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The factors that influence Frisbee's flying trajectory and posture

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Abstract:
This article introduces the factors influencing frisbees' flying trajectory and posture, which are integral components of proficient frisbee tossing. Given that Ultimate Frisbee has gained considerable popularity as a sport, aficionados seeking to excel must acquire a comprehensive understanding of the techniques involved in Frisbee throwing. The trajectory and orientation of frisbees are contingent upon various factors, including the style of grip employed, the angle of release relative to the horizontal plane, as well as the dimensions and diameter of the frisbees. A series of experiments was conducted, and the resultant data were meticulously recorded to substantiate the findings. Athletes are thereby equipped with the knowledge to modify their grip style and release angles to meet their specific requirements, thereby achieving a satisfactory frisbee toss.

Keywords: trajectory, posture, grip, angle, size

1. Introduction

Ultimate Frisbee is a very interesting sport in daily life. The discs used to play Frisbee are round discs which made of light plastic like nylon. There are also some discs that are made of polyethylene. People make Ultimate Frisbee a sport by throwing frisbee discs, catching them, and achieving coordination. There are also frisbee competitions, which exercise people's ability to cooperate and test their frisbee skills. Therefore, it takes some skills to throw a frisbee disc well, which is flat and far, or make it easy for your teammates to catch (Except evading defenders, proficiency, and other factors that have nothing to do with the frisbee disc itself). The purpose of this article is to study the factors that affect the flying trajectory and posture of the frisbee discs, and to help people achieve the desired effect of the frisbee discs. While there has been much research on how to throw frisbee discs and many analyses of it (N. Landell-Mills 2020), there are some factors that haven't been studied in detail, such as the grip type, throwing angle, and the size of frisbee discs. This paper focuses on how various factors influence the flying path and posture of frisbee discs, which are relevant to the way the frisbee discs fly. Through reading this article, you will understand the mechanism behind Frisbee, the math and the physics involved in Frisbee, learn to predict Frisbee discs' flying trajectory and posture, and know how to throw a Frisbee disc with the effect you want.

2. Literature review

History of The Frisbee: From Pie Tins to Disc Sports, by Alan (2023), is a valuable resource, including information on the history of the Frisbee. The Frisbee's history began in the late 19th century when college students in New England, especially at Yale, tossed empty pie tins from the Frisbie Pie Company. In 1948, Walter Frederick Morrison invented a plastic version called the "Flying-Saucer," and in 1955, he sold it to Wham-O, who rebranded it as the "Pluto Platter." By 1958, Wham-O renamed it "Frisbee," honoring the original pie tins. The Frisbee gained widespread popularity, leading to the creation of various Frisbee-based sports in the 1960s and 1970s, including disc golf, freestyle Frisbee, and Ultimate Frisbee, which emerged in 1968 in Maplewood, New Jersey. Today, Frisbee sports have professional leagues and governing bodies like the World Flying Disc Federation (WFDF) and the Professional Disc Golf Association (PDGA). Modern Frisbees use advanced materials and aerodynamic designs, enhancing performance and versatility for sports and recreation. From a simple pie tin to a globally recognized toy and sports equipment, the Frisbee has evolved significantly, enjoyed by millions worldwide.

V.R. Morisson (2005) explains the physics involved in Frisbee in his article The Physics of Frisbee. He said that the two physical concepts behind the Frisbee are aerodynamic lift and Gyroscopic inertia. Aerodynamic lift, in simple terms, is the forces that act on the Frisbee discs. This can be seen with a spinning Frisbee in flight. A spinning frisbee can be viewed as a wing in free flight with the Bernoulli Principle, which means under ideal conditions, the sum of kinetic energy, potential energy, and pressure potential energy per unit volume of fluid at any cross-section of the same pipe is a constant. Its most famous inference is that when flowing at an equal height, the higher the flow velocity, the lower the pressure. Bernoulli's Principle is the cause of the lift and the angular momentum of the disc, providing its stability. The two main aerodynamic forces acting on a Frisbee are the drag and lift forces. However, the various forces applied are not centered on the disc, so it is necessary to prevent the frisbee disc from acquiring high angular momentum. As for Gyroscopic inertia, the rotation of a Frisbee disc is necessary for composing the mechanics of how a Frisbee disc flies. Without rotation, a Frisbee disc would just flutter to the ground like a falling leaf and fail to produce the long-distance, stable flights that people find so entertaining. This is because the aerodynamic forces are not directly centered on the Frisbee. In general, the lift on the front half of the disc is slightly larger than the lift on the back half, which causes a torque on the frisbee. (see Figure)

