MAGNUM SHIELDING CORPORATION

MAGNUM BOWLING PRODUCTS

The Investigation of the Preservation Effect of the Immortalizer® bag enclosure on Bowling Balls' Physical Properties and Lane Engagement Performance over Time

Dated: November 10, 2020

Abstract

The Bowling community is an active and curious community on and off the lane. Contemporary bowlers are especially interested in learning about the effects of various factors on their bowling ball arsenal's performance and lane engagement. There have also been many articles hypothesizing the possible causes of spontaneous circumferential cracking of reactive resin bowling balls with no one clear explanation for the phenomena.

Magnum Bowling Products' commitment to the technological advancement of the sport has generated a novel new product that directly addresses both performance and cracking concerns. This product will not only enhance a bowler's experience on the lane but will also protect and preserve a bowling ball's integrity and physical properties. It will inevitably change how the industry services and maintains bowling balls.

This investigation primarily pertains to the effect a patented vapor barrier enclosure, called The Immortalizer®, has on a ball's fundamental physical properties such as durometer, footprint (or contact patch), coefficient of friction, weight, and diameter. It further documents with reasonable evidence that these properties directly affect a bowling ball's performance and lane engagement characteristics.

Our study concludes with statistical significance that a bowling ball that is protected by the Immortalizer® enclosure technology maintains its designed ball motion and intended "factory-fresh" performance characteristics. This provides bowlers with extended equipment reliability needed for their diversified bowling ball collection required for the diverse lane oil-patterns and oil surface transitions between oiling's. The study also bursts some traditions bowlers and service providers routinely practice regarding bowling ball maintenance and rejuvenation techniques.

Keywords

Bowling ball, Immortalizer®, Durometer, Footprint, Ball Performance, Lane engagement, Vapor Barrier, Plasticizer, Dry-lane Coefficient of Friction, On-lane Coefficient of Friction, Ball Motion Study

Contents

1 Background

A common problem many bowlers experience is sporadic circumferential cracking of bowling balls. Many bowlers have also experienced that newly purchased reactive-resin bowling balls tend to begin losing their original lane reaction performance after 6 months. This phenomenon is sometimes referred to as a ball "dying" and it occurs no matter how bowlers might maintain the surface of their bowling balls. Another issue that frustrates bowlers is the sporadic circumferential cracking of their bowling balls for no apparent reason.

It should be noted that reactive-resin coverstocks are very porous by design and are wholly filled with microscopic air pockets and channels. The average thickness of this layer is generally less than one inch. This intentional porosity is responsible for both lane engagement traction and lane oil absorption observed on the balls' surface. However, a side effect of the low-density nature of this coverstock composition allows certain resin chemicals (softening agents) to evaporate out.

It is a reasonable assumption that both these issues, i.e., performance declines and circumferential cracking, are interrelated. After trying numerous methods to resolve the latter, it was observed that an insulated vapor barrier was effective in inhibiting an already desiccated ball from cracking. It was observed that the potential for cracking was exacerbated when a ball was placed (during storage) on a surface that was at least 6-7° F cooler than the surrounding ambient temperature, such as on a concrete floor that experiences evaporative cooling. More importantly, it was noted that the vapor barrier impeded any further deterioration by preserving the remaining plasticizers within the polyisocyanate resin structure. After seeing its effect on an older ball, studies were conducted to evaluate the effect on brand new bowling balls. Early prototype testing increased confidence in the findings which led to the extensive testing that this report describes in further sections.

Figure 1: The Immortalizer®

If the performance of a new bowling ball can be preserved, it would significantly improve a bowler's experience on the lanes by maintaining the diversified performance attributes of their bowling ball collection. It would also enhance bowler interest in the sport. With their bowling arsenal protected from transitioning, aka “dying”, bowlers can confidently choose any of their reactive-resin balls and know that its lane reaction properties will continue to remain predictable and consistent over time.

1.1 Initial Testing

In order to effectively record a potentially lengthy study, it is important to create baseline expectations. A collection of bowling balls with a variety of coverstocks, cores, and brands was initially used to gather large amounts of data to obtain preliminary results. The manufacturing date of each ball was also noted along with additional specifications as noted on the original packaging cartons.

The equipment required for the study was either purchased or fabricated by Magnum in order to test and record the data. The recorded data included durometer (shore D), diameter, weight, temperature, footprint, and co-efficient of friction. A description of the testing equipment is listed below:

- Durometer Gauge – HOTO Instruments (NIST traceable Calibration Certificate# 051619-5J180567)
- Durometer test stand – Made by Magnum in compliance with ASTM-D2240

Figure 2: Durometer and the Pneumatic Test Stand

- Outside Micrometer (8”-9” range) – Fowler – In-house Calibration

Figure 3: Outside Micrometer 8"-9" range

- Footprint Measurement Gauge – precision ball bearing aluminum rails support a platform with adjustable weights to match the exact weight of the ball. An etched millimeter microscope glass slide with an illuminated digital microscope camera is mounted on the platform to precisely measure the ball’s surface contact patch. Fabricated by Magnum.

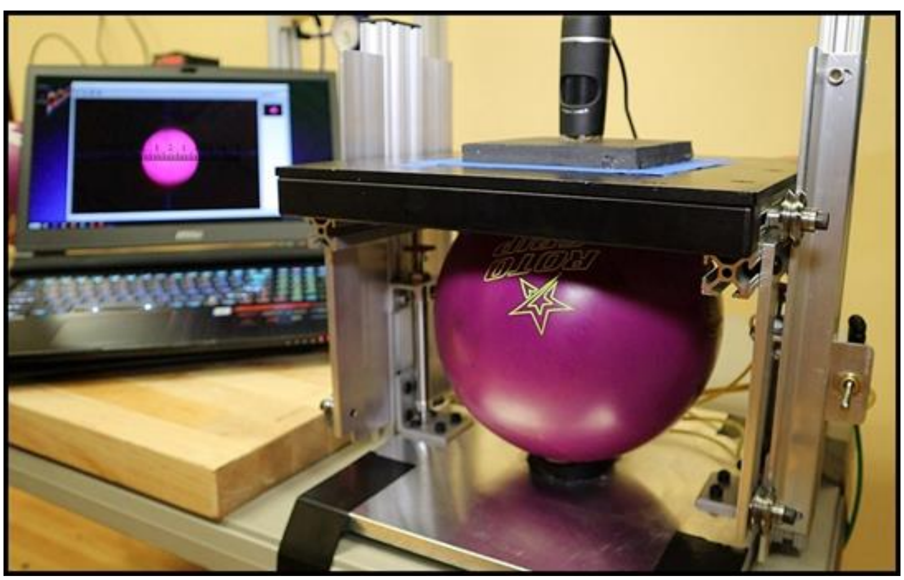


Figure 4: Apparatus for Footprint Measurement

- Weight Scale – Calibrated Industrial scale

Figure 5: Industrial Weighing Scale

- Oven – PLC temperature-controlled circulating oven with random orbital/rotational capability to house two bowling balls

Figure 6: Oven with Circulating air and Ball rotation apparatus

- Apparatus for (On-lane / Dry Lane) Coefficient of Friction – USBC inspired design made by Magnum

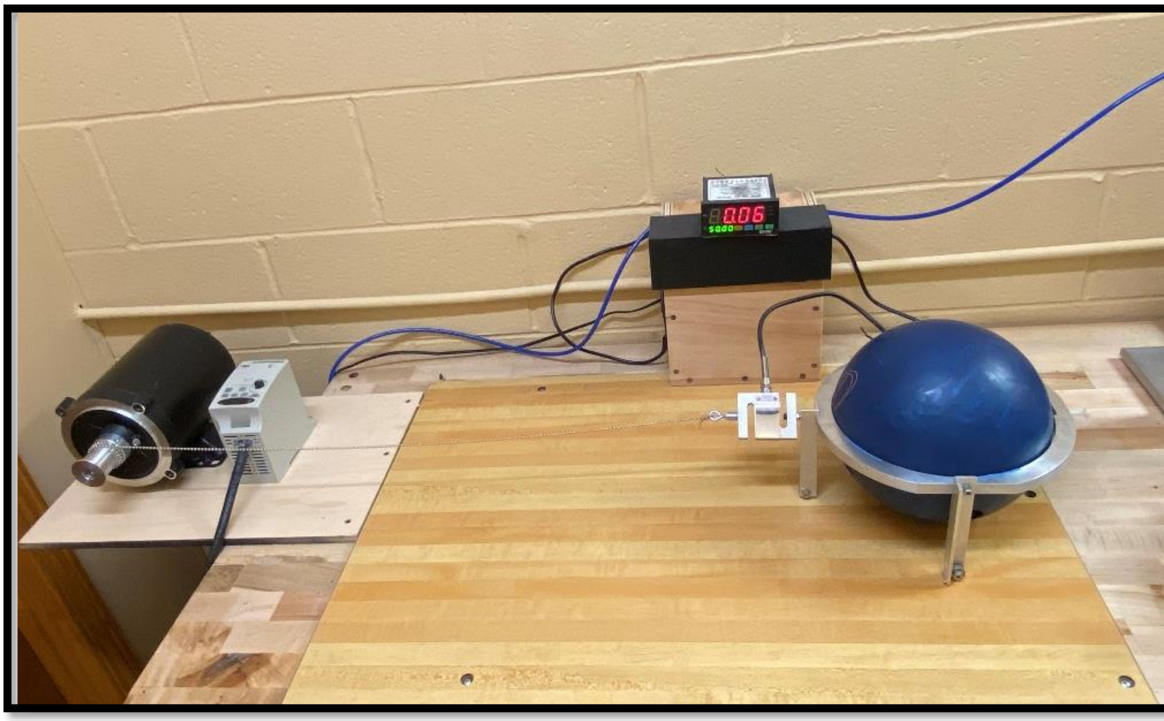


Figure 7: Apparatus for Coefficient of Friction measurement

- Temperature (Figure 8)– multiple probed thermocouple digital thermometers measure polar temperature differentials (thermal shock) w/multiple data points - latitudes 90°, 60°, 30°, 0°, -30°, -60°, -90° using a small chiller plate.
- Temperature (Figure 9)– polar differentials are recorded and compared using different support ring constructions using a large chiller plate

