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Introduction

My aim is to find the equation for the curve of a horses jump at three point: front legs, back legs, and tummy. Furthermore, once I have found the curve of the front legs I will find the angle at which a horse jumps by using the tangent of the line. All the above will be done with a set jump at 135cm. This all lead me to a concrete research question:

What is the equation for the jump of a horse and at what angle does the horse jump?

This topic interests me because I am a professional show jumper and I just started showing at 135cm. At the first few shows I always hit a pole down, this made me curious for what happened and why wasn't the horse jumping a clear round. This lead me to question what is a "perfect jump," which brought me to believe that a perfect jump is a perfect curve where the horse doesn't either jump too high over the obstacle nor hit it, therefore creating a perfect curve which would allow the horse to pass the jump clearly without over doing.

There are two types of obstacles a horse can jump in a competition. One is called and oxer, which consists of two rails which can be even or uneven and is a jump in height and length.

Figure 1: Oxer Jump

The other is called a vertical, which consist in poles placed one on top of the other vertically from the ground and it's a jump height but not in length.

Figure 2: Vertical Jump

Nonetheless, this investigation will focus on a horses jump over a vertical which will not involve calculating the distance a horse needs to jump.

A horse's jump consists of four phases: approach, take off, flight, and landing.

Figure 3: Approach

The approach if fundamental for a horse to complete a good jump. The approach consists in the last stride of a horses coming up to the jump. This is where the horse starts shifting its weight backward to allow its legs to get underneath its body for the next step which is the takeoff.

Figure 4: Takeoff

Takeoff consists in the horse shifting its weight to its hind legs to allow its for legs to rise. This happens when the horse pulls its legs as close together underneath its body to then drop his hind downwards and raise his for legs upwards.

Figure 5: Flight

After takeoff comes the flight, this is where the horse reaches the maximum height of the jump and lifts its hind legs off the floor. This is a very delicate phase for both horse and rider because all four legs of the horse are off the ground and there for it all depends on the flexibility and balance of both horse and rider.

Figure 6: Descent

After passing the jump and the maximum height of the jump, descent phase starts. The descent consists in two parts, there is the first part which you can see above and there is a second part where the horse has all four legs on the ground again. Part one of descent consist is the horse tucking in his hind legs for them not to hit the jump and for his for legs to stretch out in order for them to touch the ground and find the horse to find the equilibrium it needs.

Figure 7: Descent pt.2

Part two consist of the horses four legs touching the ground and shifting its weight back again for it to find its equilibrium to the propel forwards for the next jump.

Information

On average, a horse canters at a speed of 4mph in order to perform a jump. However, during the "approach" phase of the jump the horse pull backwards and thus slows down in order to take

off. On average a horse takes off and lands about 2 meters from the jump. We will not be taking into considerations any variables such as speed and time for they would end up effecting the result acquired. The height of the jump taken into consideration graph wise was 1.2cm which equivalent to the 130cm jump in real life:

Figure 8: Still shot of Jump

These are the coordinates found from the front hooves, back hooves, and tummy of the horse.

Front Hooves	Tummy	Hind legs
(2.5 , 0)	(-0.5 , 1.4)	(0.5 , 1.5)
(1.4 , 0.5)	(-1 , 1.3)	(-1.7 , 0.5)
(0.8 , 1)	(0.3 , 1.4)	(2 , 0)
(-1 , 1)	(1.3 , 1.2)	(0.3 , 1.5)
(-1.6 , 0.5)	(2.8 , 0.8)	(0 , 1.5)
(0.2 , 1.5)	(0.9 , 1.5)	(-0.3 , 1.5)
(1.9 , 0.7)	(2 , 1.1)	(0.5 , 1.1)
(-1.8 , 0)	(-1.4 , 1)	(-2 , 0)
(-2 , 0)	(-2 , 0)	
(0 , 1.7)	(-1.6 , 0.9)	
	(0 , 1.6)	
	(0.5 , 1.5)	

Figure 9: Points of jump

Mathematical Processes

To find the curve of the jump, I had to create a scatter plot from still images taken from a video of a jump. In order for me to create a scatter plot I drew a x-axis and a y-axis and measured the points at which the legs or the tummy were at. I decided to use the $Y = ax^2 + bx + c$ this is because the parabola of a horses jump has a U shape and therefore I used this quadratic equation.