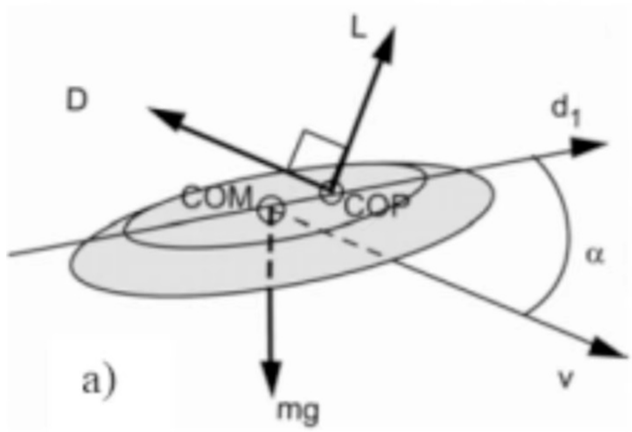

Fig. 1 diagram of the off-center of pressure and the center of mass that results in a torque exerted on the frisbee

Morisson used the numerical technique, Euler's method, to write a computer program to simulate the trajectory of a flying Frisbee. He ran different experiments with different angles of attack and observed the different distances and heights the frisbee disc reached. He concluded that at lower velocities, the lift force was greatly reduced, and the frisbee discs just dropped to the ground faster. At higher velocities, the lift force was greater, and their trajectories were higher and longer.

N. Landell-Mills (2020) used Newtonian mechanics to explain the physics of how frisbees fly. In his article Newton's Laws Explain How Frisbees Fly, he suggests that these mechanics are based on the mass-flow rate that focuses on the forces created by the wing(disc) airflows. A frisbee flies through a mass of air, and each second it accelerates to a velocity downwards. This action creates a downward force. The frisbee disc with a positive angle of attack pushes air down, the equal and opposite force pushes the frisbee disc up. The Coanda effect on the top side of the disc is very important for the frisbee disc's flight. The Coanda effect has a significant impact on the physics of lift for frisbees. Fluid flow (airflow) naturally follows a curved surface due to the Coanda effect. For example, air flowing around the curved topside of a Frisbee is similar to how falling water is redirected by a spoon. In general, frisbees produce a stronger Coanda effect at lower angle-of-attack (AOA) and higher airspeeds. Also, in these circumstances, turbulence tends to be least. A stronger Coanda effect primarily maximizes the mass of air displaced downwards each second and thus the lift. The amount of air redirected by the Coanda effect also depends on the maintenance of laminar (smooth) airflow. In turn, this depends mostly on the angle of attack (AOA) and shape of the frisbee and stability of the disc in flight. Landell concluded that Newton's laws can explain why a

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frisbee thrown flat (small AOA) generates better lift and will fly further than a frisbee thrown high, on a parabolic type of path. This explanation of lift can also be applied to all objects that fly, including airplanes.
Debidatta Dwibedi and Senthil Purushwalkam concluded the mechanics of Frisbee throwing in their article Mechanics of Frisbee Throwing. They suggested the flight of a Frisbee involves rotation and velocities about three axes. A frisbee disc's dynamics is composed of an airfoil and a gyroscope. An airfoil is a structure like the wing of an airplane. There are four components that affect the flight of a Frisbee disc. The first one is Gravity, which is a constant vertical force that acts at the center of mass of the frisbee discs. The second one is drag, which acts in the direction parallel to the direction of motion, which acts on the center of pressure of a Frisbee disc and causes the disc to decrease velocity. The third one is lift, which acts in a perpendicular direction of motion. Although there is no vertical velocity component, lift causes the rise in height of a Frisbee disc. The last one is Aerodynamic Moments, since the center of pressure and center of mass don't coincide, the roll moment, pitch moment, and spin-down moment appear. The spin of the Frisbee disc provides stability in flight due to the angular momentum and gyroscopic precession. There are essentially two force components that affect the Frisbee as a gyroscope. The first one is angular momentum, which is the product of the spin angular velocity vector of Frisbee discs and the moment of inertia. The second one is wobble. The two sources of wobble are induced by the thrower and aerodynamic forces. And Debidatd and Spurushw also gave the formulas for the magnitude of drag and lift.