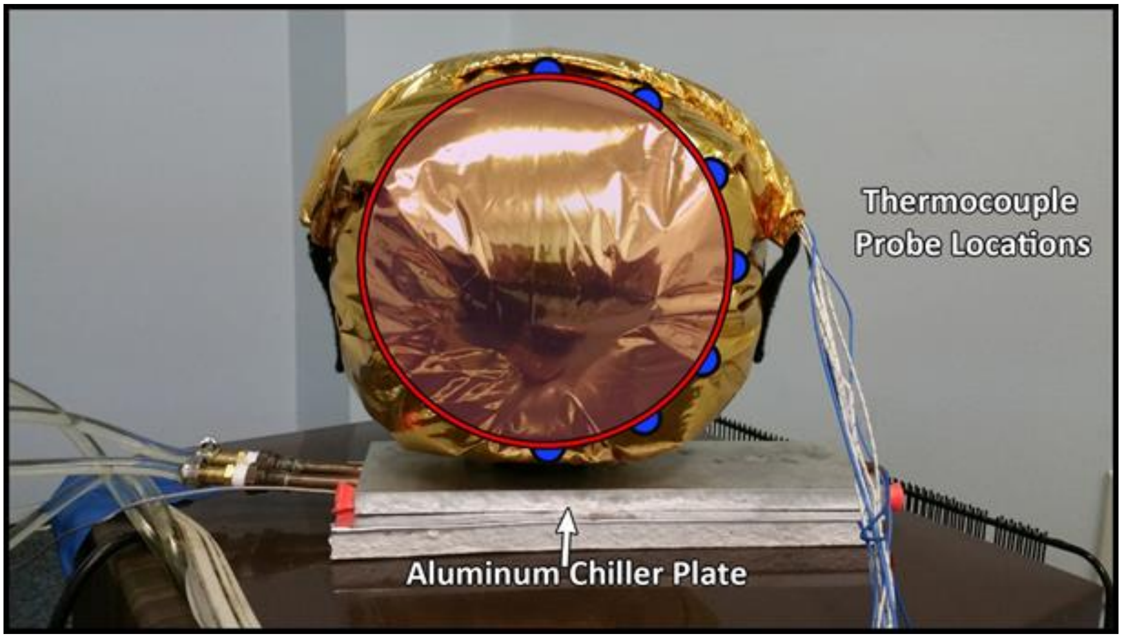


Figure 8: Apparatus for measuring polar differential

Figure 9: Apparatus for measuring polar differential

Bowling balls ranging in age from 0-4 years were used with the above listed measuring equipment to record numerous statistics. Polar differential analysis indicated that the Immortalizer® is effective in keeping the ball temperature uniform throughout the ball surface to within 3-4° F, eliminating the polar temperature differential of 6-7°F which has been determined to be generally responsible for circumferential cracking due to thermal shock. The impact of thermal shock is most prevalent when the coverstock resin becomes susceptible as it desiccates and shrinks creating increased surface tension. The thermal protective benefits of the Immortalizer® can be attributed to the insulation material sandwiched between two vapor-barrier layers.

Early performance data indicated that as bowling balls age, coverstock durometers increase, ball weight decreased, and diameters shrunk in size. All of these factors culminate in a reduced footprint, resulting in lane reaction characteristics that differs from the manufacturer's published specifications for a new ball. The initial evidence strongly indicated that these parameters affect how the ball engages with the lane. Lane engagement characteristics of a bowling ball have a direct effect on a bowling ball's performance and a bowler's experience and success on the lanes. The results were significant enough to justify the next stage of the study – Controlled Testing.

2 Controlled Testing

Controlled testing required procuring physically identical bowling balls, freshly poured, so that they can be tracked for any changes from the beginning of their life-cycle. Such testing also provides numerous scientific advantages.

- Bowling balls poured in the same batch tend to have similar features and characteristics including RG, Differential, Weight, Top, and Pin
- Elimination of most "special cause variation"
- Availability of baseline data
- Ability to put subjects through different environments and treatments for pairwise comparison; and more.

To obtain the highest quality identical bowling balls, Magnum requested assistance from Storm Products located in Brigham City, Utah. After discussing the scope of the testing and the intentions of the study, Storm furnished Magnum with the choice of 3 identical bowling balls. A fourth identical ball, still in its original factory packaging with the same manufacturing date was subsequently sourced by Magnum 12 months later from an on-line distributor's inventory in order to expand the scope of the study. Each ball was subjected to different treatments as shown in Table 1. For example, the treatment for Ball 2 was to subject it to a moderately high temperature environment for a period of time equivalent to one summer season's exposure (southern state) while being protected by the Immortalizer®. The enclosure method mentioned in the table was implemented immediately upon receiving the balls and was maintained throughout with the exception of taking periodic readings.

Table 1: Treatment for each test ball

Ball #	Environmental condition	Enclosure
Ball 1 (Control A)	None – Room conditions	Protected by Immortalizer®
Ball 2	Circulating Oven - heated for a limited time	Protected by Immortalizer®
Ball 3 (Control B)	None – Room conditions	Stored in Manufacturer's Packaging
Ball 4	Circulating Oven - heated for a limited time	No protection

2.1 In-house Testing

Initial readings including durometer, weight, and diameter was taken for all balls in accordance with USBC's Standard Operating Procedures. Footprint readings were taken using the contact patch optical comparator. To accelerate the ball aging process, Ball 2 and Ball 4 were placed in a PLC controlled circulating oven for a total of 6 weeks (1000 hours) at a maximum of 120 °F, a temperature well below most manufacturers' maximum allowed temperature for warranty, i.e., 140° F. In order to prevent plasticizer build-up at the bottom of the ball due to heat induced viscosity changes and gravity, Ball 4 was placed on a rotating apparatus which would continuously rotate the ball at a constant speed with random direction changes. Periodic readings were taken for each ball (every 24 – 168 hours).

Table 2 represents the summary of readings when the balls were factory-fresh (@t_0) and when the balls were 1.5 years old (@$t_{1.5}$) and went through the different treatments as mentioned in Table 1. Outside of the abovementioned 6-week period of oven heating, Ball 2 and Ball 4 were also stored at room temperature (~70°F) in their intended enclosure. It is clear that the balls not protected by the Immortalizer® showed an increase in durometer and a decrease in weight, diameter, and footprint (Figures 10-13). An additional factor affecting the reduction in the footprint for Ball 4 can be attributed to its reduced weight from loss of plasticizers through evaporation since footprint is proportional to the ball weight.

Ball #	Durometer (HD)[1]			Weight (lbs.)			Diameter (Inches)			Footprint (mm)		
	@t_0	@$t_{1.5}$	Change	@t_0	@$t_{1.5}$	Change	@t_0	@$t_{1.5}$	Change	@t_0	@$t_{1.5}$	Change
Ball 1	73.5	73.125	-1.2%	15.12	15.12	0.0%	8.585	8.585	0.0%	4.0	4.0	0.0%
Ball 2	73.5	73.375	-0.8%	15.17	15.17	0.0%	8.585	8.585	0.0%	4.0	4.0	0.0%
Ball 3[2]	73.5	76	+3.4%	15.19	15.14	-0.3%	8.585	8.582	-.04%	4.0	3.80	-5%
Ball 4	73.6	77.5	+4.6%	15.21	14.78	-2.9%	8.589	8.550	-0.5%	4.1	3.15	-23%

Table 2: In-house testing results at factory fresh and 1.5 years later

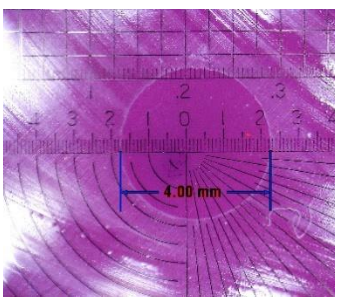


Figure 10: Footprint of Ball 1

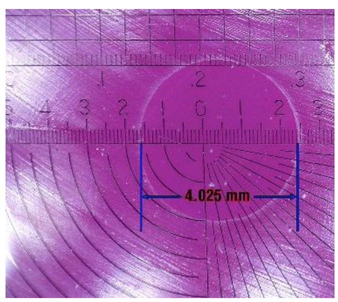


Figure 11: Footprint of Ball 2

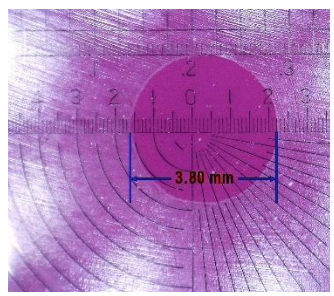


Figure 12: Footprint of Ball 3

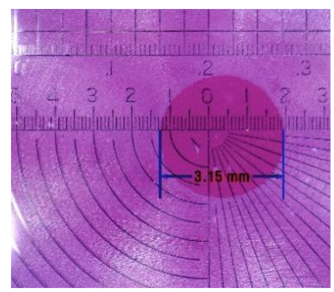


Figure 13: Footprint of Ball 4

[1] The precision of the Durometer gauge is ±1 HD. A minor durometer difference can also be attributed to seasonal ambient humidity level differences.

[2] This ball was obtained later to expand the scope of testing. The readings were not taken right after it was poured. The specification provided by the manufacturer indicates the Durometer is between 73-75. It can be assumed that since the pour date is identical to the other three balls, it's physical specifications may also be considered to be the same as those tested for the sake of the study.

Table 3: Dry-lane and On-lane Coefficient of Friction readings

[3]COF @$t_{1.5}$	Ball 1	Ball 2	Ball 3	Ball 4
Dry-lane COF	0.160	0.150	0.170	0.190
On-lane COF	**0.070**	**0.071**	**0.065**	**0.055**

Table 3 represents the readings of both types of Coefficients of Frictions. Ball Motion Study conducted by USBC goes to prove that both On-lane and Dry-lane COF significantly affect the performance of a bowling ball. Specifically, the higher the Dry-lane COF, the less overall performance the ball will have. On the other hand, the higher the On-lane COF, the better overall performance the ball will have. Results from Table 3 clearly indicate that the bowling balls protected by the Immortalizer® (Ball 1 and 2) would likely have better performance compared to the ball protected by Manufacturer's packaging (Ball 3), and especially, the unprotected ball (Ball 4).

Overall, the changes are more pronounced in the ball that had no protection and was subjected to heat. On the contrary, Ball 2, which was subjected to exact same conditions but with the protection of the Immortalizer®, did not show any change in vital characteristics affecting the ball performance. These results exemplify the effectiveness of the Immortalizer® on the bowling ball's physical properties.

2.2 External – Testing using a Robot

The next, and potentially the most important stage of the testing, was to evaluate the actual lane performance of the test bowling balls. There are several ways of executing this stage. However, the most credible and reliable way is to use a mechanical robotic arm designed to provide accuracy and reliability to throw the ball on a bowling lane, and to record the data using SPECTO. Since Magnum does not have the capability in-house, Magnum used a neutral third-party accredited tester. After discussion of the test balls and preliminary test results, a plan to evaluate the performance of each ball using the robotic arm was formulated and agreed upon.

[3] The COF data for t_0 is not available because the COF measurement apparatus was not made until later.

2.2.1 Execution

- All balls remained undrilled in order to prevent “special cause variation”
- Prior to using the robot, all the test balls’ surfaces were prepared identically to a factory-like finish of 2000 grit.
- The robot was set up with the same identical launch parameters and settings for all four test balls as indicated by Table 4.
- All four balls were scribed such that accurately positioning them in the robot was consistently maintained.
- Each ball was thrown 20 consecutive times along the same path at predetermined robot setting to record travel data points over the naturally transitioning lane surface.
- Time intervals between the consecutive 20 launches was kept constant (± 10 seconds) to account for lane oil absorption on the ball’s coverstock surface.
- All four test balls were thrown down the same lane to eliminate differences in lane topography.
- The lane was re-oiled with the same oil pattern for each individual test ball.
- Video recording as well as SPECTO® data were recorded and saved for each shot.
- The position of the robot was consistently monitored and maintained for each shot.

Table 4: Preset launch parameters for the Robot

Parameter	Preset Value
Loft Distance	0
Launch Angle	2.5°
Launch Speed	17 mph
Launch Revs	400 RPM
Robot Position	18b
Axis Rotation	45°
Axis Tilt	4.5°
Oil Pattern	Krypton 2943

2.2.2 Results - External Testing

This section first describes the performance and lane engagement of each ball, followed by statistical analysis.

