

USBC static weight limits remain relevant

Research was continuation of pioneering ball motion study

By Patrick Brettingen and Nicki Mours

When the United States Bowling Congress embarked on its landmark bowling ball motion study in 2006, research engineers set out to determine which characteristics have the greatest effects on the motion of modern, high-tech bowling balls as they roll down a lane.

The study's main finding upon completion in 2008 was that surface roughness, Ra (a measure of cover stock chemistry) is the most significant factor affecting bowling ball motion, as illustrated by Figure 1. With no regulation, cover stock porosity could become extreme and create imbalance in the sport. In fact, a specification setting limits on the microscopic indentations in a manufactured ball's cover stock was implemented in 2009.

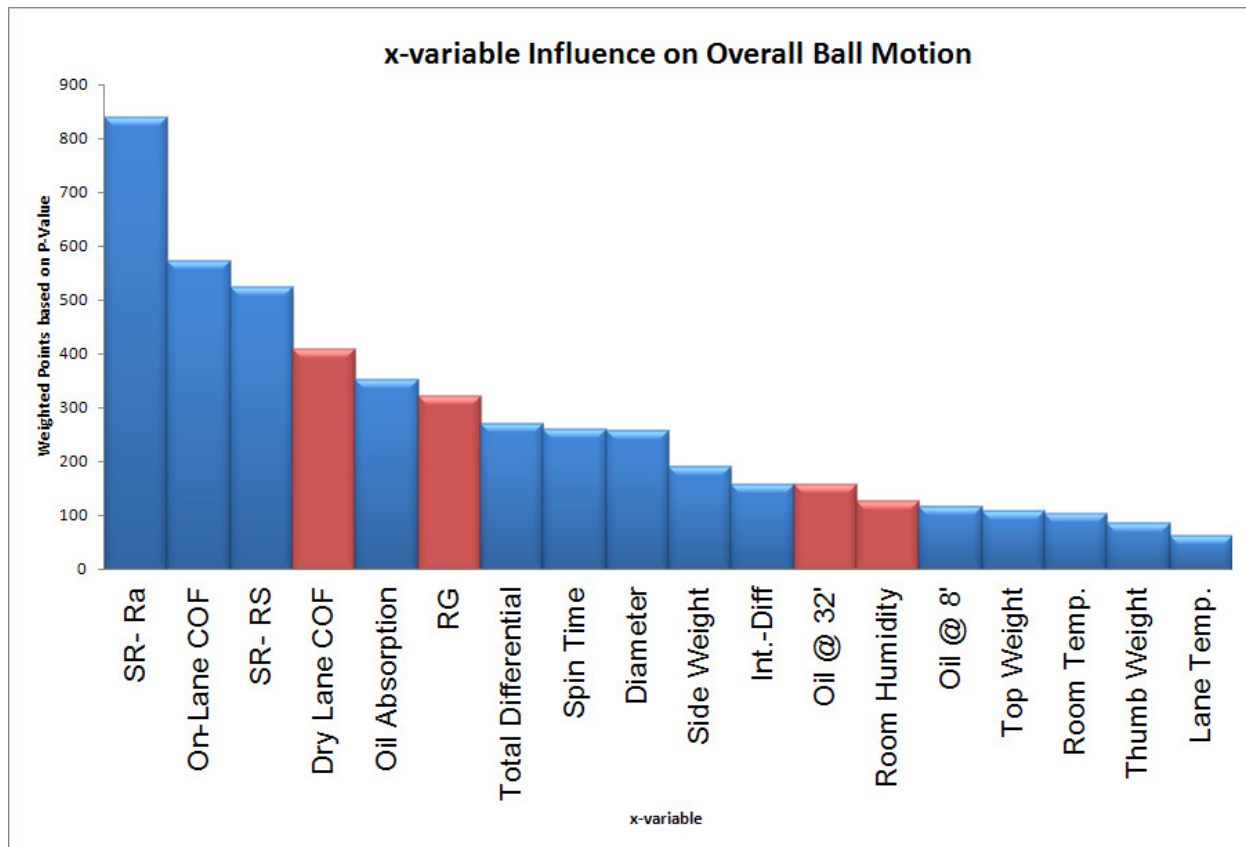


Figure 1: This graph shows X-Variables from the Ball Motion Study and their influence on overall ball motion. The red bars indicate that those variables have an inverse relationship or effect on ball motion. For example, the higher a ball's RG, the less motion the ball will have.