3. Methodology

The aim of this research is to study the factors that influence frisbee disc's flying posture and trajectory. To achieve this objective, several randomized controlled trials will be conducted using various approaches.
This study will investigate the forces acting on the frisbee itself, the angle between the frisbee and the horizontal plane when it is thrown, and the size of the frisbee.
The first experiment studies the effects of force on the flight trajectory and posture of the frisbee. The experiment requires an experimenter, various frisbees, tape (for adding weight), small weights (coins or small stones), measuring tape, stopwatches, a protractor, cameras, a marker, and a laser range finder. The experimenter first changes the grip on the Frisbee to make the point of force different. Here is how to conduct this experiment.
The independent variables are grip types, including power grip, fan grip, and forehand grip.
The dependent variables are flight trajectory, including straight, curved, or unpredictable, stability or posture, including wobble, tilt, or steady flight, distance traveled how far the frisbee travels.
First, setup and preparations
Mark the Starting Point: Use a marker or cone to indicate where you will stand to throw the frisbee, and ensure that the space around the starting point is clear and flat.
Measure the Test Area: Use the measuring tape to mark distances from the starting point at intervals (e.g., 10 meters, 20 meters). These marks will help to evaluate the distance traveled by the Frisbee.
Prepare the Recording Sheet: Create a table with columns for grip type, point of force application, distance traveled, observed trajectory, and stability.
Second, conduct the experiment.
Phase 1: Testing Different Grips
Grip Type 1: Power Grip
Step 1: Hold the frisbee using the power grip.
The Power Grip is a common and effective way to hold a Frisbee, particularly when you want to achieve maximum spin, distance, and power in your throw. It's widely used for longer throws where stability and distance are crucial.
Finger Placement:
Fingers: All four fingers (index, middle, ring, and pinky) are curled tightly around the underside of the frisbee's rim.
Thumb: The thumb is placed on top of the frisbee, near the edge, providing a strong grip and control over the disc.
Palm: The palm of your hand is pressed firmly against the bottom of the Frisbee, adding to the overall grip strength.
How to Use the Power Grip
Grip the Frisbee:
Hold the frisbee with your dominant hand, wrapping all four fingers under the rim.
Place your thumb on top, gripping the edge securely.
Throwing Motion:
Use your wrist to snap the frisbee as you release it, adding spin.
The combination of a strong grip and wrist flick will launch the frisbee with significant power and speed.
Release: Release the frisbee at the desired angle to control its trajectory.
Step 2: Apply force evenly at the center of the Frisbee and release the Frisbee at an angle of 15 degrees. Using a protractor, hold the cardboard at a 15-degree Angle to the horizontal table, and throw the Frisbee with your hand against the cardboard.
Step 3: Measure the distance from the starting point to the landing point of the frisbee, the time it takes to fly, and record the distance, trajectory, and stability of the frisbee disc.

Step 4: Repeat the throw 3 times to get an average result.
Step 5: Change the point of force application to the edge of the frisbee and repeat steps 2-4.
Grip Type 2: Fan Grip
Step 1: Switch to the fan grip and repeat the same sequence as for the power grip (center, edge).
Step 2: Record the observations in your table.
Grip Type 3: Forehand Grip
Step 1: Use the forehand grip and again repeat the sequence (center, edge).
Step 2: Record the observations.
(Make sure to throw at 15 degrees all the time. And use rubber bands to control the force acting on the Frisbee disc. Attach a rubber band or a series of rubber bands between your hand and wrist. The tension in the rubber bands can help you feel a consistent force as you pull your hand back to throw. This tension can act as a guide to help you apply a similar force each time.)

