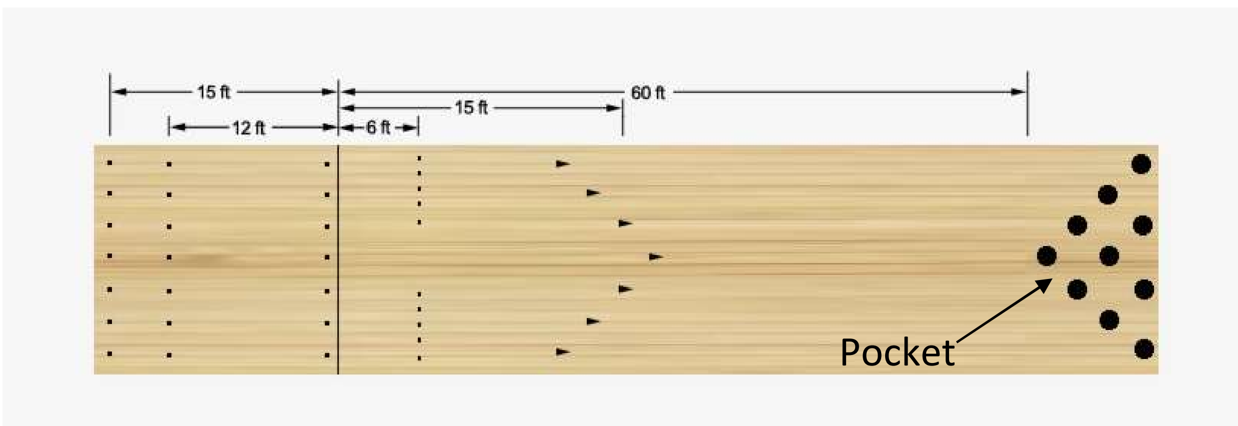

Figure 1

1	2	3	4	5	6	7	8	9	10
X	9 /	X	9 /	X	9 /	X	9 /	X	9 / X
20	40	60	80	100	120	140	160	180	200

1	2	3	4	5	6	7	8	9	10
X	X	X	X	X	X	9 /	9 /	9 /	9 / 9
30	60	90	120	149	169	188	207	226	245

Figure 2

The pocket, as seen in figure 1, is where bowlers aim to have their ball hit in order to knock over the pins. Bowlers are given two throws per frame to try and knock over all ten pins. If they knock over all the pins in 1 throw, it is a strike, denoted X, and is worth 10 pins plus the next 2 throws, for a maximum of 30 pins. If the pins are all knocked over in 2 throws, it is a spare, denoted /, and is worth 10 plus the next throw for a maximum of 20. If a bowler fails to knock over all 10 pins it is called an open frame and is worth however many pins are knocked over. Games consist of 10 frames with the final frame allowing a maximum of 3 throws if either a strike or a spare is recorded. Due to the compounding nature of strikes, it is extremely important to string together multiple strikes in order to achieve a higher score in bowling. Figure 2 shows 2 bowling games each with 6 strikes and the rest spares. The first game has no consecutive strikes and has a score of 200, while the second game has all 6 strikes in consecutive frames and has a score of 245, showing how important it is to strike in consecutive frames.

Bowling balls are 8.5 inches wide and weigh between 9 and 16 pounds, although the bowler in this study only throws 15 pounds. Bowling balls are comprised of two components: the Coverstock and the core or weight block. The two primary bowling ball coverstocks are urethane and reactive. In general, urethane bowling balls offer less aggressive, more controllable movement than reactive, however the weaker finish of urethane leads it to striking less when hitting the pocket, also known as worse carry (Carubba, 2012). The two primary styles of core are symmetrical and asymmetrical. In general, symmetric cores offer a smoother and predictable motion while asymmetrical cores offer a more pronounced shape and sharper motion (Carubba, 2012).

