Impact of Rim Weight and Torque in Discus Performance

by

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ABSTRACT

The discus throw is one of the oldest sporting events in track and field. Despite this, there has not been very much dynamic analysis on the throw and the ability of an athlete to apply the proper forces and torques to the discus. This paper looks at measuring the ability of the athlete to create spin on the discus by applying torque in the throwing process. The results from the experiment described in this paper were inconclusive, though there was a general trend that as the normal force into the discus increases, the angular velocity increased. However, this was minimally correlated from the data supplied.

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1. Introduction

The Discus throw dates back to Ancient Romans. It was one of the original events in the Olympics in the sport of track and field. The goal in the discus is to throw the discus as far as possible. This takes a combination of talent, strength, speed and technique. When the four are combined together, the sight is awe-inspiring.

Figure 1: Greek Discus thrower statue[1]

This paper focuses on the torque that the athlete applies to the discus. This can be measured by measuring the normal force going into the discus from the hand. The torque application affects how fast the discus spins and thus maintain stability in flight.

As athletes come through the sport, technique becomes especially important to throwing far. As better techniques become discovered, jumps in distance across the spectrum occur. In 1912, the men's discus world record was 47.48m[2]. For reference, MIT's Varsity Discus record is 52.12m set in 2003 by Chris Khan[3]. The current discus world record is 74.08m set in 1986, a large improvement in 74 years. On the women's side the difference is even more drastic. The record set in 1923 was at 27.39m. By 1988, the record almost tripled to be 76.80m[2]. Today, the records haven't changed in 30 years (partially due to the banning of steroids), but also because the technique has not changed much. A progression of the world records can be seen in Figures 2a and 2b.

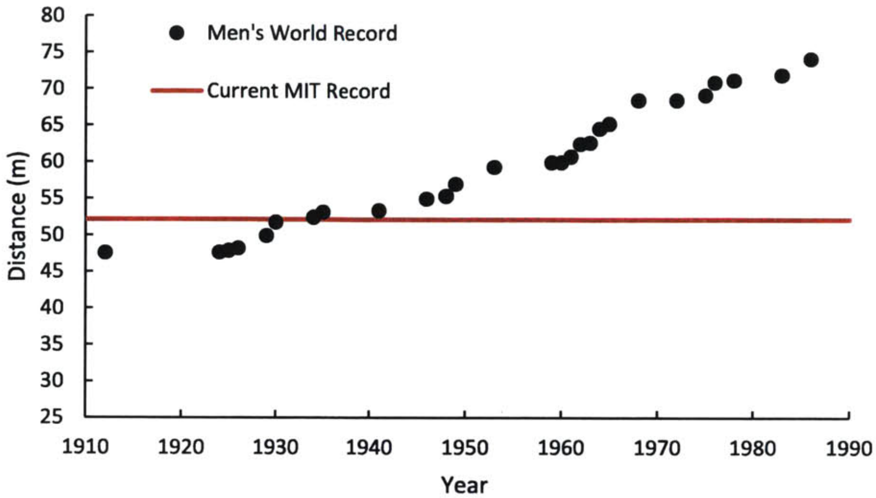

Figure 2a: Progression of the Men's World Record[2] and the Current MIT Record[3].

