Where 'Raygunn' Went Wrong: Limitations of Theoretical Methods in Applied Breakdancing

Tommy 2-Time[1] Sarah 'The Spin Dr (PhD)' Hernendez[2], et al.

[1]Department of Hip-Hop-ology, Cranberry-Lemon University, Pittsburgh, PA, USA
[2]President of the Society of B-Girl Excellence

Abstract I hate to call out Rachel 'RayGunn's impressive work in theoretical breakdancing and the development of the sportification and gender inclusion of the art, but her recent set showed there is an immense gap in the development of applied breakdancing missing in her research. She crashed HARD, like offbeat, no flow, janky power moves strung together. That was no Olympic performance. No disrespect to Raygunn's crew but their theoretical breakdancing framework is no cypher when thrown down to applied breakdancing research! In this paper, we'll go through the physics assumptions of where she went wrong.

1 Introduction

We love Raygunn. Supporting breakdancing as a gender inclusive sport has inspired many [1, 2]. Unfortunately, a closer look at her applied work [3] has shown that many of her invented moves only work in the lab [4] in simulation [5] or just on paper [6]. For example, as shown in [7], her head spinning techniques applied a negligibly zero coefficient of friction and many of her moves were tested in a vacuum to validate the estimated inertial moments [8]. In order to close the gap of the cutting edge of theoretical break dancing, this paper will correct those dangerous assumptions ending in disastrously lame performances.

2 False Assumptions

Breaking is a very real sport based in science. No matter how much time a B-boy or B-girl spends estimating the required escape velocity to perfect a floor flip spin, it will land you on the left side of the judge if you use the wrong assumptions.

2.1 Air Resistance

Outside of aeronautical engineering, it is common to ignore air resistance for cheater reasons. As shown in post battle analysis or the Colorado Breakdance regional finalists tanking in the Miami nationals due to a sharp increase in air density [9], the air resistance of your moves can make a world of difference. As proposed in [10], the additional force or torque required per move should be estimated using the equation's below where C_d is the coefficient of drag, and ρ is the air density, and all the letters should be self-explanatory since everyone uses Greek letters the same in physics and breaking since the dawn of the free body diagram. If Raygunn just applied the equations and figure below, she may have been able to execute a real power move.

$$F_d = \frac{1}{2}C_d\rho A v^2 \tag{1}$$

$$\tau_d = \frac{1}{2}C_d\rho A r^2 \omega^2 \tag{2}$$

2.2 A Break Dancer is not a sphere

Just like cows [11], it is never safe to assume that a break dancer can be modeled as a sphere no matter how easy that makes the inertial momentum calculations. Whether it's an I-beam, a Crunchwrap supreme [12], or a breakdancer, there is an enormous difference between a point load and a distributed load. Unfortunately for some of Raygunn's theoretical calculations, her irregular non-spherical body shape was not properly handled while estimating spin escape velocity calculations. It's more work but at a minimum estimating the inertial moments of a stick figure
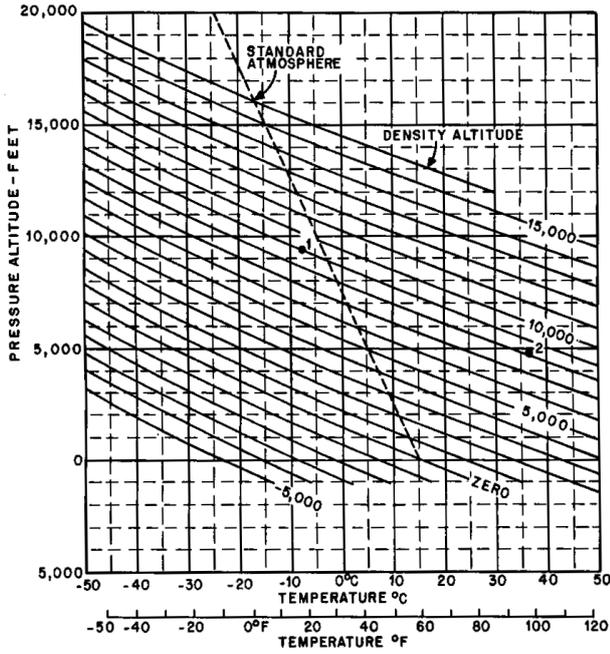
Fig. 1: Air Density by Altitude and Temperature.

model will at a minimum achieve adequate results in most break battles [13]. Balancing these loads is paramount when planning freeze moves.