Since completion of the Ball Motion Study, USBC has stated that if factors were determined to have a high impact on ball motion, a specification would be developed if one was not in place. Conversely, if factors were determined to have a lesser impact on ball motion, further studies would be conducted to investigate if modifying or removing specifications relating to those elements needed to occur. Examples of adhering to this philosophy are the surface roughness, Ra specification previously mentioned and when on July 1, 2010, USBC raised the low RG specification from 2.430 inches to 2.460 inches.

The Ball Motion Study proved that static weights showed a lower level of significance relating to ball motion. Since then, however, bowlers, pro shop operators, some manufacturers and much of the industry has expressed concerns that static weights are no longer relevant in today's world of high-performance bowling balls that are affected more by ball dynamics and cover

stock chemistry. Many called for an increase in the maximum static weight allowance or an outright elimination of the USBC static weight specification altogether.

In response to those thoughts, the USBC last year began studying the degree to which static weights affect ball motion. This study – partially completed this past May – illustrated that if the current USBC static weight limits were eliminated or increased, the typical three-phase motion of bowling balls as they travel down a lane (skid, hook, then roll) would be significantly altered. A fourth phase of unpredictable motion begins to occur that would cause problems for bowlers and pro shop operators leading to an undesirable effect on the lanes. Figure 2 shows a ball path generated during the Ball Motion Study, when the ability to mathematically predict the three phases of motion was developed. General forms of the equations are used to illustrate that skid and roll both fit the form of a linear equation in which the hook phase fits a quadratic equation. Figure 3 displays a distinct example from the Static Weight Study when further analysis of ball path showed a fourth phase that would continue to hook again to the left and can be modeled using a quadratic equation. Figure 4 displays a second example from the Static Weight Study in which further analysis of ball path displayed a fourth phase that fades to the right. The fourth phase in this example can also be modeled using a quadratic equation.