Fig. 2 The method of throwing a frisbee when conducting the experiment

Phase 2: Analysis
Compare the Results:
Analyze how different grips affected the trajectory and stability of the Frisbee.
Compare how the point of force application (center vs. edge vs. angular) influenced the flight.
Look for patterns, such as whether certain grips or force applications consistently led to more stable flights or greater distances.
Record Throws:
Record each throw with a camera. Play back the footage in slow motion to analyze the frisbee's trajectory and stability more precisely.
In the second experiment, the experimenter changed the Angle between the Frisbee and the horizontal plane when the disc was thrown out, explored the influence of the Angle between the Frisbee and the horizontal plane on the flying track and posture of the Frisbee.
Materials Needed:
Frisbee (standard size)
Protractor (to measure the release angle)
Measuring tape (to measure the distance)
Markers or cones (to mark the starting point and landing spots)
Laser range finder (measure the landing distance)
Camera or smartphone (optional, for video analysis)
Notebook or recording sheet (to record observations)
Flat, open space (like a park or field)
The independent variable is the angle of release: the angle at which the Frisbee is thrown relative to the horizontal plane. This could include angles such as 0° (horizontal), 15°, 30°, 45°, 60°.
The dependent variables are flight trajectory, including the path the frisbee takes, such as straight, curved, or wobbly, flying posture, including the orientation of the frisbee during flight, such as level, tilted, or wobbling, distance traveled, which is how far the frisbee travels from the point of release to where it lands.
Step 1: Setup and Preparation
Mark the Starting Point:
Use a marker or a cone to indicate where you will stand to throw the Frisbee.
Ensure that the space around the starting point is clear and flat.
Prepare the Release Angle Measurement:
Use a protractor to help set the release angle of the Frisbee. Using a protractor, hold the cardboard at a 15-degree Angle to the horizontal table, and throw the Frisbee with your hand against the cardboard.
Measure the Test Area:
Use the measuring tape to mark distances from the starting point at intervals. These marks will help you evaluate the distance traveled by the Frisbee.
Prepare the Recording Sheet:
Create a table with columns for the release angle, observed trajectory, flying posture, and distance traveled.
Step 2: Conduct the Experiment
Phase 1: Testing Different Angles
Set the First Angle (0° - Horizontal):
Hold the frisbee at the desired angle using the protractor for accuracy.
Ensure the frisbee is released flat (parallel to the ground) for the 0° angle.