Fig. 2: Non-Spherical Break Dancer with Distributed Loads.

2.3 Friction-less Surfaces

The final false assumption causing Raygunn's theoretical breakdancing framework to fall flat was ignoring friction. Just because a B-boy or girl is wearing nylon, or the cardboard is real fresh and salted with high grade breaking salt it don't mean that the friction is zero. Even if Raygunn had a correct calculation of horizontal or inertial momentum during a slide or spin, she ignored the kinetic coefficient of friction which caused her initial velocities to be underestimated. Below is a list of useful breakdancing specific static and kinetic coefficients of friction measured in [14] to be multiplied by the normal force.

Surface Material	Footwear/ Clothing Material	Coefficient of Friction
Wood (polished)	Rubber soles	0.6 - 0.8
Wood (polished)	Cotton	0.4 - 0.5
Wood (polished)	Denim	0.3 - 0.4
Wood (polished)	Polyester	0.2 - 0.3
Wood (polished)	Nylon	0.3 - 0.4
Concrete	Rubber soles	0.7 - 0.9
Concrete	Cotton	0.5 - 0.6
Concrete	Denim	0.4 - 0.5
Concrete	Polyester	0.3 - 0.4
Concrete	Nylon	0.4 - 0.5
Cardboard	Rubber soles	0.5 - 0.6
Cardboard	Cotton	0.4 - 0.5
Cardboard	Denim	0.3 - 0.4
Cardboard	Polyester	0.2 - 0.3
Cardboard	Nylon	0.3 - 0.4

Table 1: Various Coefficients of Friction for inquiring minds

3 Coriolis Effect

Unfortunate for the majority of Australian breakers everywhere and competitive basketball spinners [15], the Coriolis effect will completely reverse the natural spinning resistance of any spin move. If Raygunn really wanted to determine the correct offset force to her Australian invented move, she would have reversed the direction of the Coriolis down under using the air density of section 2.1 to estimate the air mass m, and v is her tangential velocity and Ω is her angular velocity. Using the equation below, Raygunn could have solved for the Coriolis force and reversed directions. Now I'm not gonna assume that she used a southern hemisphere Coriolis direction in the northern hemisphere, but stranger things have happened.

$$F_c = -2(\Omega \times v) \tag{3}$$

4 Gyroscopic Stability

A lot of B-boy and B-girl fans can't believe we can do what we do while spinning so fast but bro, we can ONLY do what we do because we're spinning so fast. By the power of gyroscopic stability, we

can make our bodies do whatever we want whenever we want as long as we have enough rotational inertia. That's the conservation of angular momentum my homie. Thankfully due to the decision of the IOC to boot the Russians and ban MEMs and fiber optic gyroscopic stability's, all the B-boys and girls have to stabilize and solve for angular positions the ol fashion way by turning their bodies into a flywheel and use the precession effect.

It's great that Raygunn applied the gyroscopic stability equations from [16], unfortunately she left out the majority of precession effects of irregular bodies. Unlike spinning a rigid body wheel with negligible losses, break dancers are a collection of connected segments similar to a robotic exoskeleton. As discovered in [17], one can cheat the spin by leaning forward or backward to reverse direction or modify the axis of rotation using the kinetic energy from your own body rather than relying on gravity or surface traction.