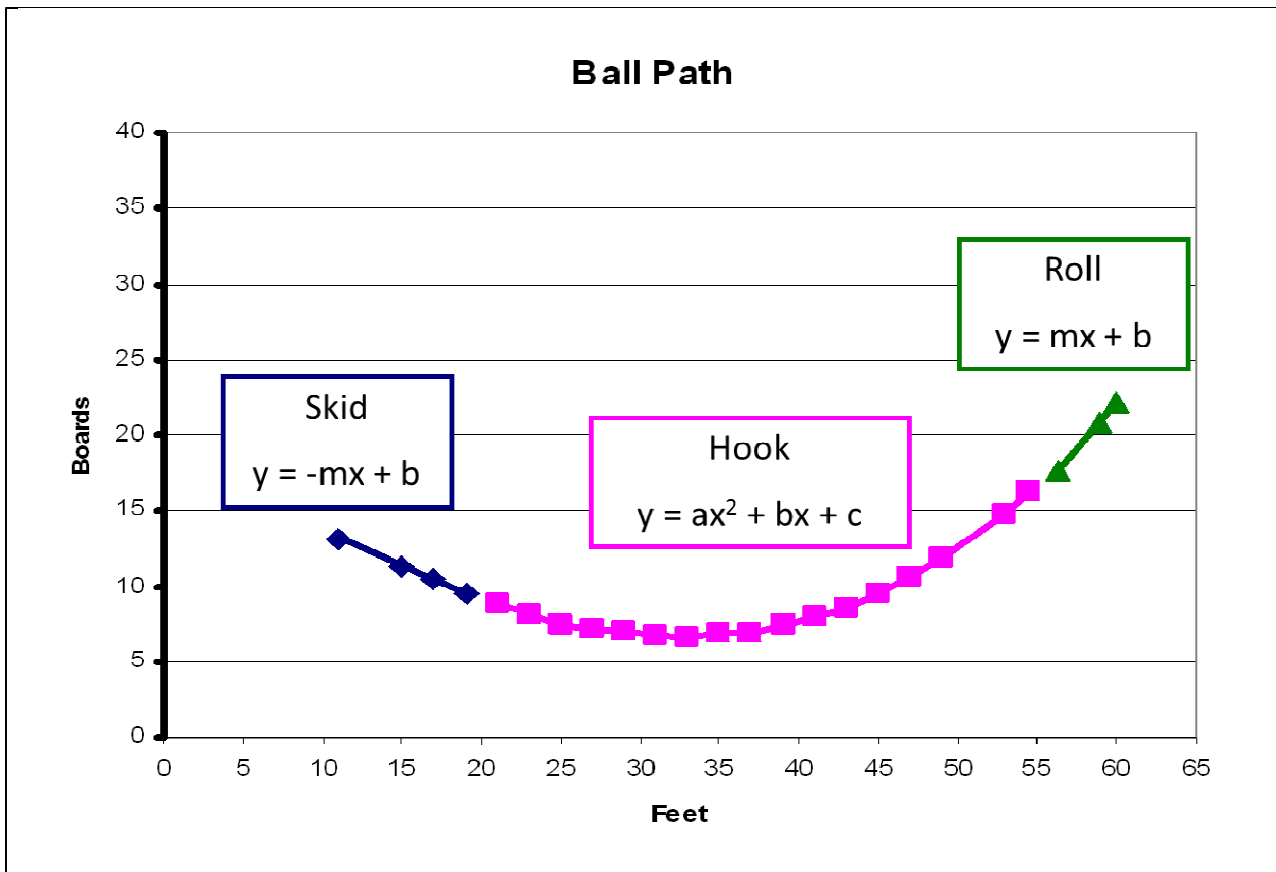


Figure 2: This graph from the USBC Ball Motion Study illustrates how the three phases of ball motion are mathematically characterized.