Ball 1 (Control – Protected by Immortalizer®): The bowling ball read the lane very early and began to transition from the PAP to the PSA in a very gradual predictable manor. This resulted in the ball beginning its hook phase in the earlier portion of the lane and therefore not skidding as far to the right at the breakpoint as Balls 3 and 4. Ball 1 maintained this reaction through the pins and demonstrated a consistent, controllable, and smooth ball motion. This ball was able to consistently hit the pocket. See Figure 14

Ball 2 (Circulating Oven heated with Immortalizer® protection): The bowling ball read the lane the earliest out of the 4 balls and began its transition from the PAP to the PSA in a gradual manor, very similar to Ball 1. This resulted in the ball beginning its hook phase in the front part of the lane and therefore controlling the breakpoint down the lane. Furthermore, Ball 2 demonstrated an extremely smooth ball motion that was consistent and reliable down the lane. This ball was also able to consistently hit the pocket, virtually identical to that of Ball 1. See Figure 15.

Ball 3 (Control – Manufacturer's packaging): The bowling ball did not read the lane as early as Ball 1 or 2, but did not skid as much as Ball 4. The increased skid and decreased friction in the front part of the lane caused the ball to retain more axis rotation and resulted in a more violent and angular motion down the back end of lane. Also, due to the lack of lane engagement and friction in the front part of the lane, the ball skidded further right than Ball's 1 and 2 and therefore did not reach the same breakpoint even though it was launched at the same angle. As a result, the ball ended up very light most shots and often left split combinations involving the 2, 4, and 10 pins. See Figure 16.

Ball 4 (Circulating Oven heated – no protection): The bowling ball did not read the front part of the lane and skidded the longest in comparison to Balls 1, 2, and 3. Due to the almost non-existent lane engagement in the front part of the lane, the ball reached a breakpoint that was even further right than Ball 3 and ended up falling in the gutter multiple times even though it was thrown with the same launch parameters. It is important to note that Ball 4 was the only ball that went into the gutter. It also left a significantly high number of splits. See Figure 17 and Figure 18.

All the shots, as mentioned earlier, have been recorded using SPECTO for further analysis. An "Outlier Test" was performed on the dataset as a whole, on individual response variables, and on initial parameters in order to ensure reliability of the analysis. Cook's distance was also used to detect and then remove outliers. As a result, the individual analysis of variables recorded by SPECTO include 15-17 shots per ball depending on the number of outliers for each.

Our null hypothesis for the analysis is that all the means are equal (for all response variables). The alternate hypothesis is that at least one mean is different among several treatments. When we have more than two treatments (in our case, balls), it is inappropriate to simply compare each pair using a *t*-test. The correct way to conduct the analysis is to use a one-way analysis of variance (ANOVA) to evaluate whether there is any evidence that the means differ. If the ANOVA leads to a conclusion that there is evidence that the treatment means differ, we might then be interested in investigating which of the means are different. Such an investigation can yield which treatments (Balls) statistically performed better.

Several methods were considered for statistical comparison of the performance of the bowling balls, including Tukey's Pairwise Comparison, Fisher's Pairwise Comparison, Dunnett's test, and Hsu's MCB method. The former two methods are used for comparing all the pairs. Dunnett's test compares every treatment with a selected controlled treatment. The last method compares the treatment with the highest or lowest means to the other treatments. Internally, all the methods were used to generate results, and the conclusion attained by all of the methods was same. However, to keep the report relatively brief, and also to provide as much information as possible, the final choice was narrowed down to the first two methods. However, Fisher's method has no protection against false positives built-in. Therefore, in this report, the results obtained using Tukey's pairwise comparison are presented (See Appendix II for detailed results). Tukey's method, like many others, assume that the observations have normal distribution. During our analysis, if any of the response variables failed the Normality Test, they were transformed (using Box-Cox transformation with optimal lambda) such that they would pass the Kolmogorov-Smirnov normality test.

SPECTOGRAPHS

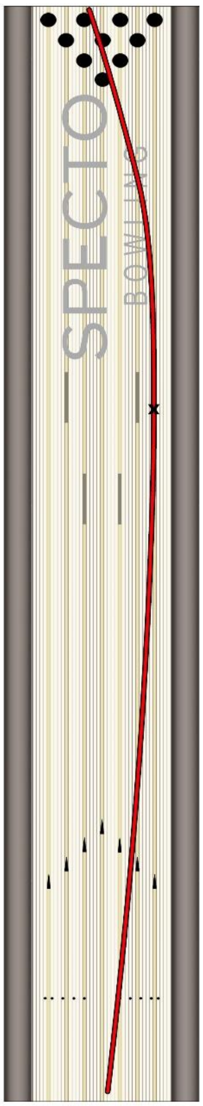


Figure 14: Path for Ball 1

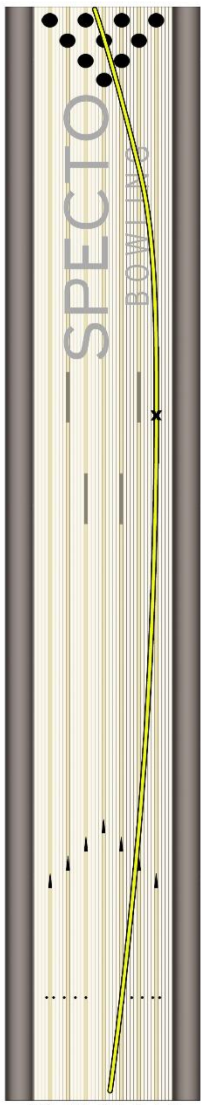


Figure 15: Path for Ball 2

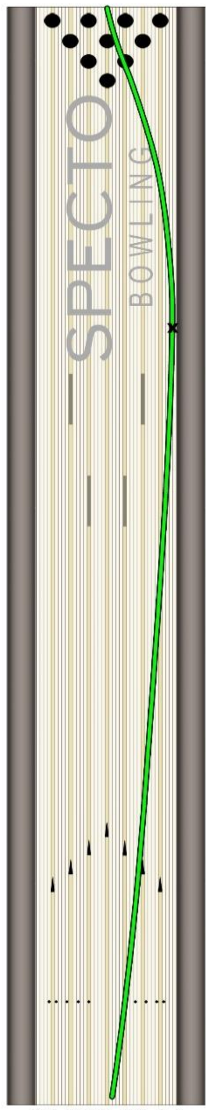


Figure 16: Path for Ball 3

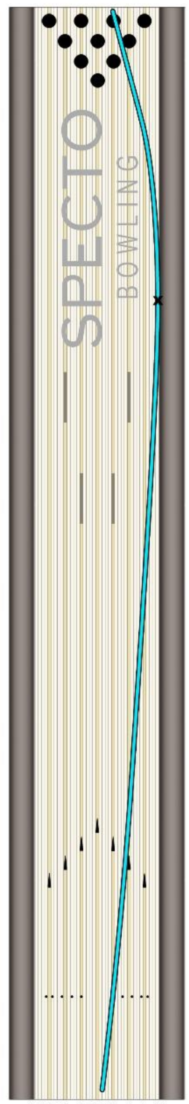


Figure 17: Path for Ball 4

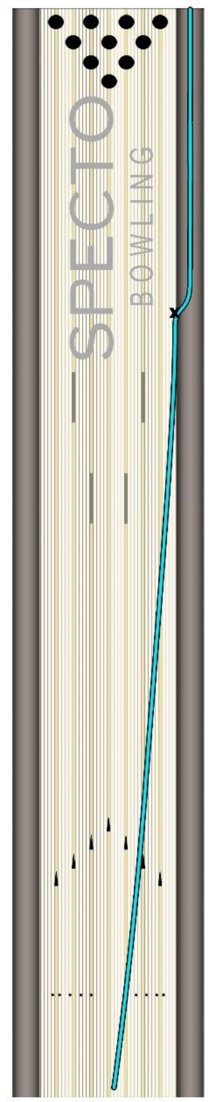


Figure 18: Path for Ball 4 when it guttered

Table 5 lists the results from the Tukey's pairwise comparison test. The test compares each treatment with one another to check for statistically significant differences. The test was performed for each of the SPECTO's recorded responses. Tukey's test can be used to assign groups to different treatments. The treatment that does not share a letter with the other treatment is statistically different. For example, consider the recorded data for 'Skid'. Tukey's pairwise comparison assigned the groups B, B, A, and A for

Balls 1, 2, 3, and 4 respectively. This means that Balls 1 and 2 are statistically significantly different from the Balls 3 and 4 whereas Balls 3 and 4 skidded the most, and Balls 1 and 2 skidded the least. In Table 5, there are also classifications such as group 'AB'. It means that the ball in group AB is statistically similar to balls in group A, as well as balls in group B.

In a similar way, we can interpret the results for each response. Also note that the results are accompanied by the *p*-value of the test. The industry standard for significance level is 0.05. Any test that has a *p*-value of less than 0.05 is statistically significant. In case of 'Skid', the *p*-value of 0.000 indicates that if the balls were thrown 100 times, the difference in means of Skid can be attributed to the different treatments 100 out of 100 times. It cannot be attributed to chance (random error).

For the responses where the *p*-value is higher than 0.05, we fail to reject the null hypothesis, such that that we cannot reject the statement that the means for all four treatments are the same. This does not necessarily suggest that all balls are really the same for these variables, but rather it implies that we do not have enough evidence to say otherwise and further investigation may be necessary.

There are variety of bowling balls available in the marketplace and each ball is designed to perform a specific way. To determine the relative performance of the balls, they can be ranked from 1 to 4, depending on how they were intended to perform for a specific response. For example, ranking for the response 'Skid' would be 1, 1, 2, and 2 for the treatments (Balls) 1, 2, 3, and 4 respectively. For the next step of the analysis, we are only considering responses for which the *p*-Value is less than 0.05.

Table 5: Tukey's Pairwise Comparison

Confidence: 98.95%	**ANOVA *p*-value**	**Ball 1 (Treatment 1)**	**Ball 2 (Treatment 2)**	**Ball 3 (Treatment 3)**	**Ball 4 (Treatment 4)**
True Breakpoint Distance	0.000	B	B	A	A
Breakpoint Position	0.410	A	A	A	A
Boards Crossed	0.000	A	A	A	B
Total Hook[4]	0.000	A	A	B	C
Breakpoint Angle[4]	0.000	A	A	B	B
Breakpoint Speed	0.147	A	A	A	A
Entry Speed	0.232	A	A	A	A
Impact Angle	0.174	A	A	A	A
Speed Loss Heads	0.493	A	A	A	A
Speed Loss Back	0.111	AB	B	AB	A
Speed Loss Total	0.264	A	A	A	A
Speed Loss Pindeck	0.850	A	A	A	A
Speed Loss Percent	0.471	A	A	A	A
Pindeck Deflection	0.407	A	A	A	A
Skid	0.000	B	B	A	A
Hook	0.022	A	A	AB	B
Roll	0.264	A	A	A	A

[4] These responses failed the normality test for residuals and hence were transformed using Box-Cox transformation. See Appendix II.

Table 6 summarizes the relative performance of balls subjected to different treatments with regards to specific response variables. It is clear that the Balls 1 and 2 outperformed the other two balls. Ball 3 ranked the second, followed lastly by Ball 4 which performed worst in all respects.