To begin the angular momentum $\mathbf{L}$ of a rigid body rotating in three dimensions is given by:

$$\mathbf{L} = \mathbf{I}\boldsymbol{\omega} \qquad (4)$$

where $\mathbf{L} \in \mathbb{R}^3$ is the angular momentum vector, $\mathbf{I} \in \mathbb{R}^{3 \times 3}$ is the moment of inertia tensor, and $\boldsymbol{\omega} \in \mathbb{R}^3$ is the angular velocity vector. The moment of inertia tensor $\mathbf{I}$ for a rigid body in three dimensions is:

$$\mathbf{I} = \begin{bmatrix} I_{xx} & I_{xy} & I_{xz} \\ I_{yx} & I_{yy} & I_{yz} \\ I_{zx} & I_{zy} & I_{zz} \end{bmatrix} \qquad (5)$$

where the diagonal elements I_{xx}, I_{yy}, I_{zz} represent the moments of inertia about the principal axes, or as we like to call it the stik thang, and the off-diagonal elements represent the products of inertia. Now the gyroscopic effect, or precession as we call it on the floor, occurs when an external torque τ is applied to the rotating dancer, leading to a cha-change in angular momentum my homie:

$$\tau = \frac{d\mathbf{L}}{dt} + \boldsymbol{\omega} \times \mathbf{L} \qquad (6)$$

The rate of precession $\boldsymbol{\Omega}_p$ is related to the torque crankin down on ya by that sweet ass equation

$$\boldsymbol{\Omega}_p = \mathbf{I}^{-1}\tau \qquad (7)$$

Okay, now this one's gonna be real quick. The equation of motion for the break dancer's body,

considering the full three-dimensional rotation, is given by:

$$\tau = \frac{d\mathbf{L}}{dt} + \boldsymbol{\omega} \times \mathbf{L} \qquad (8)$$

Stability is achieved when the gyroscopic precession counteracts any destabilizing torques or bad vibes with

$$\boldsymbol{\Omega}_p \cdot \tau \geq 0 \qquad (9)$$

For a break dancer, this condition ensures that even in tha thack of a wack ass power move the dancer remains stable during a dope ass spin.

Now sometimes you may assume the dancer's body is modeled as a uniform cylinder spinning about the vertical axis (z-rizza-rizza-axis). The moment of inertia tensor $\mathbf{I}$ which simplifies to:

$$\mathbf{I} = \begin{bmatrix} \frac{1}{2}mR^2 & 0 & 0 \\ 0 & \frac{1}{2}mR^2 & 0 \\ 0 & 0 & mL^2 \end{bmatrix} \qquad (10)$$

where m is the mass, R is the radius, and L is the length of the cylinder if ya knows what I' sayin. Now I get the feeling Raygunn may have stopped there but it totally changes, like real deal changes when the dancer extends their arms or legs, the moment of inertia increases. The contribution from an extended limb which can be approximated as:

$$\mathbf{I}_{\text{limb}} = \begin{bmatrix} m_{\text{limb}}L_{\text{limb}}^2 & 0 & 0 \\ 0 & m_{\text{limb}}L_{\text{limb}}^2 & 0 \\ 0 & 0 & I_{zz,\text{limb}} \end{bmatrix} \qquad (11)$$

where m_{limb} is the mass and L_{limb} is the length of the limb. Now we can find the total angular momentum for the dancer to be

$$\mathbf{L}_{\text{total}} = \mathbf{I}_{\text{body}}\boldsymbol{\omega} + \sum_i \mathbf{I}_{\text{limb},i}\boldsymbol{\omega}_{\text{limb},i} \qquad (12)$$

Ya dig? Now maybe some lazer light show may let some new younger dancers take advantage of that fat Sagnac effect but this is how ya do it old school

5   Results and Discussion

K. so. you can clearly see in the figure below that if you go at it with all your theoretical Buulll-shitz then ya well your tightness meter's basically zero no matter how beast mode you go. Now if you adjust for Re-Al-a-T baby, like we talked about in
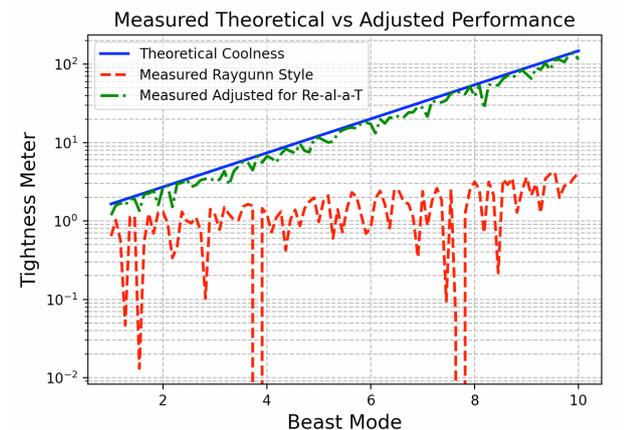
Fig. 3: Yo look at how bad this is oh sheeeet.

this paper; now you won't be perfect, but you'll be the best B-boy or girl you ever can be.