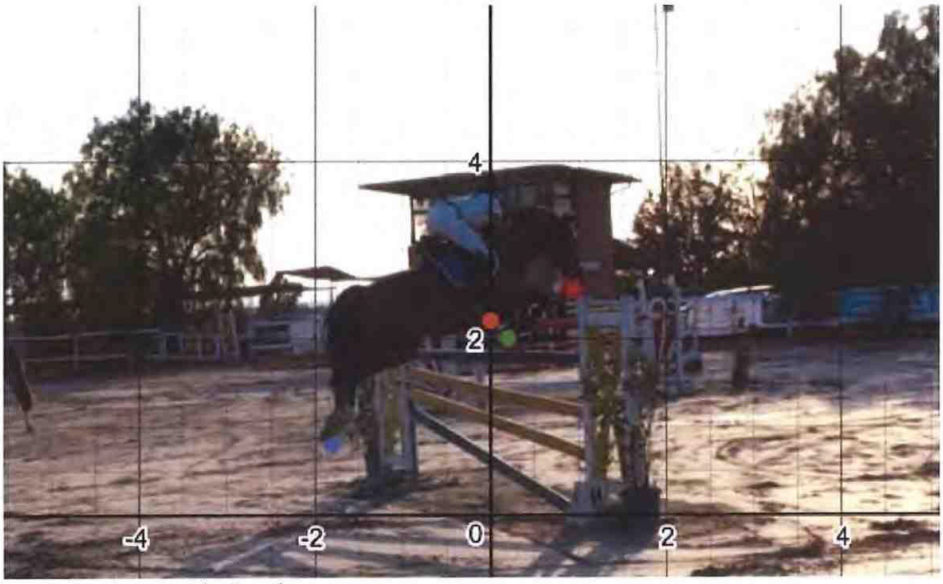

Figure 10: Jump with Graph

Purple point: Hind hooves

Green point: Front Hooves

Red point: Tummy

The first curve we will be looking at is the front hooves. For this scatter plot two curves came out for the both could have been suitable for the horse to jump the obstacle without hitting the pole down. However, the most suitable and the most natural jump curve for a horse would be the black curve in the graph below, nevertheless, the purple curve would have been effective for a horse to jump the obstacle without hitting it only with its front hooves.

Points on graph chosen: (-1 , 1) & (0.8 , 1)

I chose these points because they would have an equal answer to Y, therefore allowing me to use the quadratic equation above.

C can be found immediately because it is the Y intercept.

$$1 = a(-1)^2 + b(-1) + 1.7$$

$$1 = a(0.8)^2 + b(0.8) + 1.7$$

We then bring these equations to their simplest form to find the what a and b are.

$$-0.7 = a - b$$

$$-0.7 = 0.64a + 0.8b$$

After this algebraically we come up with answers to a and be by using substitution. These are the calculations for the purple curve:

$$a = b - 0.7$$

$$-0.7 = 0.64(b - 0.7) + 0.8b$$

$$-0.7 = 0.64b - 0.448 + 0.8b$$

$$-0.7 = 1.44b - 0.448$$

$$b = -0.175$$

$$b = a + 0.7$$

$$-0.7 = 0.64a + 0.8(a + 0.7)$$

$$-0.7 = 0.64a + 0.8a + 0.56$$

$$-0.7 = 1.44a + 0.56$$

$$a = -0.875$$

$$Y = -0.875x^2 - 0.175x + 1.7$$

However, this equation wasn't precise to the coordinates take form the still image for the did not match with the takeoff and landing point. Thus, another equation was calculated. These are the calculations for the black curve:

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Points chosen on graph: (2.5 , 0) & (-2 , 0)