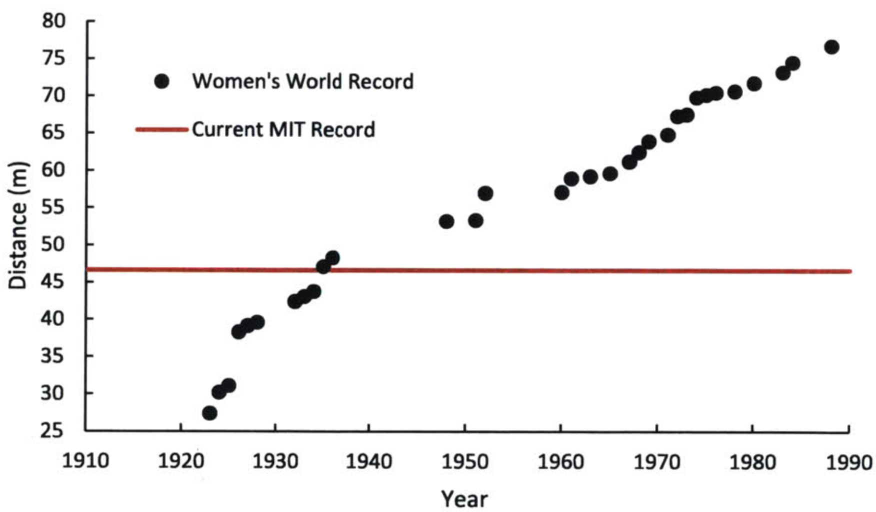

Figure 2b: Progression of the Women's World Record[2] and the Current MIT Record[3].

There are a few stages in learning the discus throw. The beginner does a standing throw, where they keep their feet shoulder-width apart take the discus in the palm of their hand and rotate as far back as possible to wind up. From this position, the athlete rotates quickly to forward and releases the discus by rolling it off of their pointer finger. As an athlete advances technically and is able to get the discus to fly properly, they add in steps that rotate them 450 degrees and across an eight foot circle. The rotation helps the athlete keep their body inside of the circle, a requirement for a legal mark. The sector in the discus throw is 34.92 degrees wide.

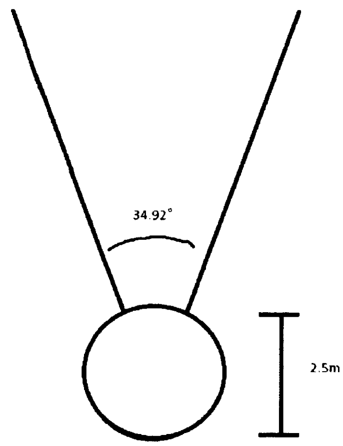

Figure 3: Discus Sector

In order to get a legal mark, the discus must land within the sector. Anything on the line or outside of it is marked as a foul. In addition, the thrower must stay controlled within the circle after the discus is released. Once under control, the thrower must walk out the back half of the circle.

As a thrower becomes more advanced, they generally move up to a higher level discus. What characterizes a higher level discus is the rim weight. A beginner would throw a discus with approximately 60% rim weight. Whereas a higher level discus thrower could be throwing a discus with a rim weight of 88%. The thought behind this is that it takes more skill to get a discus with a greater moment of inertia spinning. However, once it is spinning, it is significantly more stable in the air.

2. Experimental Setup

The theory behind the experiment is that the normal force should relate linearly to the angular velocity. To test this theory, a force sensor was attached to the thrower's index finger, where the peak force occurs in the throw and the last point of contact between the thrower and the discus. The wires attached to the sensor were attached along the thrower's body to avoid hurting the thrower's body by the whipping effect of the wire, as well as to protect the sensor.

The set up can be seen in Figure 4. In addition, a camera was set up behind the thrower to measure the angular velocity. However, this part of the setup was not reliable due to the equipment used as well as the angle of video compared to the angle of attack to measure the actual angular velocity.

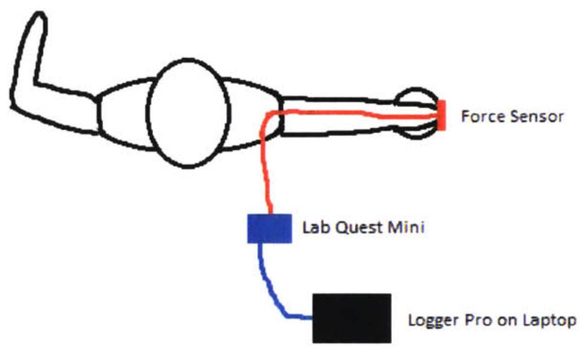

Figure 4: A top down illustration of the experimental setup.

The force sensor used was a FlexiForce-100 Sensor. The idea behind using this set up was to be able to get the value of the torque applied to the discus due to friction. Figure 5 shows a free body diagram of the discus before release.