Oil is applied on the front 45 feet of the lane in order to provide a buffer between the ball and the lane, reducing friction. When the ball rolls over heavier concentrations of oil, it tends to skid rather than hook (Frohlich, 2004). How much oil is placed and how it is applied on the lane depends on the ‘oil pattern’. A typical ‘house pattern’ that a bowling alley would place down for league has a larger volume of oil in the middle of the lane, leading to the outer 8 inches or so to be dryer and create more friction. This house shot allows for bowlers to miss in and have their ball hold and also allows them to miss out and have their ball hook back. Different oil patterns can result in different levels of difficulty, with the patterns that professionals bowl on being exponentially more difficult than a typical house pattern. Every time a ball is thrown on a lane, it picks up or moves around the oil on the lane resulting in higher amounts of friction in parts of the lane that have had more throws. This is also called breakdown.

Another invisible factor in bowling is the surface of the lane underneath the oil, better known as topography. Different lanes with identical oil patterns can play differently due to the topography of the lane (Davis, 2021). The topography of a lane can be affected by regular wear and tear, faulty installation, or even bad weather. Lane topography is not visible to the naked eye; however, some tournaments and bowling centers provide pamphlets that show the topography of every lane allowing for bowlers to gain a better read on the lane.

There are multiple ways to throw a bowling ball, but the two main styles used today are the one-handed and two-handed approaches. The one-handed approach uses two fingers and a thumb and, as the name applies, has only one hand on the ball throughout the bowler’s backswing. The two-handed approach uses two fingers but no thumb. Two-handed bowlers keep both hands on the ball throughout the back swing. In general, the lack of thumb use in the two-handed approach allows for more revolutions, spin, to be placed on the ball due to the wrist motion they can achieve. However, the absence of the thumb also makes speed control and target control more difficult. The bowler in this study uses a two-handed approach.

There are three phases of a throw: the skid, the hook, and the roll phase (Carubba, 2012). The skid phase is where the side roll of the bowling ball causes the ball to skid through the front 1/3rd of the lane instead of hooking on the lane. The hook phase happens throughout the middle 1/3rd of the lane where the ball begins to lose speed and side roll and begins to gain end-over-end roll. The roll phase is the final 1/3rd of the throw where the ball hits the breakpoint, where the oil ends, and begins hooking towards the pocket. The ball is completely rolling end-over-end during the roll phase allowing it to drive through the pins rather than deflect off of them.

Expectations

Research on the physics of bowling has shown clear differences in bowling ball materials. Urethane bowling balls offer a more controllable ball motion than reactive, allowing for an easier time hitting the pocket (Carubba, 2012). Urethane, however, has very little back end reaction and struggles to drive through the pins, resulting in poor carry. Reactive, on the other hand, offers much more hook potential and stronger finishes than urethane, resulting in better carry even when missing the pocket (Carubba, 2012). Knowing this, we expect reactive to have a higher strike rate and higher carry rate than urethane, but we expect a higher rate of hitting the pocket with urethane.

Methods

The bowler in this study bowled 30 total games, 15 games with a reactive ball and 15 with a urethane ball, over the course of 5 sessions. Each session consisted of three games with one ball then three games with the other ball, swapping the order of balls each session. Each session was on a different lane with various lane conditions, including 2 days on fresh oil and 2 days on very little oil. For each shot, the bowler denoted the ball used, foot position, eye position, where the ball was at 15 feet, if the ball hit the pocket, and how many pins were knocked down. In total, the subject ended with 169 shots with the urethane ball and 166 shots with the reactive ball. From this, plenty of data analysis was conducted on various different aspects of the data set.

Findings

The first metric looked at in this data set was strike rate. Table 1 provides the calculations for strike rate overall and across balls. As we can see on the table,

	Overall	Urethane	Reactive
Total Strikes	165	86	79
Total Shots	335	169	166
Strike Rate	49.25%	50.89%	47.59%

Table 1

	Overall	Urethane	Reactive
Total Pocket	224	110	114
Total Shots	335	169	166
Pocket Rate	68.87%	65.09%	68.67%

Table 2

the strike rate for urethane is actually slightly higher than the strike rate for reactive, despite expecting the other way around. While these two strike rates don't differ at a statistically significant level, it is still interesting that our results were opposite than our expectations. Another metric looked at in this analysis was the pocket rate, how often our subject hit the pocket. Table 2 shows the calculations for pocket rate. Despite expecting urethane to have a higher pocket rate, due to controllability, we actually get that our reactive pocket rate was slightly higher than our urethane pocket rate. Again, this is not statistically significantly different, but it is still interesting that we got opposite results again.