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Throw the Frisbee:
Release the frisbee at the measured angle with a consistent amount of force.
Observe and record the distance it travels, the trajectory it follows (straight, curved, etc.), and its posture during flight (level, tilted).
Repeat for Accuracy:
Throw the frisbee 3 times at the same angle to get an average result.
Record the data for each throw.
Increase the Angle:
Adjust the release angle (15°, 30°, 45°, etc.) and repeat the process.
For each angle, ensure you are applying the same force and technique to isolate the angle as the variable being tested. (Using a protractor, hold the cardboard at the same degree Angle to the horizontal table, and throw the Frisbee with your hand against the cardboard)
Record and Compare:
Record the data for each angle in your table.
Note any patterns, such as how increasing or decreasing the angle affects the trajectory and posture.
Step 3: Video Analysis
Record each throw with a camera from the side.
Use the footage to analyze the frisbee's flight more precisely, checking for any subtle changes in posture or trajectory that might not be visible to the naked eye. (Convenient for subsequent calculation of Frisbee speed and acceleration)
The third experiment explored the effect of the size of the Frisbee on the flying posture and trajectory of the Frisbee, using different sizes of the Frisbee, and recorded the data.
The independent variables are size, which is the diameter of the Frisbee. Testing frisbees of different sizes, such as a standard frisbee (27 cm diameter) vs. smaller frisbees.
The dependent variables are flight trajectory, including the path the frisbee takes in the air (straight, curved), flying posture, including the orientation of the frisbee during flight (level, tilted, wobbly), and distance traveled, which is the horizontal distance from the release point to where the frisbee lands.
Flight Duration: The time the frisbee stays airborne from release to landing.
Materials Needed:
Multiple Frisbees: different sizes.
Measuring Tape: To measure the distance traveled.
Stopwatch: To time the duration of the flight.
Markers or Cones: To mark starting points and landing spots.
Camera or Smartphone: Optional, for video analysis.
Laser range finder: To measure flying distance.
Notebook or Recording Sheet: To record observations.
Flat, Open Space: Like a park or field.
Setup and Preparation
Select Frisbees:
Choose frisbees that vary in size, shape, and weight. You can buy different types or modify an existing frisbee by adding weights (coins or washers taped securely) or changing its shape slightly with tape or other materials.
Mark the Starting Point:
Use a marker or a cone to indicate where you will stand to throw each Frisbee. Keep this consistent.
Prepare Measurement Tools:
Set up a measuring tape along the direction of the throws to measure distance.
Use a stopwatch to time how long each Frisbee stays in the air.
Conduct the Experiment
Phase 1: Testing Size Variations
Step 1: Select the First Size:
Start with the standard Frisbee size.
Step 2: Throw the frisbee with a consistent force and technique.
Step 3: Observe and record the trajectory, flying posture, distance traveled, and flight duration.
Step 4: Repeat the throw 3 times to get an average result for that size.
Step 5: Change size (3 times): Switch to a different size frisbee and repeat steps 2-4.
Step 6: Record and Compare: Record the data for each size and look for patterns. Note how the size influences the flight characteristics.
Video Analysis
Record each throw with a camera for more precise analysis, allowing you to review the flight in slow motion to identify subtle changes in posture or trajectory.

4. Results and data analysis

The first experiment:
To calculate the frisbee's instantaneous speed when it leaves the hand and the magnitude of the force acting on the frisbee, we can use the following physics principles:
Instantaneous Speed (v):
The instantaneous speed of the Frisbee when it leaves the hand can be estimated using the formula:
$v=d/t$
Where: d is the distance traveled by the frisbee, t is the time taken to travel that distance.
Force (F):
The force applied to the Frisbee can be estimated using Newton's second law of motion:
$F=m\times a$
Where: m is the mass of the frisbee, a is the acceleration

of the frisbee.

Acceleration can be derived using the formula:

$a=v/t$release

Where: v is the instantaneous speed at the moment of release, $t$release is the time duration over which the force was applied (assumed to be very short, 0.1 seconds).

Mass of the frisbee m: 0.175 kg

Time of force application

$t$release: 0.1 seconds (a reasonable estimate for the duration of a quick throw).

With these formulas and assumptions, we can calculate the instantaneous speed and force for each trial.

Power Grip

Table 1. The data on using power grip

Power grip				
Center Point of Force Application	distance(m)	time(s)	speed(m/s)	force exerted(N)
trial 1	28.5	3.2	8.91	15.59
trial 2	29	3.1	9.35	16.34
trial 3	28.7	3.3	8.71	15.22
average	28.73	3.2	8.99	15.72
Edge point of force application				
trial 4	26.2	2.8	9.36	16.38
trial 5	26.5	2.9	9.14	16
trial 6	26.1	2.8	9.32	16.31
avrage	26.26	2.83	9.27	16.23

Fan grip

Table 2. The data on using fan grip

Fan grip				
Center Point of Force Application				
trial 7	25.4	2.9	8.76	15.33
trial 8	25.6	3	8.53	14.91
trial 9	25.2	2.9	8.69	15.2
average	25.4	2.93	8.66	15.15
Edge point of force application				
trial 10	23.8	2.7	8.81	15.43
trial 11	24	2.8	8.57	15
trial 12	23.5	2.7	8.7	15.22
average	23.77	2.73	8.69	15.22

Forehand Grip

Table. 3 The data of using forehand grip

Forehand grip				
Center Point of Force Application				
trial 13	20.5	2.5	8.2	14.34
trial 14	20.7	2.6	7.96	13.92
trial 15	20.3	2.4	8.46	14.79
average	20.5	2.5	8.21	14.35
Edge point of force application				
trial 16	19.2	2.3	8.35	14.58
trial 17	19.5	2.4	8.13	14.19
trial 18	19	2.2	8.64	15.09
avaerage	19.23	2.3	8.37	14.62

Analysis:

Power grip generally produced the longest distances, particularly when force was applied at the center of the disc. The central application of force maximized spin and stability, resulting in a straight flight path that allowed the Frisbee to travel further. When force was applied at an an-

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gle, the trajectory became curved, however, it maintained a level of stability, indicating that while the path was altered, the Frisbee was still able to stay airborne effectively.