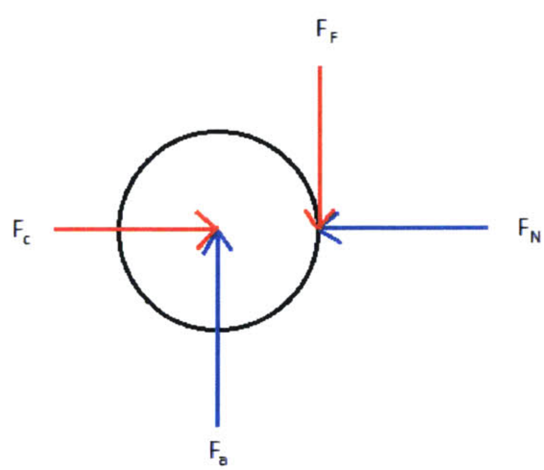

Figure 5: Free-body diagram of the discus before release.

Friction is represented by F_F. Friction can be calculated using the equation $F_F=\mu F_N$, where μ is the coefficient of friction and F_N is the normal force. F_c and F_a represent centripetal force and the force applied linearly by the athlete respectively.

The goal in the discus is throw as far as possible, a lot of this is the linear force behind the discus. So that raises the question: why does it matter how fast the discus is spinning? The discus spinning allows stability in the flight. It creates more lift and minimizes drag. This can be seen in Figure 6, a free-body diagram of the discus in its flight.

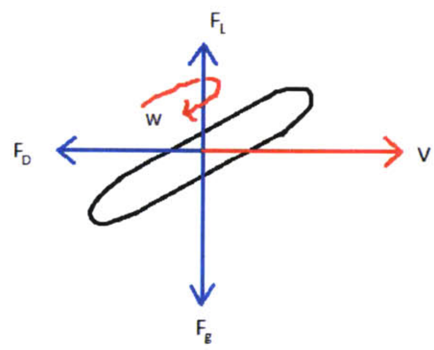

Figure 6: Free-body diagram of discus in flight. Forces are represented by blue arrows and kinematic values in red.

The discus spinning increases the amount of time that the discus is in the air. This is also effected by the angle of attack in the discus, which can be seen in Figure 7. The angle of attack also effects the lift and drag of the discus. The ideal angle of attack is around 35 degrees, but varies from person to person as well as external conditions, such as wind speed[4]. The angle of attack is represented with Θ. The initial velocity is represented by V_o and H represents the height of release. Given all of these initial conditions, in addition to external conditions. A model should be able to estimate how far a throw will go[5]. Unfortunately, controlling all but one of these variables is difficult and while still maintaining the human factor, nearly impossible.

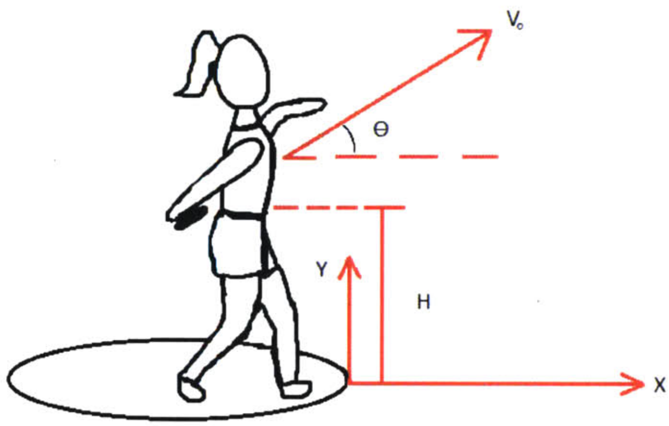

Figure 7: General model of release of the discus.

3. Discussion of Results

Using the video camera to calculate angular velocity and the force sensor to calculate the normal force, the results were very off target. This is due to high uncertainty in the measurements as well as the many other factors of this throwing event.