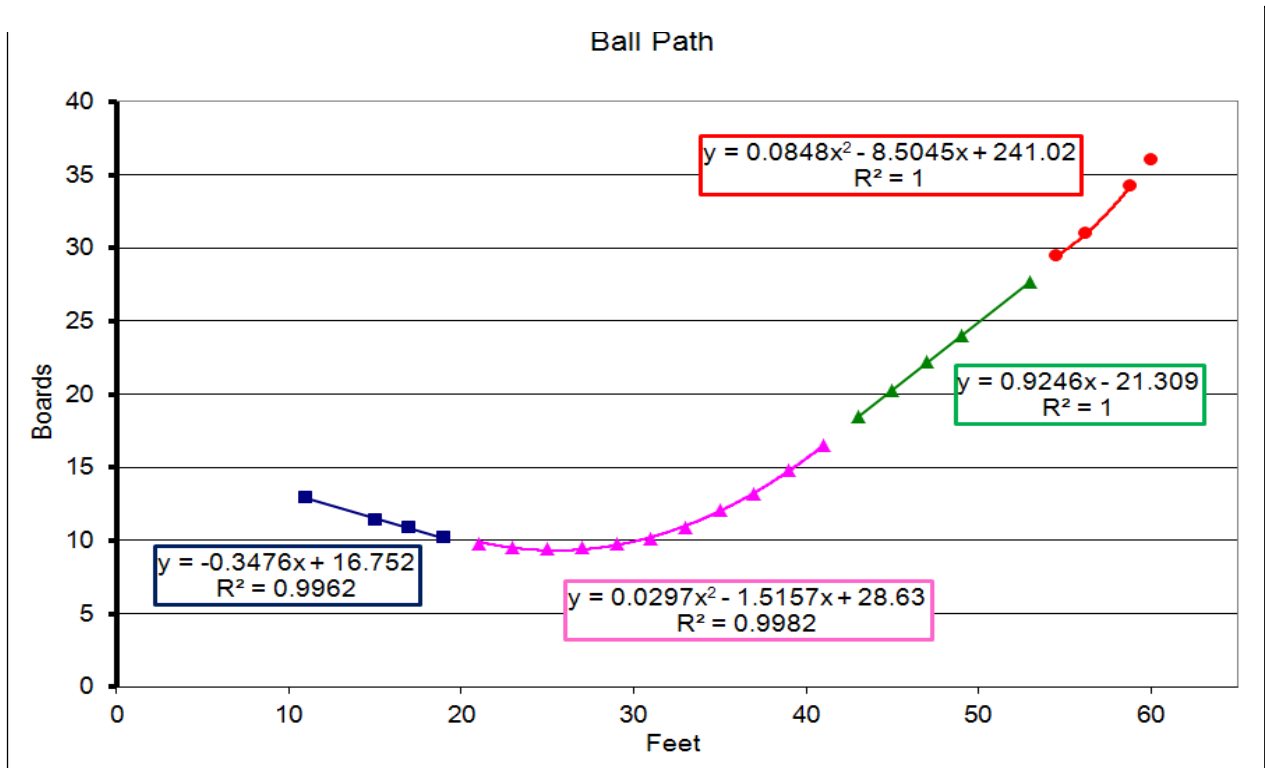


Figure 3: This graph shows a sample ball path from the USBC Static Weight Study depicting the fourth phase of ball motion. This run had DOE settings of 5.875 oz. bottom weight, 3.75 oz. right side weight, 3.75 oz. finger weight, was rolled at 14 mph with 200 rpm using a ball with no intermediate differential.