Throws utilizing the fan grip resulted in slightly shorter distances compared to the power grip. However, when force was applied centrally, the trajectories remained stable, showing that the grip can still facilitate effective throws. Notably, when force was applied at the edge or angularly, the Frisbee produced more pronounced curved trajectories, suggesting that this grip may introduce variability in flight path stability.

The forehand grip typically resulted in the shortest distances, especially when force was applied at the edge of the disc. This grip often led to curved and less stable trajectories, reflecting its reduced effectiveness for distance throws. The instability observed could be attributed to the grip's mechanics, which might not generate as much spin or control as the power grip, leading to unpredictable flight paths.

The second experiment:

Release Angle:

0° (Horizontal)

Table. 4 The data when the angle is 0°

Release angle			
0 degree	distance(m)	trajectory	posture
trial 1	25.1	straight	level
trial 2	24.5	straight	level
trial 3	25.2	straight	level
average	24.93		

15°

Table. 5 The data when the angle is 15°

15 degree			
trial 4	27.3	slightly curved	slightly tilt
trial 5	26.8	slightly curved	slightly tilt
trial 6	27.1	slightly curved	slightly tilt
average	26.96		

30°

Table. 6 The data when the angle is 30°

30 degree			
trial 7	23	curved	tilt
trial 8	22.8	curved	tilt
trial 9	23.2	curved	tilt
average	23		

45°

Table. 7 The data when the angle is 45°

45 degree			
trial 10	17.9	highly curved	tilted and wobbly
trial 11	17.8	highly curved	tilted and wobbly
trial 12	18.3	highly curved	tilted and wobbly
average	18		

60°

Table. 8 The data when the angle is 60°

60 degree			
trial 13	15.4	highly curved	tilted and wobbly
trial 14	14.7	highly curved	tilted and wobbly
trial 15	14.6	highly curved	tilted and wobbly
average	14.9		

Analysis:

At 0° (Horizontal), the Frisbee traveled in a straight line and maintained a level posture, covering the most distance on average. The lack of upward or downward tilt allowed for optimal aerodynamics, minimizing drag.

As the angle increased to 15°, the Frisbee began to curve slightly. This slight tilt did not drastically impact distance, with a small increase observed. The trajectory remained relatively stable, indicating that this angle strikes a balance between lift and distance.

At a 30° angle, the curve became more pronounced, and the Frisbee exhibited significant tilting, which resulted in reduced distance traveled. This suggests that while some lift is beneficial, excessive tilt can lead to instability and decreased aerodynamic efficiency.

At a 45° angle, the trajectory at this angle became highly curved, with the Frisbee starting to wobble. The increased drag and altered airflow dynamics led to further decreases in distance, illustrating the trade-off between lift and forward momentum.

Finally, at 60°, the Frisbee displayed an unpredictable flight path characterized by significant wobbling. This resulted in the shortest distance covered, as the high angle likely caused it to stall and lose forward velocity, demonstrating the critical importance of release angle in Frisbee flight dynamics.