The next metric looked at was the subject's carry rate between balls. Carry rate is defined as the number of strikes that hit the pocket out of the number of shots that hit the pocket. It is the rate in which shots that hit the pocket strike. Our subject's overall carry rate was 153/224 or about 68.3%. Our subject's odds of striking were almost 18 times higher when hitting the pocket then when missing the pocket. When we aggregate by material, we see that our subject's urethane carry rate was 80/110, about 73%, while his reactive carry rate was 73/114, about 64%. Our subject's carry rate was around 9 percentage points higher with urethane than with reactive despite expecting the opposite.

Another metric that we analyzed was rate of striking while on a string of strikes. We know that stringing together strikes is pivotal to achieving high scores in bowling, so how frequently did our subject do that? As seen in figure 3, our rate of striking with urethane stays fairly consistent through 5 strikes in a row before dipping off. The same figure shows the rate of striking immediately dropping off for reactive with no strings of 5 strikes or more in a row. This large difference in rates of striking shows that our subject was able to string strikes together more frequently and at a higher rate with urethane than with reactive.

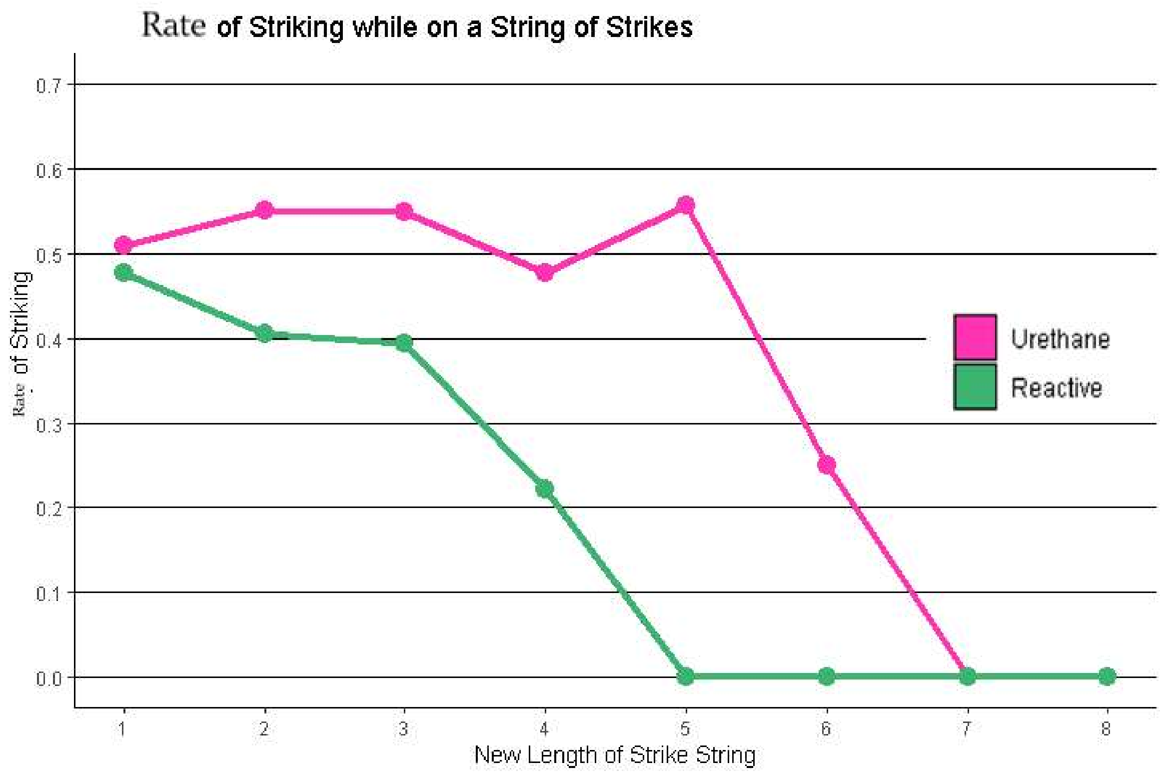

Figure 3

Figure 3 posed a question: Are the results of a shot dependent on the results of the previous frame's shot? When running a chi-squared test for independence an interesting result popped up. When not aggregating by bowling ball we get that the results of a shot were in fact independent of the previous frame's results. However, when aggregating by bowling ball we get that for urethane current frame results are still independent of the previous frame's results, but with reactive, we get that current frame results are *not* independent of the previous frame's results. This interesting result is known as Simpson's paradox. The reason for this paradox is not quite clear, but it could be due to the strike rate with urethane being fairly constant whereas the reactive strike rate decreased while on a string of strikes. In order to better understand this result, the methods used in Yaari and David (2012) to generate random games were replicated with this data set. Sets of games were rearranged as to keep the same number of strikes and non-strikes but to rearrange in a different order than they appeared.

