Optimization Of A Volleyball Serve

Rationale

Volleyball is one of my favorite sports that I play although I only play two and that was the reason I decided to focus my mathematical exploration on this simple topic. When told I had to do this exploration, I instantly started searching for topics and/or things I could do but nothing interested me. After looking at the stimuli given to me and many other examples, I decided that I would stick to what I was known for: sports—volleyball and basketball. I thought that relating this mathematical exploration to a more personal matter would be the better choice. Having played volleyball from my 8th grade year to my senior year in high school, I know that serving is an important part of the game, but my question was “How would I model this?” Serving a volleyball is one of the most important factors in the game of volleyball and I knew that I would need to consider the physics of serving. Projectile motion is something that most definitely needs to be considered when talking about the optimization of a serve.

Introduction

Volleyball is an internationally renowned sport that is currently ranked as number 5 according to world atlas. It is essentially a game that consists of two teams, normally six players, in which a ball is hit over a high net. The aim of the game is to score points by forcing the ball on the opponent’s side of the court. One prevalent strategy is the use of a serve. I’ve played it since my 8th grade year of middle school and I’ve been a great server ever since. An optimized serve will either result in a point (due to it not being returned) or weakly returned allowing the serving team to use this to an advantage. In this paper, I will construct a model to interpret the optimization of a volleyball serve.

In order to correctly model ‘serving’ optimization, I decided to base the optimization of the serve on the dimensions of the court and the volleyball and the forces acting upon the ball. I realized that I first needed to consider these small factors when it comes to serving. The other most important forces to be considered are: the initial velocity put on the ball by the player, the force of the spin of the ball, and the distance the ball has traveled. Not only those things but also gravity plays a crucial role in the serving of a volleyball as it gravitates towards the Earth.

Dimensions and Limits

A volleyball has a diameter of 8.15 inches which gives a radius of slightly over 4 inches. It weighs about 10 ounces when rounded from 9.9 oz. The ball has narrow indentations along its outer surface which affect the way the air moves around the ball. When hit hard without a spin, the ball tends to flurry—known as a float—in the air, moving erratically as it descends toward the ground. When hit hard with a spin, the ball tends to gravitate towards the ground faster with what is known as topspin.

A typical volleyball court is 29 feet, 6 in. (9 m) wide by 59 feet long (18 m) in the shape of a rectangle (see Figure 2). The net in NCAA women’s volleyball is 7 feet, 4 ½ in. high. The net in the middle separates the court into two equal playing areas. Spreading from the end of each side of the court is an area from which the ball is served. The server may stand at any spot behind the line to serve efficiently.

To calculate these models, x will represent the distance the ball travels horizontally, while h will be the height of the ball. The total distance will be represented by dt. In order for the ball to be served, one must hit the ball with an initial speed, therefore, VI will represent the initial velocity of the ball. As air resistance plays a big part in this model, time will be a factor to the model. Time will be represented as t due to the faster a ball comes, the less time an opponent has to get to the ball and return it.

Explanations of Models

a.1- Spin

We must take into account the spinning of the ball. A spin on the ball allows the ball to move faster towards the ground on the opponent's side of the court. It creates a force that along with the initial velocity that would make a serve a good serve that may end with an awarding point. A top spinning ball is where the top of the ball in spinning in the same direction of its projected motion; thus causing the molecules on the ball to gravitate towards the means of the Earth due to gravity. Because of this very reason, servers tend to typically use this strategy rather than a serve with no spin to acquire a quick point. To calculate this model, we must take the magnitude of the force and relate it to the angular velocity of the ball, which will be represented by ?. Angular velocity is a velocity that applies to objects that move along a circular path. Since, due to the spin, the magnitude is proportional to the angular velocity and the velocity of the actual volleyball.

a.2- Gravity

This model is based off assumptions that gravity (freefall) is the only force acting upon the ball. In this model, the magnitude of the gravity force will be mg in the –y direction since the ball is traveling downwards; m is the mass of the ball and g equals 9.8 meters/second2 whereas it's the acceleration due to gravity by the physics law of projectile motion. Also, the ball will move with a constant velocity in the x direction until it completes its path by landing on the ground. This model will be represented by the physics law of force (see figure 4):

Calculations and Substitutions

To accomplish a successful evaluation of an optimized volleyball serve, I had to experiment with three different volleyball players that I selected to execute the task of optimal serving. Three trials were taken all with different intentions for each specific trail to determine the best combinations of serving for optimal serving. For the first trial, they were all given the task to serve at different angles to determine the best angle to serve at and different strengths to help with initial velocity. I recorded the times which were affected by the angles that the ball was hit from and the distances which were affected by the initial speed applied to the ball. However, the time may still calculated by the distance of which the ball traveled.

To get appropriate angles, one server was asked to serve at an angle of 60 degrees, another was asked to serve at an angle of 45 degrees, and the third was asked to serve at an angle of 30 degrees. In the first trial, all three served at different angle with the same initial velocity of 3.2meters/second.

Both the time and total distance have large effects on the optimal serve whereas the distance itself has a huge effect for optimal time on a serve. The distance from the net is best when closest as possible to the net because landing the ball close to the net makes it difficult for the opposite team to pass—making hitters have to pass balls rather than the backline of defensive specialists [passers]. Now, because gravity is still the main force, the lower the serve, the shorter the time will be for the ball to hit the ground. Furthermore, the optimal serve was the 45 degree-angled serve as it took the fastest to hit the ground and the shortest distance from the net which are both good things. The 30 degree didn't even make it over the net because how low the serve was while mentioning gravity being added to the ball's force. The 60 degree-angled serve took too long for the ball to hit the ground which could benefit the other team with enough time to see where the ball is landing to be able to pass the ball.

Conclusion

Moving on I calculated the results again based off spin using the results of no spin. Increasing the spin on a ball allows the server to serve the ball with a much greater velocity, which makes it much harder to return. If the serve uses spin on the ball of the 45 degree ball, it will allow for a 14% more increase in getting the defender too "shank" a pass creating a point for the server's team.

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