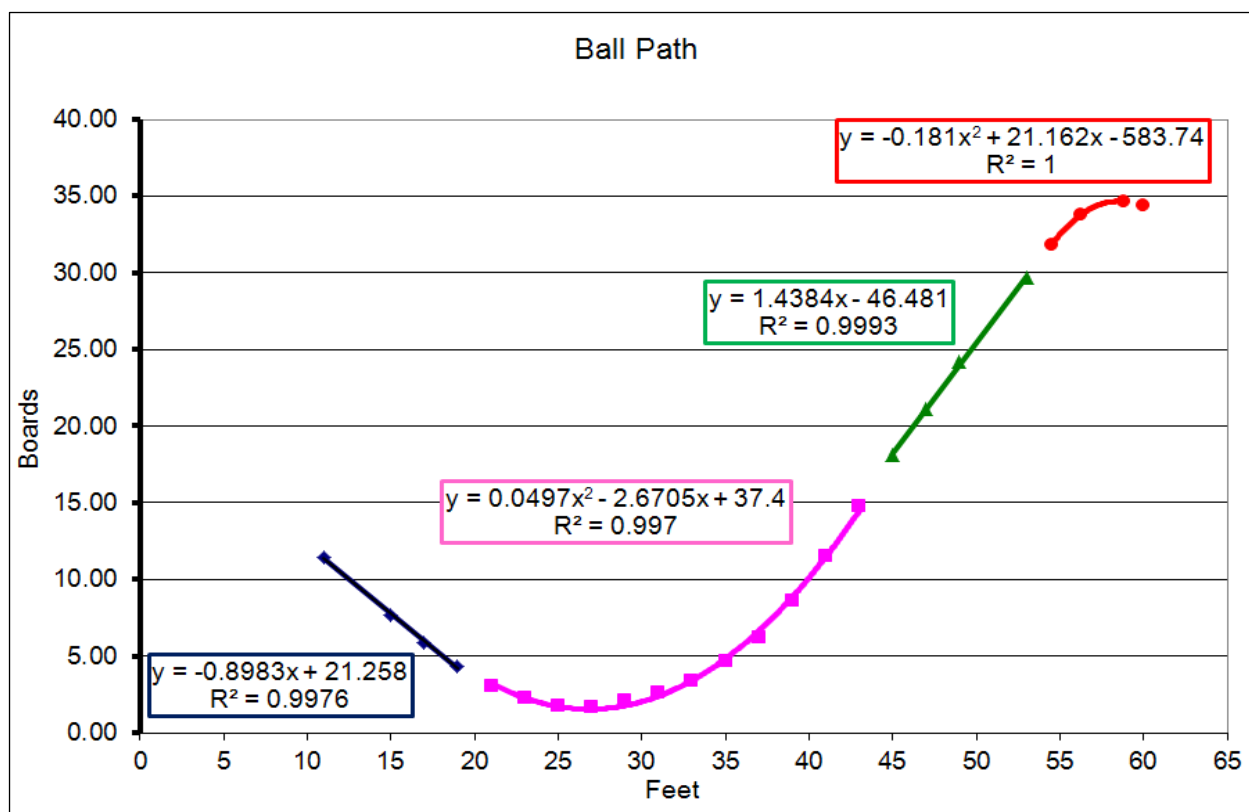


Figure 4: This graph shows a sample ball path from USBC Static Weight Study depicting the fourth phase of ball motion. This run had DOE settings of 5.875 oz. bottom weight, 3.75 oz. right side weight, 3.75 oz. finger weight, was rolled at 14 mph with 600 rpm using a ball with an intermediate differential of 0.030 inches.

Combinations of static weight parameters yielding ball paths similar to those in Figure 3 could, with the correct knowledge, increase a bowling ball's entry angle into the pins. Previous studies using BowlScore have shown that as entry angle increases to its optimal measure of approximately 6 degrees, strikes increase. If static weights were allowed to go unregulated, ball paths that increase entry angle could be obtained through no additional skill of bowlers. Additionally, Figure 4 illustrates that if static weights were unregulated, single-pin or right-side spares (for a right-handed bowler in this example) could be converted with a ball that directs itself toward the pins again through no additional bowler skill.

After completing the comprehensive Static Weight Study using bowling robot E.A.R.L. (Enhanced Automated Robotic Launcher) and Super CATS (Computer Aided Tracking System), the USBC decided to retain its current specifications for static weight limits in its approved bowling balls. Current USBC specifications allow a maximum 3 oz. of top or bottom weight, 1 oz. maximum left or right side weight and 1 oz. maximum finger or thumb weight. Reasons for

the thinking that static weights were no longer relative in today's bowling world had some validity to them. Within USBC specifications it is known that the effect of static weights is minimal. In fact, within a "1 oz. box" of static weights (1 oz. bottom to 1 oz. top, 1 oz. left side to 1 oz. right side and 1 oz. finger to 1 oz. thumb weight) only side weight is significant to any of the ball motion variables and only in four of the 20 variables. Once outside that "box," undesirable ball motion becomes evident.

Researchers used DOE as main statistical analysis tool

Before making a decision to modify, eliminate or keep the specification as is, USBC research engineers began a formal study to evaluate its research data and come to its conclusions about static weights. In November 2010, the USBC research team – led by USBC Research Engineer Nicki Mours – began static weight testing at the International Training and Research Center (ITRC) on the International Bowling Campus in Arlington, Texas.

Engineers implemented what are called "Design of Experiments," a scientific method of planning and conducting research. These DOEs allowed the USBC team to study the effects of several input variables and interactions between those input variables that may influence bowling ball motion.

The "input factors" for the first DOE were as follows: top/bottom weight; left/right side weight; finger/thumb weight; ball speed; rev rate; and intermediate differential. With those six factors set, the engineers ran what they call a "6-factor half-fractional design," selecting low and high levels, that were well above the current static weight specifications, but not unreasonable for a ball that can be found directly off the shelf, as well as center points for each factor.