Table 6: Relative performance of the balls subjected to different treatments

Response	Ball 1 (Treatment 1)	Ball 2 (Treatment 2)	Ball 3 (Treatment 3)	Ball 4 (Treatment 4)
True Breakpoint Distance	1	1	2	2
Boards Crossed	1	1	1	2
Total Hook	1	1	2	3
Breakpoint Angle	1	1	2	2
Skid	1	1	2	2
Hook	1	1	2	3
Overall Performance Rank	***1***	***1***	***2***	***3***

3 Conclusion

The importance of a bowling ball's ability to perform the way it is intended and described by the manufacturer cannot be understated. Bowling enthusiasts maintain an arsenal of bowling balls to effectively adjust for every condition, be it the oil pattern, lane oil transition, lane surface composition, or any other factors affecting the selection of a particular ball. The purpose of purchasing such an arsenal becomes pointless if all the balls in a bowler's collection desiccate and transform into a longer skidding balls with cleaner and more angular ball motion on the back end of the lane.

This extensive study shows that the bowling balls, if not protected by an effectively designed vapor-barrier enclosure, tend to change overtime as reflected by increased durometer, dry-lane coefficient of friction, and reduced weight, diameter, footprint, and on-lane coefficient of friction. The effect of these changes was evident in the external testing conducted with a programmable robotic throw arm to launch repeatable ball shots with identical launch angle, speed, and rotation. A key finding is the extent of the effect of using the Immortalizer® bowling ball enclosure. The drastic performance difference between Balls 2 and 4, which were both subjected to similar conditions, indicates that an insulated vapor-barrier such as the Immortalizer® is effective in protecting the balls from environmental ambient conditions as well as higher seasonal temperatures which accelerate the aging process.

It must also be noted that the physical characteristics of both protected Balls 1 and 2 in terms of weight, diameter, coverstock durometer and footprint did not change over time, but the physical characteristics of Balls 3 and 4 did change (assuming Ball 3 was similar to the initial readings as the other balls that were poured from the same batch).

Plasticizers, or softening agents, are required as an essential chemistry component of bowling ball resin coverstocks. These plasticizers saturate the coverstock both at the surface and throughout the layer. Any treatment subsequent to the ball's manufacture that removes the plasticizers from the coverstock will accelerate the gradual deterioration of the resin as measured and evidenced by weight, durometer, footprint, and co-efficient of friction. The study also demonstrates that it is a myth that baking a bowling ball or subjecting it to a hot bath of water and/or chemicals (aka detoxification) rejuvenates its coverstock. In reality, any marginal improvement to durometer is only temporary without the proper protection to inhibit the loss of resin plasticizers. If additional plasticizers are removed, the desiccation process is accelerated thereby causing an even greater deviation over time from the manufacturer's published performance parameters. It is possible that short periods of baking or hot soaking may temporarily improve the durometer by bringing underlying plasticizers to the dryer harder surface, but the effect doesn't last long. Furthermore, this study also supports a natural dehydration effect occurring over time (as evident by the performance of Ball 3) and that this natural progression, if left unprotected, is intensified through exposure to hotter environments such as a trunk of a car during summer months as evident by the performance of Ball 4. Additionally, intentional and indiscriminatory removal of essential oils existing in resin coverstocks only amplifies the desiccation process.

It can be concluded that regardless of where a reactive-resin bowling ball is conventionally stored, the reactive-resin coverstock will experience physical changes which will affect its performance and lane engagement characteristics. The empirical evidence shows that storing it in an Immortalizer® insulated vapor-barrier is going to maintain the vital characteristics of the ball essential to its integrity, performance and lane engagement.

Appendix I – Definitions

ANOVA - Analysis of Variance, a statistical method in which the variation in a set of observations is divided into distinct components.

Boards Crossed - How many times the ball crossed from one board to another

Breakpoint Angle - Total angle between launch and impact

Breakpoint Distance - Distance at which the ball was at its outmost position

Breakpoint Position - Position at which the ball was at its outmost position

Breakpoint Speed - Speed of the ball at Breakpoint

Entry Speed - Entry Speed of the ball

Footprint - The diameter of the contact patch of the ball on a lane

Hook - Distance the ball traveled while changing direction

Hook board - Board position of the ball where it started to change direction

Impact Angle - Impact Angle of the ball with pins

Normal Data (Normality) - Normal data are data that are drawn (come from) a population that has a normal distribution. This distribution is inarguably the most important and the most frequently used distribution in both the theory and application of statistics.

Pin deck Deflection - The number of boards the ball deflected in the pin deck.

p-Value - A *p*-value is a measure of the probability that an observed difference could have occurred just by random chance.

Roll - Distance the ball traveled after completing the change in direction

Rollaboard - Board position of the ball when it completed its change of direction.

Skid - Distance the ball traveled without significant change in direction

Speed Loss Back - Loss of speed from 40' to 60' without pin deck

Speed Loss Heads - Loss of speed from 0' to 20'

Speed Loss Mid - Loss of speed from 20' to 40'

Speed Loss Pin deck - Loss of speed through the pin deck

Total Hook - Boards the ball hooked more than a straight shot

Tukey's Pairwise Comparison Test - Tukey's test compares the means of every treatment to the means of every other treatment; that is, it applies simultaneously to the set of all pairwise comparisons. and identifies any difference between two means that is greater than the expected standard error.

Appendix II – External Test Data – Statistical Analysis (ANOVA)

Common Components between all Responses

Method

Null hypothesis	All means are equal
Alternative hypothesis	Not all means are equal
Significance level	α = 0.05

Equal variances were assumed for the analysis.

Factor Information

Factor	Levels	Values
Ball	4	Ball 1, Ball 2, Ball 3, Ball 4

True Breakpoint Distance

One-way ANOVA: True Breakpoint Distance versus Ball

Analysis of Variance

Source	DF	Adj SS	Adj MS	F-Value	P-Value
Ball	3	26.86	8.9546	16.69	0.000
Error	62	33.26	0.5364		
Total	65	60.12			

Means

Ball	N	Mean	StDev	95% CI
Ball 1	17	40.000	0.612	(39.645, 40.355)
Ball 2	17	39.647	0.786	(39.292, 40.002)
Ball 3	16	40.938	0.680	(40.571, 41.304)
Ball 4	16	41.188	0.834	(40.821, 41.554)

Pooled StDev = 0.732399

Tukey Pairwise Comparisons

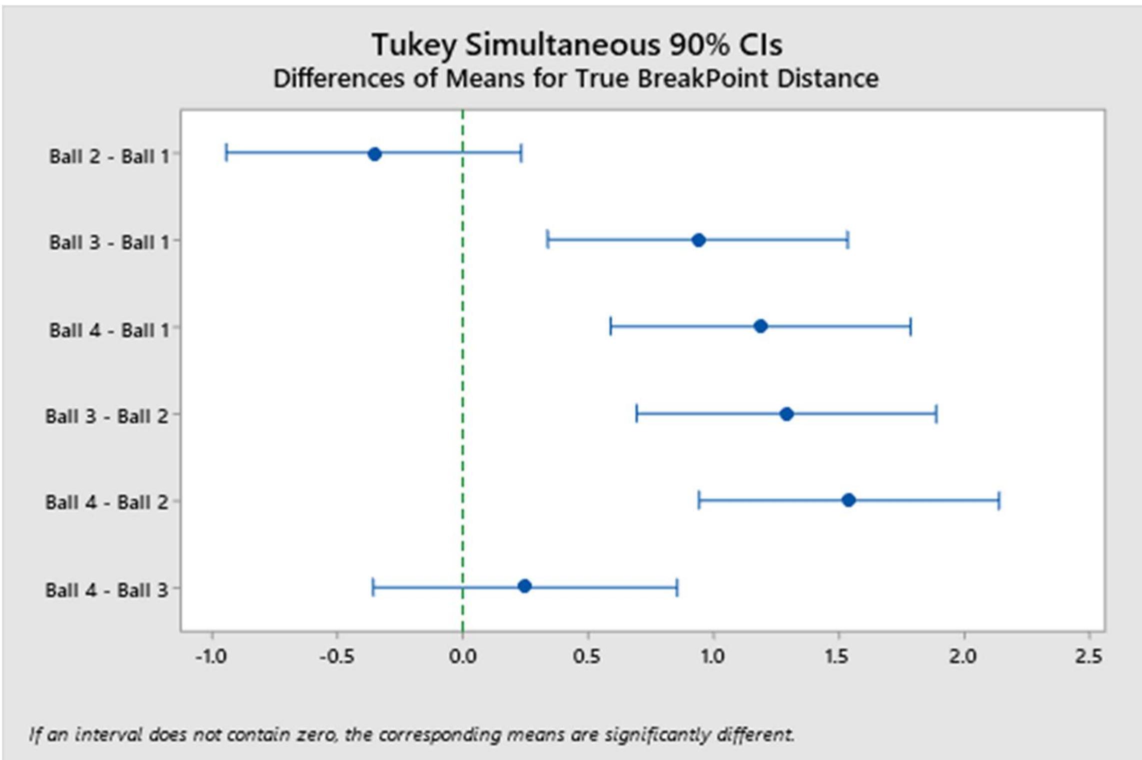
Ball	N	Mean	Grouping	
Ball 4	16	41.188	A	
Ball 3	16	40.938	A	
Ball 1	17	40.000		B
Ball 2	17	39.647		B

Means that do not share a letter are significantly different.

Tukey Simultaneous Tests for Differences of Means

Difference of Levels	Difference of Means	SE of Difference	90% CI	T-Value	Adjusted P-Value
Ball 2 - Ball 1	-0.353	0.251	(-0.941, 0.235)	-1.40	0.501
Ball 3 - Ball 1	0.938	0.255	(0.340, 1.535)	3.67	0.003
Ball 4 - Ball 1	1.188	0.255	(0.590, 1.785)	4.65	0.000
Ball 3 - Ball 2	1.290	0.255	(0.693, 1.888)	5.06	0.000
Ball 4 - Ball 2	1.540	0.255	(0.943, 2.138)	6.04	0.000
Ball 4 - Ball 3	0.250	0.259	(-0.356, 0.856)	0.97	0.769

Individual confidence level = 97.75%



Breakpoint Position

One-way ANOVA: BPPos versus Ball

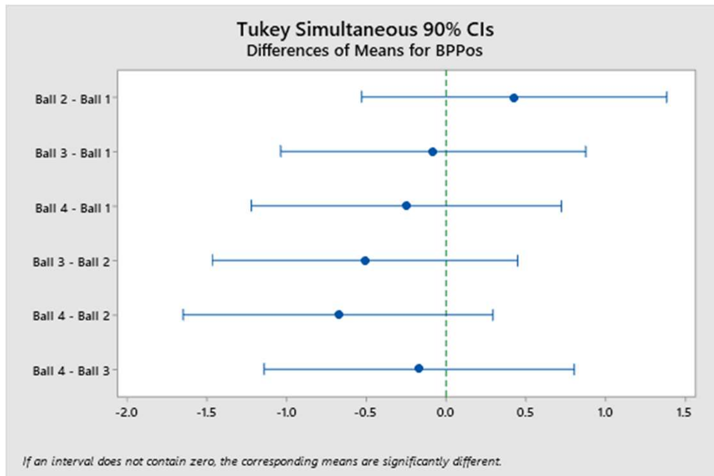
Analysis of Variance

Source	DF	Adj SS	Adj MS	F-Value	P-Value
Ball	3	4.143	1.381	0.98	0.410
Error	63	89.178	1.416		
Total	66	93.321			

Means

Ball	N	Mean	StDev	95% CI
Ball 1	17	3.597	1.115	(3.020, 4.173)
Ball 2	17	4.024	1.050	(3.447, 4.600)
Ball 3	17	3.516	1.302	(2.940, 4.093)
Ball 4	16	3.348	1.278	(2.754, 3.943)

Pooled StDev = 1.18976



Tukey Pairwise Comparisons

Ball	N	Mean	Grouping
Ball 2	17	4.024	A
Ball 1	17	3.597	A
Ball 3	17	3.516	A
Ball 4	16	3.348	A

Means that do not share a letter are significantly different.

