Too Much, Too Little, or Just Right?

There are many sports that involve the use of a spherical shaped object, most of which need to be inflated in order to function properly. But to what pressure should the sport specific ball be inflated to insure optimal performance? More specifically, how does the pressure inside the ball effect hitting a target? The specific sport under consideration is soccer. To the spectator, the pressure of the air inside a soccer ball may not seem to be a very influential factor in the overall performance of the ball or of the individual kicking it. Our team set out to find just how much pressure affects the performance of the soccer ball in use.

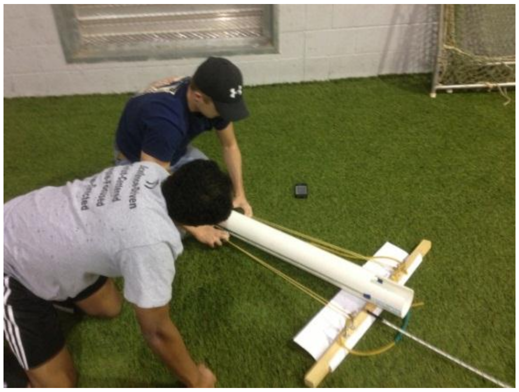
Performance can have several different meanings. Relative to a soccer ball, it could mean distance traveled when the ball is kicked in a certain way with certain energy, or it could pertain to how consistently a ball can be kicked at a target. So what makes a soccer ball perform better? One could say the material on the outside largely affects the amount of friction where the ball comes into contact with the ground. Perhaps it has to do with the outside temperature, what is actually kicking the ball (whether bare feet or a type of cleat), or maybe even the pressure inside the inflated ball. Pressure has a direct effect on several different facets of a soccer ball. But before diving into this, a further explanation of the dynamics of a soccer ball will be needed. A soccer ball is not just an inflated piece of synthetic leather. Rather, there is a type of inflatable material (either latex or butyl) that fits inside and is inflated. This piece of the soccer ball is known as the bladder, which, when inflated, gives the ball its spherical appearance. If a soccer ball's bladder is insufficiently inflated, the circularity of the ball will be lost depending on how much or little it is deflated. Using the same logic, if a ball is overinflated, it will lose its circularity at points on the soccer ball where wear and tear is more prevalent. However, when overinflated, a soccer ball has better potential for staying circular than when underinflated, but circularity is not the only thing that makes a soccer ball perform better. In fact, still being related to the idea of pressure, the inflation of the ball will greatly affect the energy absorbed and will determine how far the ball can be kicked. Given an underinflated soccer ball, a player that kicks a soccer ball with a certain force will see less distance traveled with less accuracy and precision than if the ball were to be inflated to a normal level. Along the same lines of thinking, an overinflated ball will make a player's kick to a ball travel further than what would be expected when normally inflated with a standard pressure. According to FIFA laws, the pressure inside the soccer ball must be between 8.5 psi and 15.6 psi in order to be used in a regulation game. For our intents and purposes, as will be shown later, the standard pressure of the soccer ball was chosen to be 7 psi. This would insure comfortability of using bare feet to kick the ball at certain points in our experimentation. We began with experimentation pertaining to effects of pressure on the accuracy of a kicked ball.

Our first experiment was held in Union University's Fesmire Field House. Using this indoor facility helped eliminate the problems of weather, temperature, and uneven terrain. Two cones were then set up 46.5 feet away from each other. Experimentation then began by having a soccer player wearing shoes kick a regularly inflated soccer ball at one cone, and to the best of his ability hit the other cone. The point of this experiment was to find the consistency of a human, preferable an experienced soccer player, in hitting a desired target at a reasonable distance. Experimentation proceeded after 25 runs were taken for a player wearing shoes and 25 kicking the ball barefoot.

	7 psi		4 psi		10 psi	
	shoes	barefoot	shoes	barefoot	shoes	barefoot
Average:	47.92	42.52	61.68	42.16	36.34	45.24
+/-	8.22	9.88	12.37	7.06	6.26	10.87

Table 1: The averages and uncertainties of one full set of data at the 95% confidence level.

The experiment was repeated for both overinflated and underinflated soccer balls for two separate people. A student-t test was then conducted to ensure that differences were not due to experimental error. In general, the standard pressure seemed to be more accurate than when the ball was over or under inflated, but it was not a largely significant amount. Also, the people kicking the soccer balls in general were more accurate barefoot. This is because the player has more control because of his ability to put his foot beneath the ball.



Our second experimental procedure was designed to find how the inflation of a ball affects the distance traveled by the ball. Using a t-shirt gun designed by undergraduate freshman engineering majors at Union University, we were able to apply a certain force similar to that of a person kicking a ball. The catapult helped eliminate the human error of kicking a soccer ball and increased the consistency of the experiment. A wooden block was placed in the cocked catapult which was laid down parallel to the surface of the turf. When released, the wooden block would hit the soccer ball of standard pressure, sending it down the field. This distance was then measured and repeated 15 times for overinflated and underinflated soccer balls. The results verified our hypothesis that with increased air pressure inside the ball, greater distance would be achieved.

Pressure (psi):	7	4	10
Average Distance (inches):	994.79	988.29	1165.12
+/-	52.01	55.88	54.39

Table 2: Average distance and uncertainty (95% confidence) at various pressures

The final experiment tested the strain that the inflated inside bladder put on the synthetic leather on the outside of both a new and used soccer ball. Strain gauges were attached across the

stitching of the soccer ball when completely deflated, and voltage differences were measured across two nodes on a Wheatstone bridge for 4 psi, 7 psi, and 10 psi. The experiment showed that the used ball deformed more with increasing internal air pressure than the new ball.

		Old				New			
Pressure	Psi	0	4	7	10	0	4	7	10
Pressure	Pa	0	27,579	48,263	68,948	0	27,579	48,263	68,948
Force	N	0	1,010	1,767	2,525	0	1,010	1,767	2,525
Stress	Pa	0	690,473	1,208,328	1,726,182	0	690,473	1,208,328	1,726,182
Strain	m/m	.003	.0293	.0306	.0323	.0003	.0212	.0246	.0255
Elastic Modulus	Pa	0	18,518,095	31,045,699	41,992,045	0	25,538,471	38,566,719	53,262,014

Table 3: The calculated stresses and strains for the old and new soccer balls.

It should be noted that the strain measured in this experiment is not the actual strain, rather a sort of secondary strain. Since the bladder inside is first being inflated, a certain strain is applied to the bladder directly, which applies a stress to the outside synthetic leather layer of material. This stress applied to the outside layer yields a different strain that is directly correlated to the strain on the inside bladder. The "elastic modulus" shown in the table above is not the same as Young's Modulus due to the fact that it shows the nonlinear behavior of the strain which is not the usual case.

Overall, the pressure of a soccer ball has not been shown to greatly affect its performance, although drastic variations in pressure can create changes. From the experiments, accuracy, distance, and maneuverability have fluctuations depending on the pressure of a soccer ball. We can conclude that barefoot was slightly preferable to the player's accuracy, explaining a possible reason why cleats are made thinner and lighter. Rules and regulations of FIFA are in place to insure consistency in the sport in order to achieve the best combined experience.

-A group project by Cody Giles, Alex Wainscott, Zac Baker, Zach Wadley, William Murray, and Rainer Pires. December 5, 2012.

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