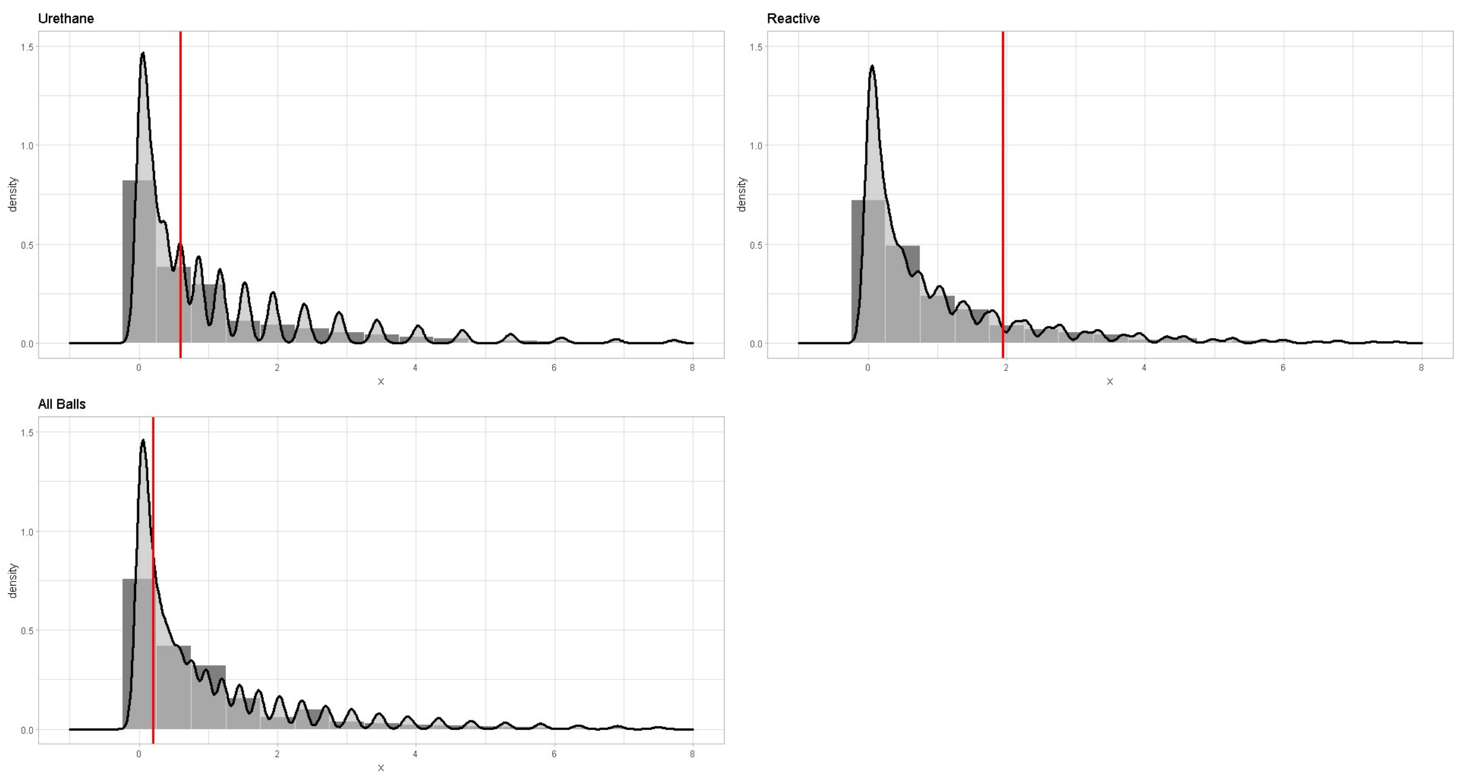

Figure 4

Chi-squared tests for independence were run on the generated games in order to form a distribution in which the observed chi-squared value could be compared against. Figure 4 shows the distribution of 100,000 chi-squared values aggregated by ball and combined. The red line corresponds to the observed chi-squared value. Figure 4 shows a different distribution between the balls as well as very different observed values. This figure suggests that for urethane shots are independent of one another, but for reactive there may be some dependence on the previous shot. Comparing these results to the results of Yaari and David

(2012) and Dorsey-Palmateer and Smith (2004) we get a slightly different conclusion. While there is seemingly evidence that shots with reactive bowling balls have a dependence on the result of the previous frame, it is not as conclusive as the other journals. This is likely due to the sample size of shots being too small and other lurking variables that were not tested for. Other various statistical tests were carried out including but not limited to, testing the effects of fatigue, the effects of hitting target, the effects of distance from target, and many others that turned up interesting results but these results were the same between balls so they were not included in this analysis.

Interpretation

As stated before, we expect reactive to have a higher strike rate and higher carry rate than urethane, but we expect a higher rate of hitting the pocket with urethane. But in reality, our subject had a higher strike rate and carry rate with urethane and had a slightly higher pocket rate with reactive. Why might we have gotten opposite results than what we expected? Human error and flaws in the data collection methods may have led to some incorrect analysis, but the real reason has to due with confidence. Confidence in one's ability directly correlates with probability of success (PARFITT & PATES, 1999). When our subject was confident with the shot he was going to make, he was more likely to succeed, when he was not confident and was uncomfortable with the shot, he was less likely to succeed. Why might our subject be comfortable with urethane over reactive? In his current league session, 82 out of 87 games were bowled with urethane. In his recorded practice sessions from last fall, he averaged 220 with urethane and 207 with reactive. Our subject uses