Tukey Simultaneous Tests for Differences of Means

Difference of Levels	Difference of Means	SE of Difference	90% CI	T-Value	Adjusted P-Value
Ball 2 - Ball 1	0.427	0.408	(-0.528, 1.382)	1.05	0.723
Ball 3 - Ball 1	-0.080	0.408	(-1.035, 0.875)	-0.20	0.997
Ball 4 - Ball 1	-0.248	0.414	(-1.218, 0.722)	-0.60	0.932
Ball 3 - Ball 2	-0.508	0.408	(-1.463, 0.448)	-1.24	0.602
Ball 4 - Ball 2	-0.675	0.414	(-1.645, 0.294)	-1.63	0.370
Ball 4 - Ball 3	-0.168	0.414	(-1.138, 0.802)	-0.41	0.977

Individual confidence level = 97.76%

Breakpoint Speed

One-way ANOVA: BPSpd versus Ball

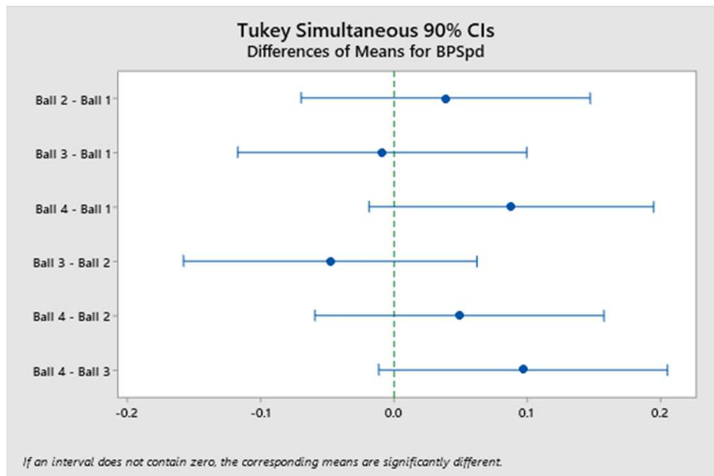
Analysis of Variance

Source	DF	Adj SS	Adj MS	F-Value	P-Value
Ball	3	0.09792	0.03264	1.85	0.147
Error	62	1.09274	0.01762		
Total	65	1.19066			

Means

Ball	N	Mean	StDev	95% CI
Ball 1	17	16.2844	0.1633	(16.2201, 16.3488)
Ball 2	16	16.3233	0.1223	(16.2570, 16.3897)
Ball 3	16	16.2757	0.1118	(16.2093, 16.3420)
Ball 4	17	16.3725	0.1261	(16.3081, 16.4369)

Pooled StDev = 0.132759



Tukey Pairwise Comparisons

Ball	N	Mean	Grouping
Ball 4	17	16.3725	A
Ball 2	16	16.3233	A
Ball 1	17	16.2844	A
Ball 3	16	16.2757	A

Means that do not share a letter are significantly different.

Tukey Simultaneous Tests for Differences of Means

Difference of Levels	Difference of Means	SE of Difference	90% CI	T-Value	Adjusted P-Value
Ball 2 - Ball 1	0.0389	0.0462	(-0.0694, 0.1471)	0.84	0.835
Ball 3 - Ball 1	-0.0088	0.0462	(-0.1170, 0.0995)	-0.19	0.998
Ball 4 - Ball 1	0.0881	0.0455	(-0.0185, 0.1946)	1.93	0.225
Ball 3 - Ball 2	-0.0477	0.0469	(-0.1575, 0.0622)	-1.02	0.741
Ball 4 - Ball 2	0.0492	0.0462	(-0.0590, 0.1574)	1.06	0.713
Ball 4 - Ball 3	0.0968	0.0462	(-0.0114, 0.2051)	2.09	0.166

Individual confidence level = 97.75%

Entry Speed

One-way ANOVA: EntSpd versus Ball

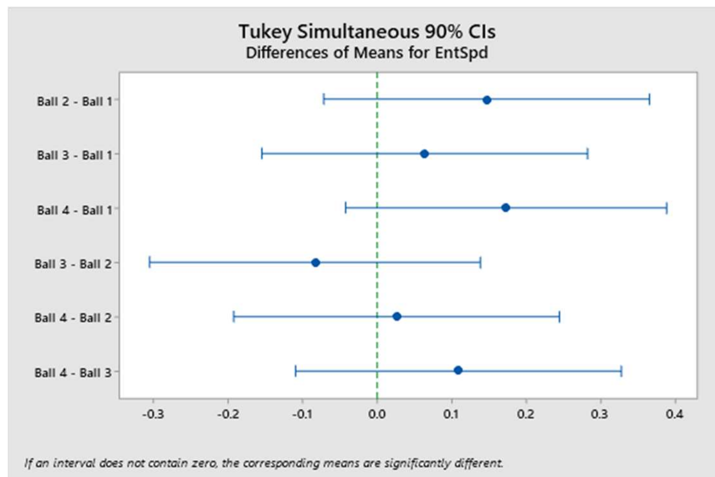
Analysis of Variance

Source	DF	Adj SS	Adj MS	F-Value	P-Value
Ball	3	0.3152	0.10507	1.47	0.232
Error	62	4.4406	0.07162		
Total	65	4.7558			

Means

Ball	N	Mean	StDev	95% CI
Ball 1	17	13.8111	0.2205	(13.6814, 13.9409)
Ball 2	16	13.9579	0.2017	(13.8242, 14.0917)
Ball 3	16	13.8750	0.2465	(13.7412, 14.0087)
Ball 4	17	13.9841	0.3658	(13.8543, 14.1138)

Pooled StDev = 0.267625



Tukey Pairwise Comparisons

Ball	N	Mean	Grouping
Ball 4	17	13.9841	A
Ball 2	16	13.9579	A
Ball 3	16	13.8750	A
Ball 1	17	13.8111	A

Means that do not share a letter are significantly different.

Tukey Simultaneous Tests for Differences of Means

Difference of Levels	Difference of Means	SE of Difference	90% CI	T-Value	Adjusted P-Value
Ball 2 - Ball 1	0.1468	0.0932	(-0.0713, 0.3650)	1.58	0.400
Ball 3 - Ball 1	0.0638	0.0932	(-0.1543, 0.2820)	0.68	0.902
Ball 4 - Ball 1	0.1729	0.0918	(-0.0419, 0.3878)	1.88	0.245
Ball 3 - Ball 2	-0.0830	0.0946	(-0.3044, 0.1385)	-0.88	0.817
Ball 4 - Ball 2	0.0261	0.0932	(-0.1921, 0.2443)	0.28	0.992
Ball 4 - Ball 3	0.1091	0.0932	(-0.1091, 0.3273)	1.17	0.648

Individual confidence level = 97.75%

Impact Angle

One-way ANOVA: ImpAn versus Ball

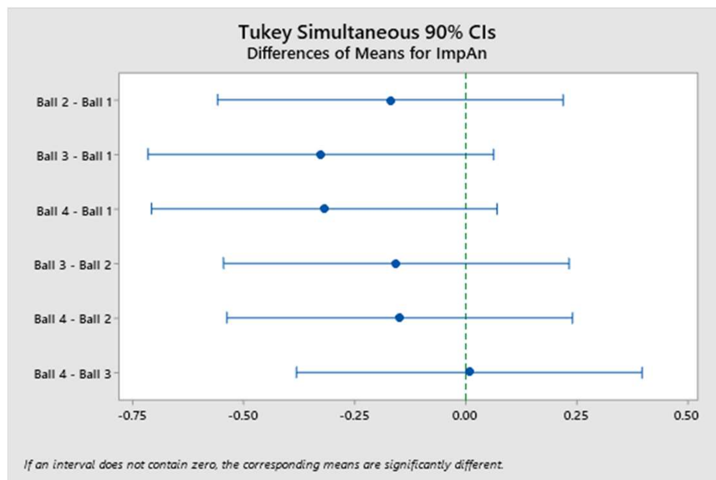
Analysis of Variance

Source	DF	Adj SS	Adj MS	F-Value	P-Value
Ball	3	1.201	0.4002	1.71	0.174
Error	64	14.993	0.2343		
Total	67	16.194			

Means

Ball	N	Mean	StDev	95% CI
Ball 1	17	6.8677	0.4018	(6.6332, 7.1022)
Ball 2	17	6.6980	0.3058	(6.4635, 6.9325)
Ball 3	17	6.542	0.551	(6.307, 6.776)
Ball 4	17	6.550	0.616	(6.315, 6.784)

Pooled StDev = 0.484010



Tukey Pairwise Comparisons

Ball	N	Mean	Grouping
Ball 1	17	6.8677	A
Ball 2	17	6.6980	A
Ball 4	17	6.550	A
Ball 3	17	6.542	A

Means that do not share a letter are significantly different.

Tukey Simultaneous Tests for Differences of Means

Difference of Levels	Difference of Means	SE of Difference	90% CI	T-Value	Adjusted P-Value
Ball 2 - Ball 1	-0.170	0.166	(-0.558, 0.219)	-1.02	0.737
Ball 3 - Ball 1	-0.326	0.166	(-0.714, 0.063)	-1.96	0.213
Ball 4 - Ball 1	-0.318	0.166	(-0.707, 0.071)	-1.92	0.232
Ball 3 - Ball 2	-0.156	0.166	(-0.545, 0.232)	-0.94	0.783
Ball 4 - Ball 2	-0.148	0.166	(-0.537, 0.240)	-0.89	0.808
Ball 4 - Ball 3	0.008	0.166	(-0.381, 0.396)	0.05	1.000

Individual confidence level = 97.76%

Speed Loss Heads

One-way ANOVA: SLhead versus Ball

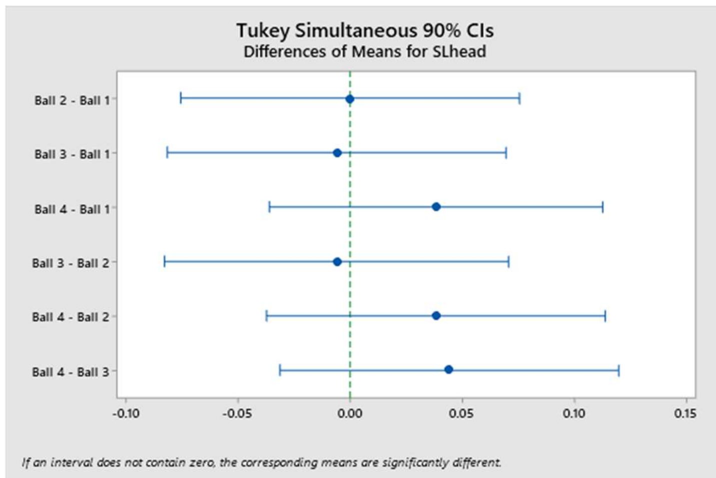
Analysis of Variance

Source	DF	Adj SS	Adj MS	F-Value	P-Value
Ball	3	0.02082	0.006939	0.81	0.493
Error	62	0.53062	0.008558		
Total	65	0.55143			

Means

Ball	N	Mean	StDev	95% CI
Ball 1	17	0.1915	0.1047	(0.1466, 0.2363)
Ball 2	16	0.1915	0.1109	(0.1453, 0.2377)
Ball 3	16	0.1855	0.0677	(0.1393, 0.2317)
Ball 4	17	0.2298	0.0797	(0.1849, 0.2746)

Pooled StDev = 0.0925114



Tukey Pairwise Comparisons

Ball	N	Mean	Grouping
Ball 4	17	0.2298	A
Ball 2	16	0.1915	A
Ball 1	17	0.1915	A
Ball 3	16	0.1855	A

Means that do not share a letter are significantly different.