The third experiment:

Frisbee Size: 20 cm diameter

Table. 9 The data when the diameter is 20cm

size				
20 cm diameter	distance(m)	time(s)	trajectory	posture
trial 1	24.4	3.2	straight	level
trial 2	24.8	3.1	straight	level
trial 3	25.2	3.5	straight	level
average	24.8	3.27		

Frisbee Size: 23 cm diameter

Table. 10 The data when the diameter is 23cm

23 cm diameter				
trial 4	22.5	2.9	straight	level
trial 5	22.8	2.8	straight	level
trial 6	23	3	straight	level
average	22.78	2.9		

Frisbee Size: 27 cm

Table. 11 The data when the diameter is 27cm

27 cm diameter				
trial 7	18.4	2.6	slightly curved	level
trial 8	17.9	2.6	slightly curved	level
trial 9	18.6	2.4	slightly curved	level
average	18.3	2.53		

Analysis:

A 20 cm diameter disc averaged the longest distance traveled at 24.8 meters, indicating superior aerodynamic efficiency. The 20 cm Frisbee maintained a straight flight trajectory, suggesting that its smaller size reduces drag, allowing for better lift and stability throughout the flight.

23 cm diameter disc averaged 22.78 meters, which, while slightly shorter than the 20 cm Frisbee, still maintained a straight trajectory. The reduction in distance may point to the increased surface area leading to slightly higher drag, though it still retained a stable flying posture.

The 27 cm diameter disc averaged the shortest distance at 18.3 meters. Although it exhibited a slight curve in its trajectory, its level posture remained consistent. This in-

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dicates that while larger discs can offer greater stability, their increased size may hinder distance due to higher drag and altered lift dynamics, making them less efficient for long throws.

5. Evaluation

Summary of the dissertation:
After a thorough review of limited existing research around Frisbee, probably due to the fact that it is a newly emerged sport that keeps broadening its population, the study settled with a particular focus on variables including grip type, release angle, and disc size. The experiments conducted revealed noticeable differences in Frisbee's aerodynamic performance and its corresponding flying trajectories, which means contributing to this study.
The first experiment demonstrated that the grip types can, to some extent, affect the aerodynamics of Frisbee as the results showed that power grip consistently yielded the greatest stability and distance while the forehand grip resulted in shortest flying distances with curves and exhibited an unstable trajectory, indicating that the throwing process can greatly determine the flying pattern afterwards. Different grip types can result in the level of control of the disc when initiating the flying, which is similar to the process of flying a paper airplane. The initial velocity will vary as different grip types will get different groups of muscles involved and affect the control and force exertion of players over the disc.
The second experiment regarding release angle revealed that an angle closing to 15° produced optimal flight trajectories, showing a good balance between distance and stability. Higher angles, such as 45° and 60°, resulted in shorter distances due to the fact that the greater angle of attack (AOA) increased drag force and led to non-favored flying postures, verifying the hypothesis that an appropriate angle of release is critical for high-quality throws.
The third experiment regarding different disc sizes has shown anticipated results that larger disc sizes can facilitate stability and greater flying distance under the same conditions. Discs with smaller sizes can be more easily maneuvered but will be subjected to the drag force to greater extent, while the discs with greater sizes can be capable of retaining more amount of air underneath, which may result in greater stability and also pressure that sustains the disc for a longer period of time.
Experiment results indicated that both the geometry of discs and the throwing techniques can vary the flying performance of the disc. From an application perspective, the grip type and angle of throwing (Angle of Attack in aerodynamics) are the factors that the players can manipulate and practice to get advantages during competition. Understanding these dynamics can provide guides for coaches to customize training regimes that incorporate these findings to help athletes improve their throwing techniques.

Limitations of the Study:

Indeed, the experiment has provided valuable insights for Frisbee training and design. This study has its own limitations. A primary one is that the experiment is conducted under a wind-free environment, which is actually a crucial factor that is expected to alter the flying trajectory. The results from the experiment do not cover the windy conditions that sometimes exist during real games. Moreover, due to the lack of access to professional equipment, the magnitude of forces that were applied over the disc when conducting the experiment trials could not be accurately manipulated, which may result in being unable to control the same force acting on the frisbee every throw. Additionally, the factors that only include grip type, angle, and disc size were relatively few, which may limit the generalizability of the findings. Future research could look into other aspects, such as the material and shape of the frisbee at its edge, or specifically the curling degree of the frisbee as well as introducing equipment that is capable of throwing the disc with predetermined forces, or introducing a greater variety of environmental conditions and levels of proficiency of participants.