$$0 = a(2.5)^2 + b(2.5) + 1.7$$

$$0 = a(-2)^2 + b(-2) + 1.7$$

$$-1.7 = 6.25a + 2.5b$$

$$-1.7 = 4a - 2b$$

$$b = 0.85 + 2a$$

$$-1.7 = 6.25a + 2.5(0.85 + 2a)$$

$$-1.7 = 6.25a + 2.125 + 5a$$

$$-1.7 = 11.25a + 2.125$$

$$a = -0.425 + 0.5b$$

$$-1.7 = 6.25(-0.425 + 0.5b) + 2.5b$$

$$-1.7 = -2.65625 + 3.125b + 2.5b$$

$$-1.7 = 5.625b - 2.65625$$

$$b = 0.17$$

$$Y = -0.34x^2 + 0.17x + 1.7$$

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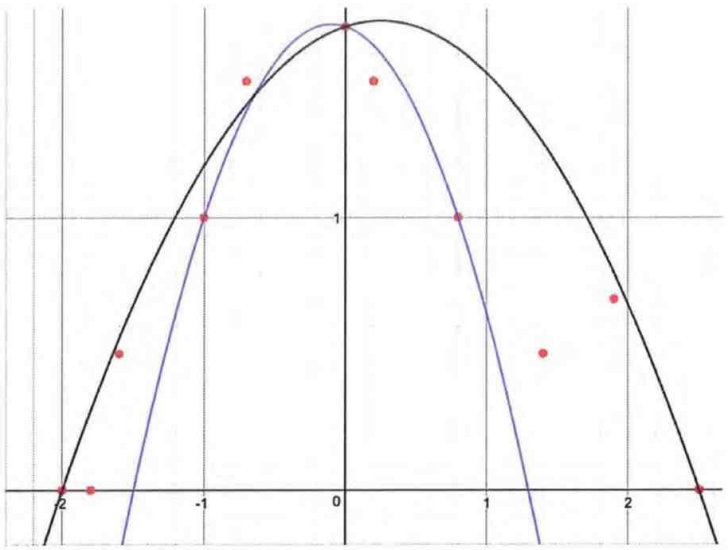

Figure 11: Curve of front hooves

For the tummy and the hind hooves, the same process was repeated. However, points on the graphs were chosen to match takeoff and landing points. The graphs and equations below were obtained using this method.

$$Y = \frac{-1}{7}x^2 + \frac{4}{35}x + 1.6$$

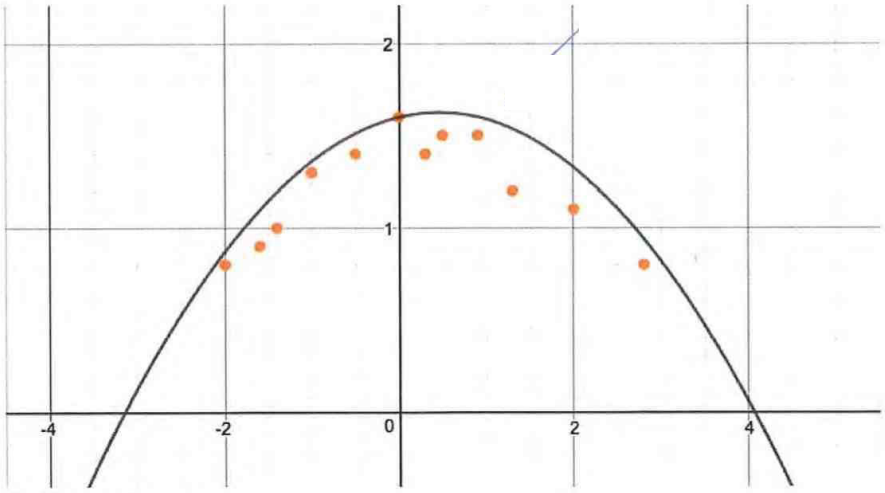

Figure 12: Curve of tummy

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$$Y = -0.4x^2 - 2x + 1.5$$

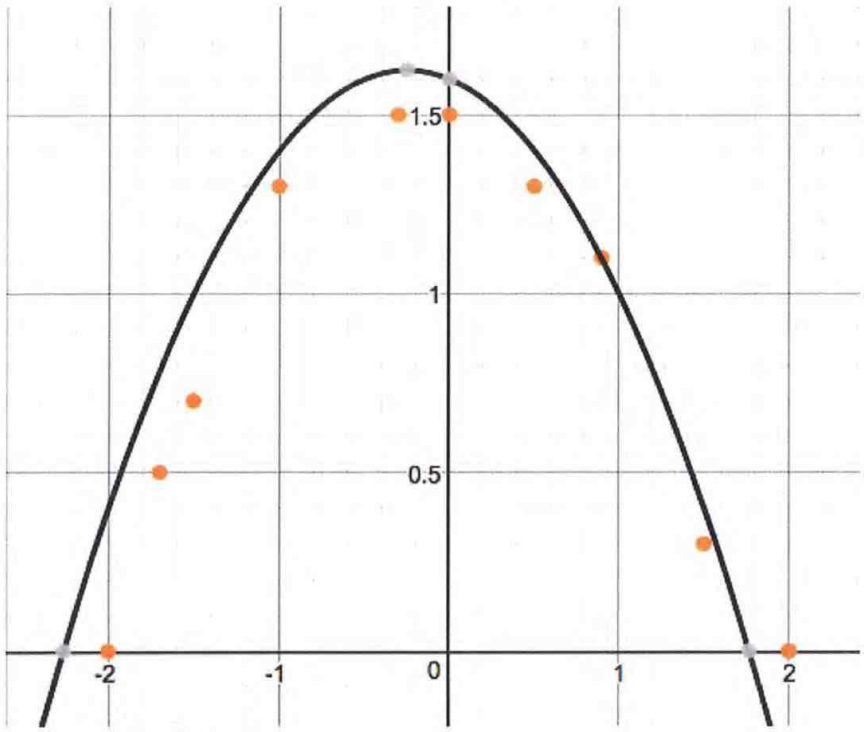

Figure 13: Curve of Hind hooves

Now using the curve found for the front hooves we will find the angle at which a horse jumps. This will be done through finding the tangent of the line.