Tukey Simultaneous Tests for Differences of Means

Difference of Levels	Difference of Means	SE of Difference	90% CI	T-Value	Adjusted P-Value
Ball 2 - Ball 1	0.0000	0.0322	(-0.0754, 0.0755)	0.00	1.000
Ball 3 - Ball 1	-0.0060	0.0322	(-0.0814, 0.0695)	-0.18	0.998
Ball 4 - Ball 1	0.0383	0.0317	(-0.0360, 0.1126)	1.21	0.625
Ball 3 - Ball 2	-0.0060	0.0327	(-0.0826, 0.0706)	-0.18	0.998
Ball 4 - Ball 2	0.0383	0.0322	(-0.0372, 0.1137)	1.19	0.637
Ball 4 - Ball 3	0.0443	0.0322	(-0.0312, 0.1197)	1.37	0.521

Individual confidence level = 97.75%

Speed Loss Back

One-way ANOVA: SLbck versus Ball

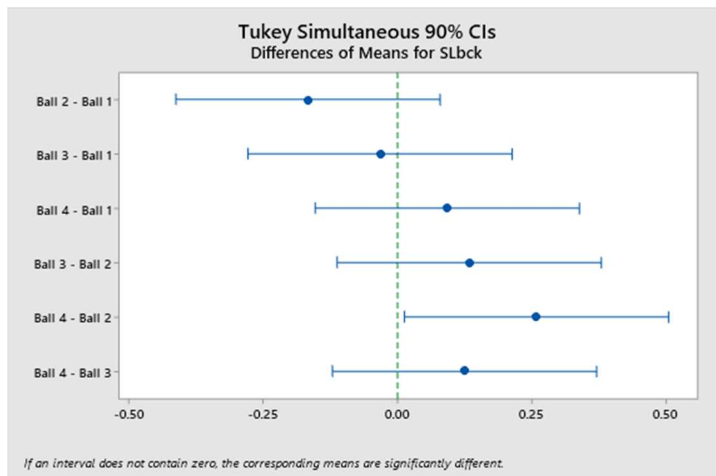
Analysis of Variance

Source	DF	Adj SS	Adj MS	F-Value	P-Value
Ball	3	0.5839	0.19464	2.08	0.111
Error	64	5.9822	0.09347		
Total	67	6.5662			

Means

Ball	N	Mean	StDev	95% CI
Ball 1	17	2.4937	0.2742	(2.3455, 2.6418)
Ball 2	17	2.3281	0.2928	(2.1799, 2.4762)
Ball 3	17	2.4617	0.2671	(2.3135, 2.6098)
Ball 4	17	2.5866	0.3763	(2.4385, 2.7347)

Pooled StDev = 0.305733



Tukey Pairwise Comparisons

Ball	N	Mean	Grouping	
Ball 4	17	2.5866	A	
Ball 1	17	2.4937	A	B
Ball 3	17	2.4617	A	B
Ball 2	17	2.3281		B

Means that do not share a letter are significantly different.

Tukey Simultaneous Tests for Differences of Means

Difference of Levels	Difference of Means	SE of Difference	90% CI	T-Value	Adjusted P-Value
Ball 2 - Ball 1	-0.166	0.105	(-0.411, 0.080)	-1.58	0.397
Ball 3 - Ball 1	-0.032	0.105	(-0.277, 0.213)	-0.31	0.990
Ball 4 - Ball 1	0.093	0.105	(-0.153, 0.338)	0.89	0.812
Ball 3 - Ball 2	0.134	0.105	(-0.112, 0.379)	1.27	0.583
Ball 4 - Ball 2	0.259	0.105	(0.013, 0.504)	2.47	0.075
Ball 4 - Ball 3	0.125	0.105	(-0.121, 0.370)	1.19	0.634

Individual confidence level = 97.76%

Speed Loss Total

One-way ANOVA: SLttl versus Ball

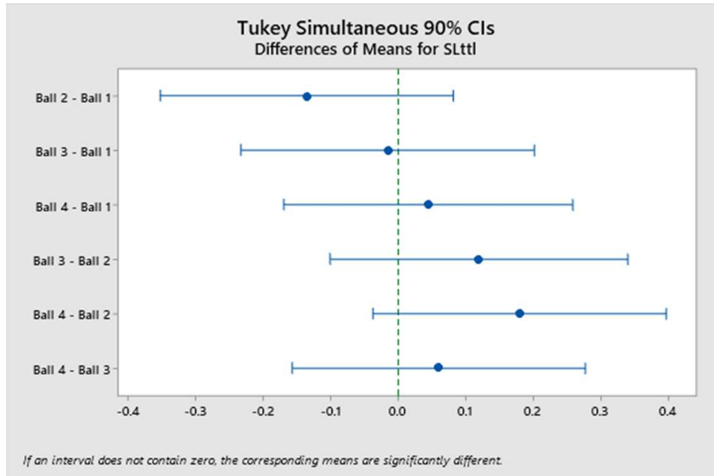
Analysis of Variance

Source	DF	Adj SS	Adj MS	F-Value	P-Value
Ball	3	0.2881	0.09604	1.36	0.264
Error	62	4.3815	0.07067		
Total	65	4.6696			

Means

Ball	N	Mean	StDev	95% CI
Ball 1	17	3.5377	0.2499	(3.4088, 3.6666)
Ball 2	16	3.4026	0.2522	(3.2698, 3.5355)
Ball 3	16	3.5222	0.2589	(3.3894, 3.6551)
Ball 4	17	3.5822	0.2983	(3.4534, 3.7111)

Pooled StDev = 0.265837



Tukey Pairwise Comparisons

Ball	N	Mean	Grouping
Ball 4	17	3.5822	A
Ball 1	17	3.5377	A
Ball 3	16	3.5222	A
Ball 2	16	3.4026	A

Means that do not share a letter are significantly different.

Tukey Simultaneous Tests for Differences of Means

Difference of Levels	Difference of Means	SE of Difference	90% CI	T-Value	Adjusted P-Value
Ball 2 - Ball 1	-0.1350	0.0926	(-0.3518, 0.0817)	-1.46	0.469
Ball 3 - Ball 1	-0.0155	0.0926	(-0.2322, 0.2013)	-0.17	0.998
Ball 4 - Ball 1	0.0446	0.0912	(-0.1688, 0.2580)	0.49	0.961
Ball 3 - Ball 2	0.1196	0.0940	(-0.1004, 0.3396)	1.27	0.584
Ball 4 - Ball 2	0.1796	0.0926	(-0.0371, 0.3963)	1.94	0.222
Ball 4 - Ball 3	0.0600	0.0926	(-0.1567, 0.2768)	0.65	0.916

Individual confidence level = 97.75%

Speed Loss Pindeck

FOR THIS RESPONSE VARIABLE, SPECTO COULD NOT RECORD MANY DATA POINTS, THEREFORE, THE TOTAL DATA POINTS FOR THE ANALYSIS ARE LESS COMPARED TO OTHER RESPONSES.

One-way ANOVA: SLpind versus Ball

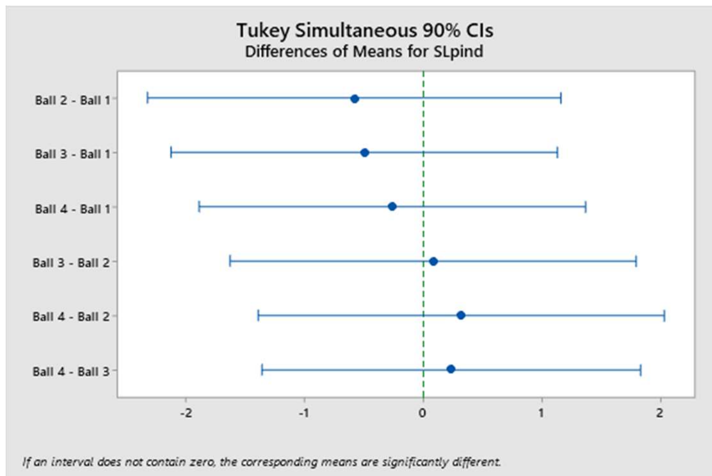
Analysis of Variance

Source	DF	Adj SS	Adj MS	F-Value	P-Value
Ball	3	2.350	0.7832	0.27	0.850
Error	44	129.920	2.9527		
Total	47	132.270			

Means

Ball	N	Mean	StDev	95% CI
Ball 1	12	6.351	1.006	(5.352, 7.351)
Ball 2	10	5.772	2.455	(4.677, 6.867)
Ball 3	13	5.855	1.997	(4.895, 6.816)
Ball 4	13	6.091	1.180	(5.131, 7.052)

Pooled StDev = 1.71835



Tukey Pairwise Comparisons

Ball	N	Mean	Grouping
Ball 1	12	6.351	A
Ball 4	13	6.091	A
Ball 3	13	5.855	A
Ball 2	10	5.772	A

Means that do not share a letter are significantly different.

Tukey Simultaneous Tests for Differences of Means

Difference of Levels	Difference of Means	SE of Difference	90% CI	T-Value	Adjusted P-Value
Ball 2 - Ball 1	-0.579	0.736	(-2.317, 1.158)	-0.79	0.860
Ball 3 - Ball 1	-0.496	0.688	(-2.121, 1.128)	-0.72	0.888
Ball 4 - Ball 1	-0.260	0.688	(-1.885, 1.365)	-0.38	0.981
Ball 3 - Ball 2	0.083	0.723	(-1.624, 1.790)	0.11	0.999
Ball 4 - Ball 2	0.319	0.723	(-1.388, 2.026)	0.44	0.971
Ball 4 - Ball 3	0.236	0.674	(-1.356, 1.828)	0.35	0.985

Individual confidence level = 97.73%

Speed Loss Percent

One-way ANOVA: SL% versus Ball

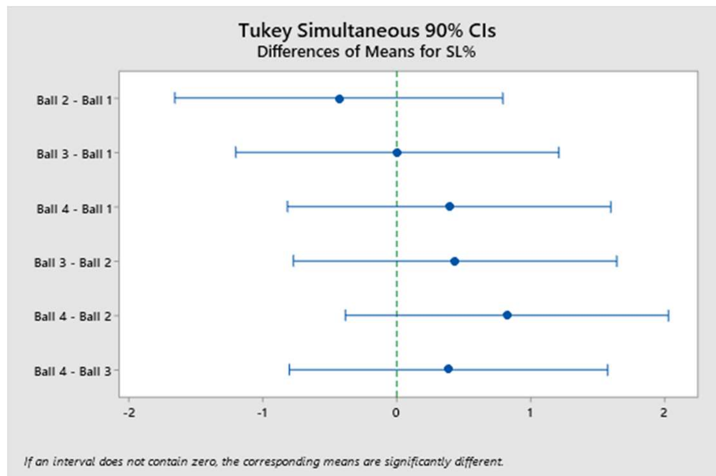
Analysis of Variance

Source	DF	Adj SS	Adj MS	F-Value	P-Value
Ball	3	5.583	1.861	0.85	0.471
Error	62	135.353	2.183		
Total	65	140.936			

Means

Ball	N	Mean	StDev	95% CI
Ball 1	16	20.067	1.195	(19.329, 20.806)
Ball 2	16	19.636	1.345	(18.898, 20.374)
Ball 3	17	20.072	1.427	(19.356, 20.789)
Ball 4	17	20.459	1.840	(19.742, 21.175)

Pooled StDev = 1.47754



Tukey Pairwise Comparisons

Ball	N	Mean	Grouping
Ball 4	17	20.459	A
Ball 3	17	20.072	A
Ball 1	16	20.067	A
Ball 2	16	19.636	A

Means that do not share a letter are significantly different.