Suggestions for Future Research:

Future investigations might explore additional environmental factors, such as the wind conditions on Frisbee performance or the effects of curling degree on the edge of the disc flight dynamics, as it may result in greater capability to retain air underneath. This may be a crucial factor for the disc to maintain its attitude and flying performance in the air.

6. Conclusion

This dissertation has explored the intricate dynamics of Frisbee disc flight, focusing on the factors that influence both trajectory and posture. Through a series of carefully designed experiments, we examined how grip type, release angle, and disc size contribute to the overall performance of Frisbee throwing.
The findings revealed that grip type significantly affects both the stability and distance of Frisbee throws, with the power grip emerging as the most effective for achieving desired outcomes. Additionally, the analysis of release angles indicated that angles between 15° and 30° optimize flight performance, while higher angles tend to decrease

distance due to increased drag. The investigation into disc size highlighted that larger discs offer greater stability, underscoring their advantages in competitive settings.

Here are some key conclusions:

1. Both the way of grip and the point of application of force have an effect on the flying path of the Frisbee. The power grip throws the furthest. The point of force is thrown farther at the center than at the edge.

2. The Angle between the outbound direction and the horizontal plane has an effect on the flight trajectory and posture. And the horizontal plane 0 degrees out of the disc, the trajectory of the disc is the straightest, and the flight posture is the flattest. The larger the Angle of the plate, the more curved the trajectory, the more inclined the flight posture of the disc.

3. The size of the disc affects the trajectory of the flight. A frisbee with a diameter of 20 centimeters travels the farthest and has the straightest trajectory. When other conditions are equal, the larger the diameter of the Frisbee, the closer the flight distance, the more curved the flight path.

4. Throwing a frisbee with an angle of 15 degrees and by using a power grip can result in the longest flying distance, straightest trajectory, and the most stable posture for all sizes of frisbee discs (20cm, 23cm, 27cm diameter).

These conclusions not only enhance the understanding of the mechanics behind Frisbee throwing but also provide practical implications for players and coaches. By applying the knowledge gained from this research, athletes can refine their techniques to improve performance in various playing conditions.

Despite the contributions made, this study also recognized its limitations, including the controlled environment of the experiments and the relatively small sample sizes. Future research is encouraged to build on these findings by incorporating diverse environmental conditions, a wider range of participant skill levels, and additional factors influencing Frisbee dynamics.

In summary, this dissertation has advanced the knowledge of Frisbee throwing mechanics and has summarized related previous studies and laid the groundwork for future studies. The interplay of grip, angle, and size not only informs practice but also invites further exploration into the physics of recreational sports. Ultimately, understanding these factors enriches the playing experience and encourages a more nuanced appreciation of Ultimate Frisbee as both a sport and a recreational activity.

7. References

[1] Alan. (2023, December 30). History of The Frisbee: From Pie Tins to Disc Sports. Disc Golf Disc Reviews. https://discgolfreviewer.com/history-of-the-frisbee/#:~:text=Frisbee%20golf,%20also%20known%20as%20disc%20golf,%20is%20a%20sport

[2] Dwibedi. D & Purushwalkam. S (2020). Mechanics of Frisbee Throwing. CMU. https://www.cs.cmu.edu/afs/cs/academic/class/16741-s07/www/sample_projects/spurushw_report

[3] Landell-Mills. N (2020, July 13). Newton's Laws Explain How Frisbees Fly. Semantic Scholar.European Journal of Applied Physics, Vol 2 | Issue 4 https://pdfs.semanticscholar.org/e7aa/006ca3fe6fa2c82bf3213bdbd4009192d7c1.pdf#:~:text=Newtonian%20mechanics%20explain%20the%20physics%20of%20how%20frisbees,force%20%28Force%20%3D%20ma%20%3D%20m%2Fdt%20x%20dv%29.

[4] Morisson. V. R. (2005). The Physics of Frisbees. Semantic Scholar. https://www.semanticscholar.org/paper/The-Physics-of-Frisbees-Morrison/ffd71e2e0500deee3187bf7fb1cc56750be4672e#:~:text=V.%20R.%20Morrison.%20Published%202005.%20Physics.%20Frisbees%20are%20a%20common