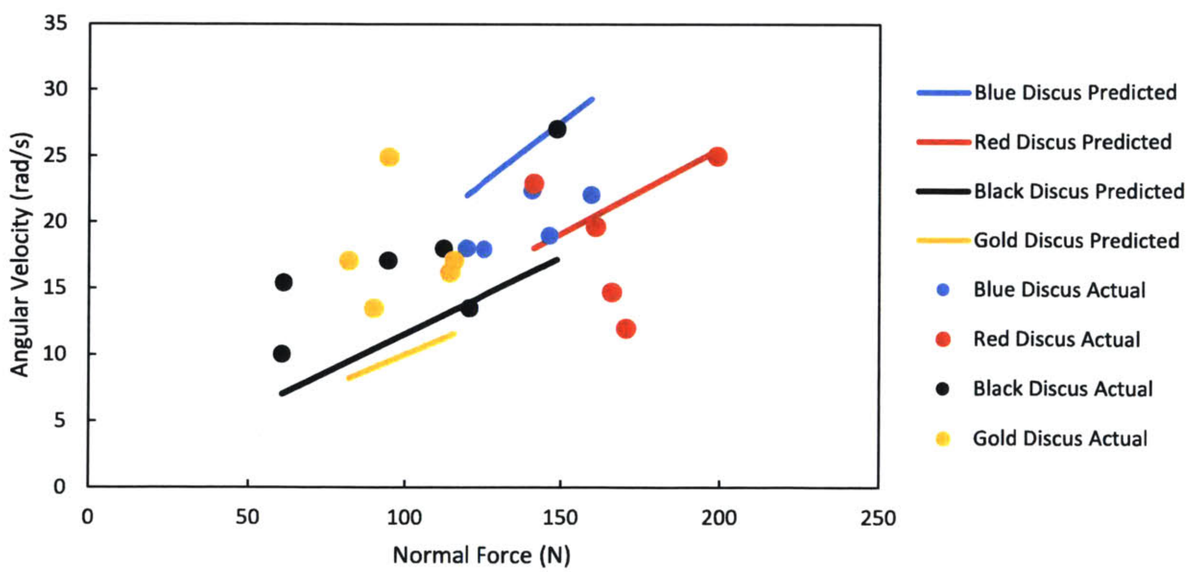

Figure 8: Actual and Predicted Angular Velocities in relation to the measured Normal Force.

As can be seen in Figure 8, the predicted values of angular velocity are significantly different than the actual. The predicted values were calculated using the following equations where μ, the coefficient of friction, is estimated to be 0.7 for human skin on metal[6], r is the radius of the discus, τ is the torque due to friction, α is the angular acceleration, I is the moment of inertia which is calculated using the rim weight percentage, Δt is the time the torque is applied to the discus which is estimated to be 0.01 seconds, and ω_o is the initial angular velocity at 0 rad/s. These are all used to calculate ω_p, the predicted angular velocity.

$$F_f = \mu \times F_N$$

$$\tau = r \times F_f$$

$$\alpha = {}^{\tau}/_{I}$$

$$\omega_p = \omega_0 + \Delta t \times \alpha$$

In addition, the predicted velocities within each of the types of the discuses was even less indicative of angular velocity. From lowest to highest rim weight, the discus colors are blue, red, black, and gold. So blue is the easiest discus to throw at 60% rim weight and gold at 88% rim weight. The higher the rim weight, the more stability it has in the air once it gets to a certain threshold of angular velocity.

The problem with this experiment was that it was not possible to measure the angular velocity accurately. In addition, the result that really matters is the distance, which was unable to be measured due to experimentation occurring inside due to the weather. The level of inaccuracy in the measurement of these values caused a large margin of error and resulted in inconclusive results. Ideally, more data points would be taken to see more of a trend, but the force sensor broke on the last day of data collection.

4. Conclusion

All in all, the data collected in this experiment was not of a high enough quality to make any conclusions. For future data collection, it would be wise to be more careful with the sensors and camera angles, measure distance instead of angular velocity, and get significantly more data points. In conclusion, further research is necessary to come to conclusive results.

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