Tukey Simultaneous Tests for Differences of Means

Difference of Levels	Difference of Means	SE of Difference	90% CI	T-Value	Adjusted P-Value
Ball 2 - Ball 1	-0.431	0.522	(-1.654, 0.791)	-0.83	0.842
Ball 3 - Ball 1	0.005	0.515	(-1.200, 1.209)	0.01	1.000
Ball 4 - Ball 1	0.392	0.515	(-0.813, 1.596)	0.76	0.872
Ball 3 - Ball 2	0.436	0.515	(-0.768, 1.641)	0.85	0.831
Ball 4 - Ball 2	0.823	0.515	(-0.382, 2.027)	1.60	0.387
Ball 4 - Ball 3	0.387	0.507	(-0.800, 1.573)	0.76	0.871

Individual confidence level = 97.75%

Pindeck Deflection

FOR THIS RESPONSE VARIABLE, SPECTO COULD NOT RECORD MANY DATA POINTS, THEREFORE, THE TOTAL DATA POINTS FOR THE ANALYSIS ARE LESS COMPARED TO OTHER RESPONSES.

One-way ANOVA: PindDef versus Ball

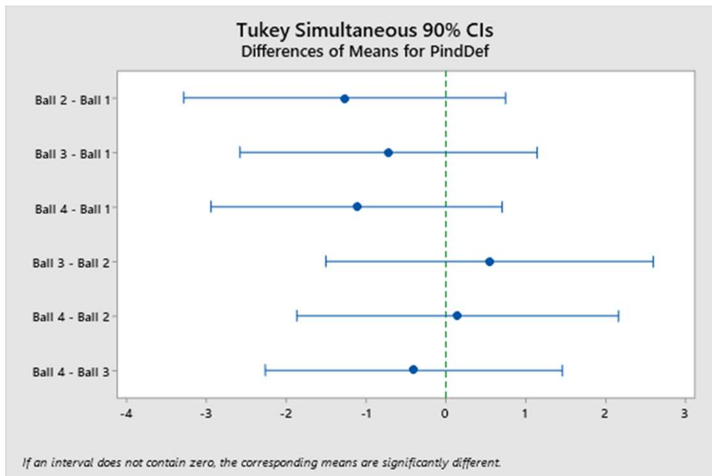
Analysis of Variance

Source	DF	Adj SS	Adj MS	F-Value	P-Value
Ball	3	11.46	3.820	0.99	0.407
Error	43	166.00	3.860		
Total	46	177.46			

Means

Ball	N	Mean	StDev	95% CI
Ball 1	13	1.608	2.293	(0.509, 2.707)
Ball 2	9	0.343	1.920	(-0.978, 1.663)
Ball 3	12	0.889	1.914	(-0.255, 2.033)
Ball 4	13	0.490	1.661	(-0.609, 1.589)

Pooled StDev = 1.96481



Tukey Pairwise Comparisons

Ball	N	Mean	Grouping
Ball 1	13	1.608	A
Ball 3	12	0.889	A
Ball 4	13	0.490	A
Ball 2	9	0.343	A

Means that do not share a letter are significantly different.

Tukey Simultaneous Tests for Differences of Means

Difference of Levels	Difference of Means	SE of Difference	90% CI	T-Value	Adjusted P-Value
Ball 2 - Ball 1	-1.265	0.852	(-3.277, 0.747)	-1.48	0.455
Ball 3 - Ball 1	-0.718	0.787	(-2.576, 1.139)	-0.91	0.798
Ball 4 - Ball 1	-1.118	0.771	(-2.938, 0.702)	-1.45	0.476
Ball 3 - Ball 2	0.547	0.866	(-1.500, 2.593)	0.63	0.922
Ball 4 - Ball 2	0.147	0.852	(-1.865, 2.159)	0.17	0.998
Ball 4 - Ball 3	-0.400	0.787	(-2.257, 1.458)	-0.51	0.957

Individual confidence level = 97.72%

Skid

One-way ANOVA: Skid versus Ball

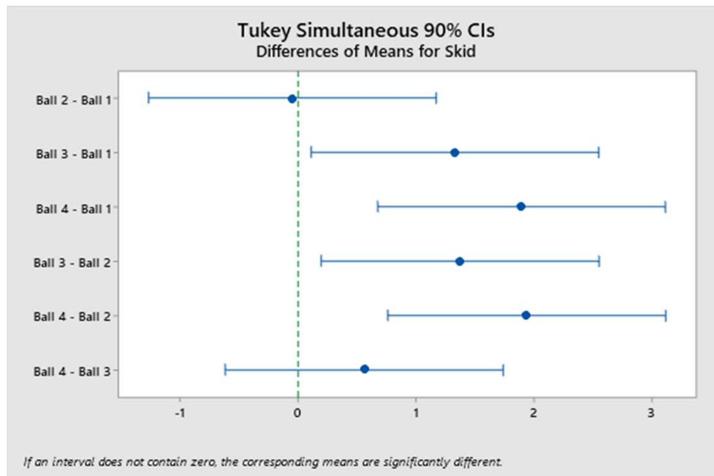
Analysis of Variance

Source	DF	Adj SS	Adj MS	F-Value	P-Value
Ball	3	43.96	14.653	7.26	0.000
Error	58	117.09	2.019		
Total	61	161.05			

Means

Ball	N	Mean	StDev	95% CI
Ball 1	14	25.357	0.842	(24.597, 26.117)
Ball 2	16	25.313	1.448	(24.601, 26.024)
Ball 3	16	26.688	0.873	(25.976, 27.399)
Ball 4	16	27.250	2.082	(26.539, 27.961)

Pooled StDev = 1.42084



Tukey Pairwise Comparisons

Ball	N	Mean	Grouping	
Ball 4	16	27.250	A	
Ball 3	16	26.688	A	
Ball 1	14	25.357		B
Ball 2	16	25.313		B

Means that do not share a letter are significantly different.

Tukey Simultaneous Tests for Differences of Means

Difference of Levels	Difference of Means	SE of Difference	90% CI	T-Value	Adjusted P-Value
Ball 2 - Ball 1	-0.045	0.520	(-1.262, 1.172)	-0.09	1.000
Ball 3 - Ball 1	1.330	0.520	(0.113, 2.547)	2.56	0.061
Ball 4 - Ball 1	1.893	0.520	(0.676, 3.110)	3.64	0.003
Ball 3 - Ball 2	1.375	0.502	(0.199, 2.551)	2.74	0.040
Ball 4 - Ball 2	1.938	0.502	(0.762, 3.113)	3.86	0.002
Ball 4 - Ball 3	0.563	0.502	(-0.613, 1.738)	1.12	0.679

Individual confidence level = 97.73%

Hook

One-way ANOVA: Hook versus Ball

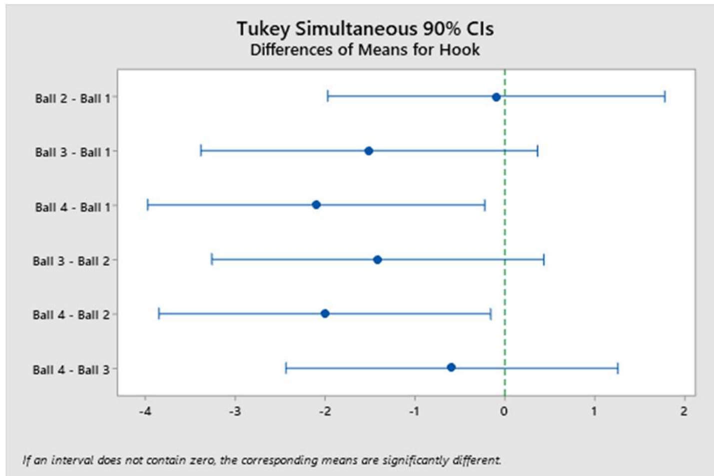
Analysis of Variance

Source	DF	Adj SS	Adj MS	F-Value	P-Value
Ball	3	54.43	18.144	3.44	0.022
Error	63	331.99	5.270		
Total	66	386.42			

Means

Ball	N	Mean	StDev	95% CI
Ball 1	16	31.625	1.500	(30.478, 32.772)
Ball 2	17	31.529	2.211	(30.417, 32.642)
Ball 3	17	30.118	1.965	(29.005, 31.230)
Ball 4	17	29.529	3.145	(28.417, 30.642)

Pooled StDev = 2.29556



Tukey Pairwise Comparisons

Ball	N	Mean	Grouping	
Ball 1	16	31.625	A	
Ball 2	17	31.529	A	
Ball 3	17	30.118	A	B
Ball 4	17	29.529		B

Means that do not share a letter are significantly different.

Tukey Simultaneous Tests for Differences of Means

Difference of Levels	Difference of Means	SE of Difference	90% CI	T-Value	Adjusted P-Value
Ball 2 - Ball 1	-0.096	0.800	(-1.967, 1.776)	-0.12	0.999
Ball 3 - Ball 1	-1.507	0.800	(-3.379, 0.364)	-1.89	0.245
Ball 4 - Ball 1	-2.096	0.800	(-3.967, -0.224)	-2.62	0.052
Ball 3 - Ball 2	-1.412	0.787	(-3.255, 0.431)	-1.79	0.286
Ball 4 - Ball 2	-2.000	0.787	(-3.843, -0.157)	-2.54	0.063
Ball 4 - Ball 3	-0.588	0.787	(-2.431, 1.255)	-0.75	0.878

Individual confidence level = 97.76%

Roll

One-way ANOVA: Roll versus Ball

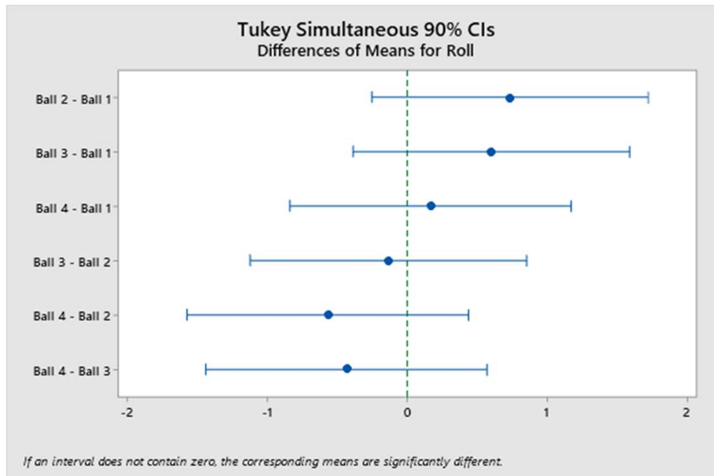
Analysis of Variance

Source	DF	Adj SS	Adj MS	F-Value	P-Value
Ball	3	5.402	1.801	1.36	0.264
Error	55	72.700	1.322		
Total	58	78.102			

Means

Ball	N	Mean	StDev	95% CI
Ball 1	15	3.333	0.900	(2.738, 3.928)
Ball 2	15	4.067	1.223	(3.472, 4.662)
Ball 3	15	3.933	1.387	(3.338, 4.528)
Ball 4	14	3.500	1.019	(2.884, 4.116)

Pooled StDev = 1.14970



Tukey Pairwise Comparisons

Ball	N	Mean	Grouping
Ball 2	15	4.067	A
Ball 3	15	3.933	A
Ball 4	14	3.500	A
Ball 1	15	3.333	A

Means that do not share a letter are significantly different.