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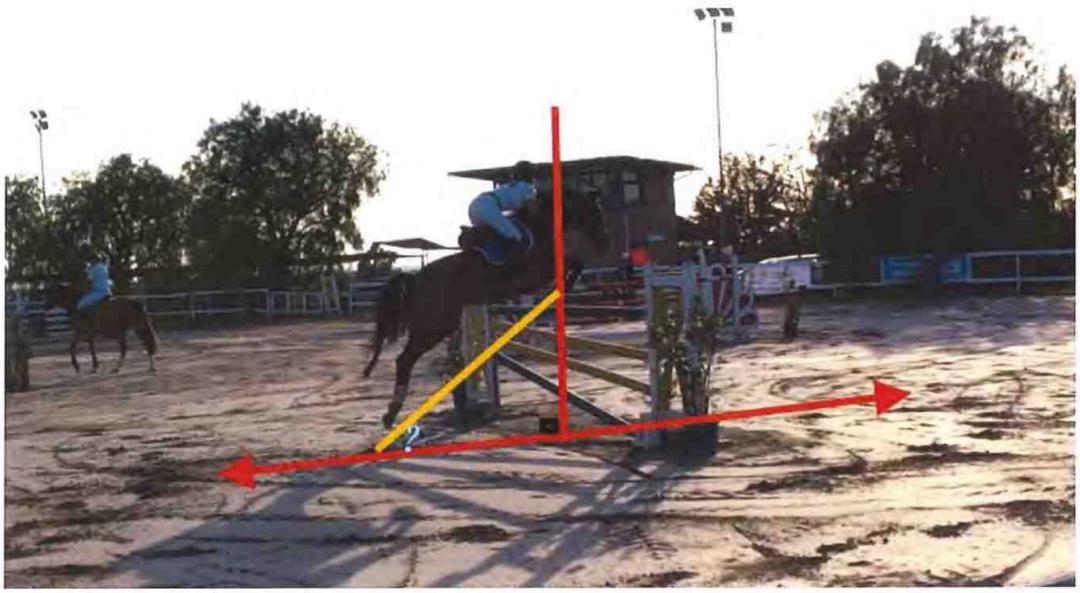

Figure 14: Angle of research

$$Y = -0.34x^2 + 0.17x + 1.7$$

$$\frac{dy}{dx} = -0.68x + 0.17$$

$$m = \frac{dy}{dx} \text{ when } x = 2.5$$

$$m = -0.68(2.5) + 0.17$$

$$m = -1.7 + 0.17$$

$$m = -1.53$$

$$\tan^{-1}(-1.53) = -56.83$$

Angle of the jump: 56.83°

Conclusion

Overall, using such an equation can give a rider the perfect curve of a horses jump and not only see the physical aspect of horseback riding but also the mathematical aspect. All the curves show the pathway my horse uses to jump over an obstacle. In addition, these curves give me as a rider an idea of what pathways his front and back legs take and what path his tummy takes, allowing me to further understand what my horse does to not hit a pole. With this investigation, I have learned to understand the dynamics and the difference between these three sections of the horse's body and it has allowed me to see how these differ between them. Moreover, finding the angle at which my horse jumps allowed me how takeoff angle is so important for the horse to perform its best possible curve during the jump.

Evaluation

Even though this investigation was thorough and particularly successful, there are some variables which might affect and change this investigation in many ways. When it comes to horseback riding there are so many things which can change a perfect scenario in simply one second. For example, a horse's force and flexibility must be kept into consideration when taking the curve of its jump. This is because not all the horses are the same, some can manage jumping an obstacle at a nearer distance and other from farther away. Furthermore, the flexibility of a horse is a very important variable, that has not been kept into consideration for this investigation, because it can change the root which a horse's hooves take especially the hind hooves. This is because if a horse is particularly flexible it will manage to arch its back more than other normal horses, therefore taking its hind legs farther up over the jump. Lastly, gravity and speed can have great impacts of a horses jump because if a horse does not have the perfect speed to jump the gravity will pull it straight back down. Also, gravity plays a huge roll in a horse jump for once the horses passes the phase of flight it starts descending because of gravity. Overall, there are too many variable in

showjumping and to hold an investigation such as this one, one must keep into consideration only a few because otherwise a conclusion cannot be reached.

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