6   Conclusion

Man, Raygunn just sucks man. Just like use air resistance, friction, you better damn well not be callin me a sphere!

References

[1] Gunn. "Deterritorializing gender in Sydney's breakdancing scene: a B-girl's experience of B-boying". In: (Aug. 2020). DOI: 10.25949/19433291.v1. URL: https://figshare.mq.edu.au/articles/thesis/Deterritorializing_gender_in_Sydney_s_breakdancing_scene_a_B-girl_s_experience_of_B-boying/19433291.

[2] GunnMarie. "The Australian breaking scene and the Olympic Games: the possibilities and politics of sportification". English. In: *Global Hip Hop Studies* 4.1 (June 2023), pp. 39–56. ISSN: 2632-6825. DOI: 10.1386/ghhs_00078_1.

[3] L. Yoyomama. "Ultra Dis Tracks: Yo you see that Disastrous Performance of Raygunn's". In: *Breaker Science Quarterly* 9.4 (2003), pp. 243–259.

[4] P. Dizzy Sticks. "Breaking it Down: The Physics of Power Moves". In: *Journal of Urban Kinetics* 5.3 (2001), pp. 333–349.

[5] Dolla Dolla T. Flipside. "The Breakdance Matrix: Simulations of B-boy Techniques". In: *International Journal of Cypher Physics* 12.1 (1999), pp. 88–99.

[6] A. Headspin. "Wipeout: Analyzing Failed Breakdancing Moves". In: *Applied Dance Mechanics* 8.2 (2002), pp. 59–76.

[7] C. Robotic and the Drip Drop Crew. "Breaking in a Vacuum: Unrealistic Assumptions in Theoretical Breakdancing". In: *Journal of Extreme Dance Environments* 18.1 (2020), pp. 75–92.

[8] J. Gravity Drefus. "Floating Freely: Breakdancing in Microgravity". In: *International Journal of Zero-G Dance* 3.1 (2010), pp. 14–28.

[9] A. Clouds and B. Sky. "Density Altitude Effects on Breakdancing Performance: A Breaddown of the Colorado team's Miami Disaster". In: *Journal of Atmospheric Hip-Hop* 21.4 (2012), pp. 101–118.

[10] Lil D. and the Cludgers. "Air Resistance in Power Moves: When Physics Meets Breakdancing". In: *Journal of Chicago Style Dip Dish Street Dance* 6.2 (2009), pp. 49–67.

[11] Will Roper et al. "COWS all tHE way Down (COWSHED) I: Could cow based planetoids support methane atmospheres?" In: *Journal of Astrological Big Data Ecology* (2022).

[12] Queso Grande, Rodriguez, et al. "Yield Strength Comparative Load Bearing Analysis of the Limited Time Cheez-It Webbed Crunchwrap Supreme". In: *Journal of Astrological Big Data Ecology* (2024).

[13] R. Fresh Twist. "Inertial Moments and Their Impact on Freeze Moves". In: *Journal of Breakdance Engineering* 15.1 (2020), pp. 42–59.

[14] DJ Slides. "Spinout: Measuring Friction in Breakdancing". In: *Journal of Kinetic Street Science* 4.2 (1999), pp. 77–90.

[15] D. Crocodile. "Down Under Spins: The Coriolis Effect in Australian Breakdancing". In: *Journal of Hemispherical Hip-Hop* 13.3 (2011), pp. 233–251.

[16] Wes 'The Human Statue' Unicycles. "Rolling and Spinning: Gyroscopic Stability in Breakdancing". In: *Journal of Urban Mechanics* 14.2 (2010), pp. 60–82.

[17] P. Spintop. "Axial Modifications in Breakdancing Rotations". In: *Journal of Rotational Kinetics* 11.2 (2017), pp. 109–130.