Tukey Simultaneous Tests for Differences of Means

Difference of Levels	Difference of Means	SE of Difference	90% CI	T-Value	Adjusted P-Value
Ball 2 - Ball 1	0.733	0.420	(-0.252, 1.719)	1.75	0.310
Ball 3 - Ball 1	0.600	0.420	(-0.386, 1.586)	1.43	0.487
Ball 4 - Ball 1	0.167	0.427	(-0.836, 1.170)	0.39	0.980
Ball 3 - Ball 2	-0.133	0.420	(-1.119, 0.852)	-0.32	0.989
Ball 4 - Ball 2	-0.567	0.427	(-1.570, 0.436)	-1.33	0.550
Ball 4 - Ball 3	-0.433	0.427	(-1.436, 0.570)	-1.01	0.742

Individual confidence level = 97.75%

Boards Crossed

One-way ANOVA: BrdsCrossed versus Ball

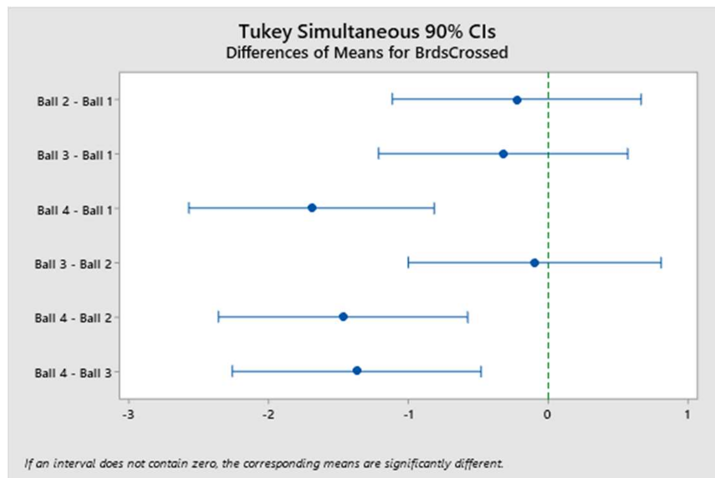
Analysis of Variance

Source	DF	Adj SS	Adj MS	F-Value	P-Value
Ball	3	29.76	9.922	8.35	0.000
Error	62	73.70	1.189		
Total	65	103.47			

Means

Ball	N	Mean	StDev	95% CI
Ball 1	17	29.326	1.133	(28.797, 29.854)
Ball 2	16	29.100	1.012	(28.555, 29.645)
Ball 3	16	29.003	0.753	(28.459, 29.548)
Ball 4	17	27.635	1.353	(27.106, 28.163)

Pooled StDev = 1.09030



Tukey Pairwise Comparisons

Ball	N	Mean	Grouping	
Ball 1	17	29.326	A	
Ball 2	16	29.100	A	
Ball 3	16	29.003	A	
Ball 4	17	27.635		B

Means that do not share a letter are significantly different.

Tukey Simultaneous Tests for Differences of Means

Difference of Levels	Difference of Means	SE of Difference	90% CI	T-Value	Adjusted P-Value
Ball 2 - Ball 1	-0.226	0.380	(-1.114, 0.663)	-0.59	0.934
Ball 3 - Ball 1	-0.322	0.380	(-1.211, 0.567)	-0.85	0.831
Ball 4 - Ball 1	-1.691	0.374	(-2.566, -0.816)	-4.52	0.000
Ball 3 - Ball 2	-0.097	0.385	(-0.999, 0.805)	-0.25	0.994
Ball 4 - Ball 2	-1.465	0.380	(-2.354, -0.577)	-3.86	0.002
Ball 4 - Ball 3	-1.369	0.380	(-2.257, -0.480)	-3.60	0.003

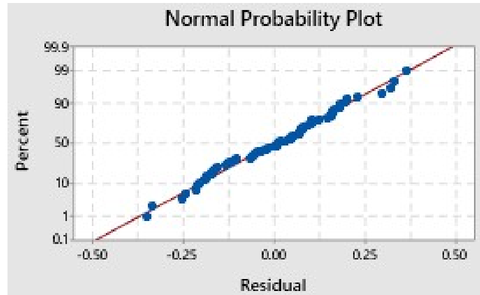
Individual confidence level = 97.75%

Total Hook

One-way ANOVA: Total Hook versus Ball

Transformation Method

Factor coding	(-1, 0, +1)
Box-Cox transformation	
Rounded λ	0.5
Estimated λ	0.311764



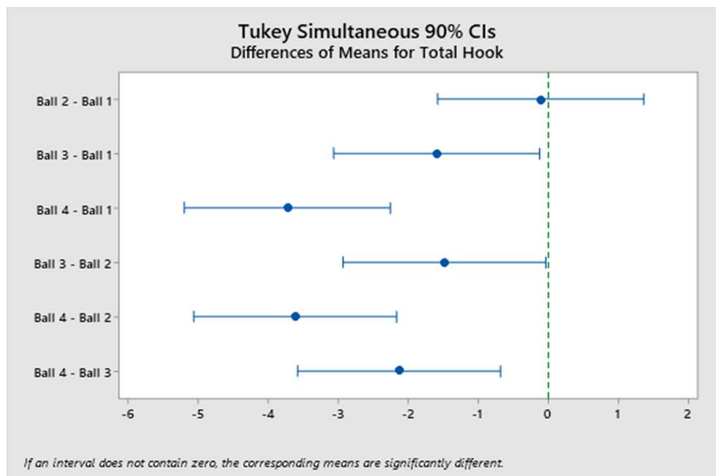
Analysis of Variance

Source	DF	Adj SS	Adj MS	F-Value	P-Value
Ball	3	142.8	47.602	15.61	0.000
Error	59	180.0	3.050		
Total	62	322.8			

Means

Ball	N	Mean	StDev	95% CI
Ball 1	15	9.183	2.392	(8.281, 10.085)
Ball 2	16	9.071	1.972	(8.198, 9.945)
Ball 3	16	7.589	1.206	(6.715, 8.462)
Ball 4	16	5.461	1.144	(4.587, 6.334)

Pooled StDev = 1.74643



Tukey Pairwise Comparisons

Ball	N	Mean	Grouping		
Ball 1	15	9.183	A		
Ball 2	16	9.071	A		
Ball 3	16	7.589		B	
Ball 4	16	5.461			C

Means that do not share a letter are significantly different.

Tukey Simultaneous Tests for Differences of Means

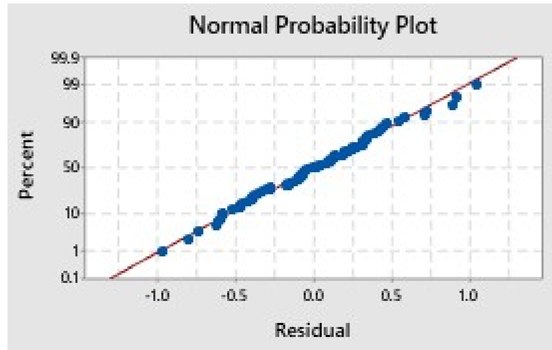
Difference of Levels	Difference of Means	SE of Difference	90% CI	T-Value	Adjusted P-Value
Ball 2 - Ball 1	-0.112	0.628	(-1.581, 1.357)	-0.18	0.998
Ball 3 - Ball 1	-1.594	0.628	(-3.063, -0.125)	-2.54	0.064
Ball 4 - Ball 1	-3.722	0.628	(-5.191, -2.253)	-5.93	0.000
Ball 3 - Ball 2	-1.482	0.617	(-2.928, -0.037)	-2.40	0.088
Ball 4 - Ball 2	-3.610	0.617	(-5.056, -2.165)	-5.85	0.000
Ball 4 - Ball 3	-2.128	0.617	(-3.573, -0.683)	-3.45	0.006

Individual confidence level = 97.73%

Breakpoint Angle

Transformation Method

Factor coding	(-1, 0, +1)
Box-Cox transformation	
Rounded λ	4
Estimated λ	3.97063



One-way ANOVA: Break Point Angle versus Ball

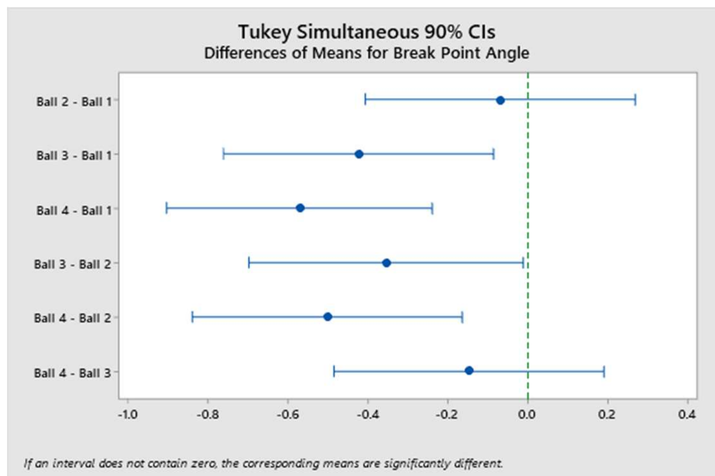
Analysis of Variance

Source	DF	Adj SS	Adj MS	F-Value	P-Value
Ball	3	3.569	1.1896	7.41	0.000
Error	58	9.318	0.1606		
Total	61	12.887			

Means

Ball	N	Mean	StDev	95% CI
Ball 1	16	1.8796	0.3664	(1.6790, 2.0802)
Ball 2	15	1.8105	0.2875	(1.6033, 2.0176)
Ball 3	15	1.456	0.397	(1.249, 1.663)
Ball 4	16	1.309	0.512	(1.108, 1.510)

Pooled StDev = 0.400809



Tukey Pairwise Comparisons

Ball	N	Mean	Grouping	
Ball 1	16	1.8796	A	
Ball 2	15	1.8105	A	
Ball 3	15	1.456		B
Ball 4	16	1.309		B

Means that do not share a letter are significantly different.

Tukey Simultaneous Tests for Differences of Means

Difference of Levels	Difference of Means	SE of Difference	90% CI	T-Value	Adjusted P-Value
Ball 2 - Ball 1	-0.069	0.144	(-0.406, 0.268)	-0.48	0.963
Ball 3 - Ball 1	-0.423	0.144	(-0.761, -0.086)	-2.94	0.024
Ball 4 - Ball 1	-0.571	0.142	(-0.902, -0.239)	-4.03	0.001
Ball 3 - Ball 2	-0.354	0.146	(-0.697, -0.012)	-2.42	0.084
Ball 4 - Ball 2	-0.501	0.144	(-0.839, -0.164)	-3.48	0.005
Ball 4 - Ball 3	-0.147	0.144	(-0.484, 0.190)	-1.02	0.737