urethane much more than he uses reactive, leading him to be more comfortable with the motion of urethane and much more uncomfortable with the aggressiveness of reactive. This lack of comfort leads to second-guessing on the approach, adjustments that didn't need to be made, missed adjustments, and overthinking. These all lead to a worse ball being thrown and a lower chance that the ball strikes.

Conclusion

Bowling ball coverstocks are different in order to lend themselves to different styles of play. Reactive allows for more aggressive angles and sharper motion while urethane allows for more subtle motion and higher controllability. Depending on where a bowler is most comfortable playing a shot, they can decide which ball is best for them. Because our subject primarily throws urethane and prefers the more subtle and straighter lines, he sees higher success with urethane over reactive. Lack of comfort with more aggressive lines leads to less confidence on the approach and less strikes with reactive. Lower confidence with reactive also results in it being more likely that results of a shot are not independent of the results of the previous shot when ideally every shot should be thrown the same and should be independent of previous results.

Flaws in Data Collection

There were a couple of flaws in the data collection method. The biggest flaw is that all metrics were measured by eye. Looking at a one-inch board 15 feet away to see if the ball hits that spot is difficult and trying to pinpoint the board the ball went over when the target was missed is even more difficult. Another flaw is that the pocket was treated as a binary (yes/no) variable rather than a categorical data. The pocket is a slightly ambiguous term and there are multiple types of pocket hits including a light-pocket, flush, and high-pocket. The difference between a pocket and non-pocket hit is sometimes very miniscule and subjective leading to shots that would be considered pocket on some days and not pocket on others.

Suggestions for Future Research

It would be interesting to see this study replicated with a larger sample size of bowlers and bowling balls in various settings such as leagues and tournaments. I'd also like to see all types of bowling balls used in a future study as well as the use of advanced tracking systems to gather various measurements of the ball at different points of the lane.

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