This DOE consisted of 32 test runs, each of which used a combination of "input factor" settings. Two specially-constructed bowling balls were used for the test runs, one with a symmetrical core and another with an asymmetrical core. Each run was conducted on Lane 19 at the ITRC (Brunswick Pro Lane) with the same flat oil pattern used in the Ball Motion Study. Tapes were

taken at eight, 32 and 51 feet to ensure the pattern was identical for each run. The balls were prepared with a fresh, 1,000-grit Arbralon surface. Ambient temperature, lane surface temperature and room humidity were closely monitored while the data was collected using E.A.R.L. and Super CATS for each test shot. After the data was saved, further calculations obtained an average of the shots and ball path graphs were generated and analyzed.

From those test runs, the research team's focus turned to the effects that static weights have on certain ball motion variables. Those "response variables" are calculations based on Super CATS data and represent how ball motion is measured. The variables included: intended ball path at 49 and 60 feet; average ball path at 49 and 60 feet; ball velocity decrease at 49 and 58 feet; angle change at 48 and 58 feet; first and second transition points; positive and negative slope; total hook length; angle per foot; "A" score; breakpoint; first and second transitions to the breakpoint; and frictional efficiency. For further definitions of the ball motion variables, please reference the USBC Ball Motion Study report on bowl.com.

A second DOE was necessary once the results of the "6-factor half-fractional design" had been analyzed. Researchers modified, through only simple drilling techniques, a commercially-available bowling ball that undrilled had 3 3/8 oz. of top weight, giving it 5 1/8 oz. of top weight, a full 2 1/8 oz. over the USBC limit. Since this scenario could easily occur in a pro shop, USBC researchers wanted to know if a fourth phase of ball motion occurred with 5 1/8 oz. set at any one of the six possible static weights. Engineers took that idea one step further and ran a Response Surface DOE of 15 runs. The Response Surface DOE allowed researchers to analyze together the desired test of the maximum static weight imbalance, 5 1/8 oz., on each of the six static weight factors and corner points that would allow researchers to analyze what happens when combinations of static weight factors were each set at 3 oz. This design was conducted with a ball speed of 14 mph and 200 rpm because those settings in the "6-factor half-fractional" design showed a fourth phase of ball motion at each combination of static weights.

Analysis showed an ‘undesirable’ fourth phase of ball motion

Once that data was analyzed with statistical software called Minitab, USBC engineers uncovered evidence of a fourth phase of ball motion in some cases. Test runs of bowling shots went through the traditional skid, hook and roll phases, but then began to either hook again or fade.

“The ball motion variable response data was entered into Minitab for analysis,” Mours said. “We determined which static weight factors or interactions are significant to each ball motion variable. In both the 6-factor half-fractional design and the Response Surface design, a fourth phase of ball motion was evident. Based on that test data, the USBC cannot modify the static weight specification.”

An anecdotal result that showed up early in the study became very important for researchers to keep in mind and led to immediate evidence that allowing unlimited static weights would not protect USBC members’ investment in the bowling balls they purchase. A test ball that was specially-constructed for the study was damaged during the data collection process for the 6-factor half-fractional design (See Figure 5). Due to the test ball’s large static imbalance, the ball jumped the ball track on its way back through the ball return and collided with a portion of the lane’s understructure.



Figure 5 - USBC Static Weight Study test ball that was damaged after jumping the ball track for the ball return and colliding with the support structure under the lanes.

CLICK [HERE](#) FOR VIDEO OF BALL “BACKING UP” AND FADING TO THE RIGHT

“Ultimately, our goal is that once a bowler purchases a ball that has been approved by USBC, there is no possibility for a pro shop operator to drill a ball through standard drilling processes and make the ball illegal,” Mours said. “It will not be simple to achieve this goal and even more research about static weights is needed, but it is something that would be extremely valuable to USBC members.”

“Our research proved that the current USBC static weight limits are still valid, even in this age of high-tech bowling balls,” said USBC Managing Director – National Governing Body Neil Stremmel. “While static weights do have a minimal effect on bowling ball motion within the current window, our research data and analysis shows that having no limit can have a negative effect on ball motion. Therefore USBC will not change the specification.”

The research findings were presented by USBC engineers at International Bowl Expo in Grapevine, Texas, and the USBC Convention in Arlington.