*Overview of aerodynamic influences in select thrown-ball athletics*

Zachary Swain[[1]](#footnote-1)

Department of Mechanical Engineering, University of Delaware, Newark, Delaware 19716

and Department of Materials Science and Engineering, University of Delaware, Newark, Delaware 19716.

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**Introduction**

From the Ancient Olympics Games to a modern day Formula-1 racing, sport has been an ever-advancing aspect of human culture and activity, documented for over 2200 years [1]. Over this time, sport has seen major technological advancements likely unimaginable to the Ancient Greeks, with specifics including usage of composite materials and more generally the detail of equipment manufacture. There are, however, certain aspects of sport that have remained as permanent fixtures – a static medium through which sport is played. While certain aspects of game performance may be improved with better technological capabilities and knowledge, there are still physical bounds by which sport is governed. These frames could mainly be considered as their entertained and physical nature – the interaction with their cultural and material media. Simply put: sport has been, is, and will be entertainment of competitive class that is operated in the medium of its physical bounds. Cleats can allow for greater traction on the ground, but one is only as fast as their legs can move. With knowledge of the physical effects of their actions, players can implement particular techniques to optimize their play. Within this frame, aerodynamics of thrown-ball sport will be discussed here.

**The Thrown-ball Sport**

Thrown-ball sport will generally consist of throwing, passing, shooting, hitting, or otherwise aiming and ejecting a ball or projectile as a core component of the game. This is often incorporated in tandem with sprinting, jumping, accelerating, or decelerating. Common games to be considered under this label include baseball/softball, football, soccer, and golf. This ascribed motion of both the player and the ball are conducted through air, with partial exception to include water polo. Motion through an air medium is a core component of the thrown-ball sport; and as such, it is important to consider aerodynamic influences on the game.

In a thrown-ball sport it is generally the goal to possess the ball in order to attempt to score – or to defend the opposing side from scoring. Players travel the playing field under their own power, and do not often encounter significant aerodynamic effects to their person. A player’s rate of motion under their own power is almost never fast enough to impose any considerable aerodynamic force relative to the momentum garnered by their bodily mass at that (relatively) low rate. Consequently, only ball effects will be considered here.

**General Aerodynamics in the Thrown-ball Sport**

Relative to the player, the ball has a much lesser mass and generally travels at faster rates. In almost all thrown-ball sport, the ball will operate within a Reynolds number range of 40,000-400,000 [2]. The ball often encounters aerodynamic forces that impose quite significant effects. Not only is it significant in magnitude, one would be amiss to forgo consideration of aerodynamics in thrown-ball sport. Indeed, it is often the situational goal of the player to impose specific aerodynamic forces onto the ball in its travel. In typical travel, a thrown ball may experience an opposing force comparable to its respective weight [3]. Namely, this is the air drag it encounters. A ball in flight can also generate large forces perpendicular to its travel, with magnitude around 50% of its weight. This factor is largely influenced by any spin applied to the ball, and by its surface geometry relative to its motion [4].

In throwing, passing, shooting, or hitting the ball, players will often apply specific initial conditions to its travel in order to achieve beneficial aerodynamic effects. These conditions are typically applied by contact forces normal and tangent to the ball surface [5]. Examples include a spiral, backspin, topspin, lateral rotation, or knuckling. These effects can be situationally advantageous to the player as to achieve greater travel distance on the thrown ball, to cause an opposing player to miss the ball in flight due to unexpected pathing, or bypass an opposing player or obstacle. It is also worth noting that ball compression is sometimes utilized on initial conditions; especially so on inflated balls and in post-impact spin [5]. These effects are secondary and are generally muted in comparison to the effects we will primarily consider here.

**Detailed Aerodynamics in the Thrown-ball Sport**

Two essential aerodynamic factors to be contextualized within thrown-ball sport are drag and lift. Aerodynamic drag and lift are given by the following expressions, respectively:

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Drag is seen to depend on drag coefficient, the free stream fluid density, the speed, and the reference area. What isn’t shown in this equation is that thrown-ball sport has a substantial dependence on both rotation and surface roughness.

There are ­­­3 main categories encompassing most other common aerodynamic effects that are applied in thrown-ball sport. These will be termed spiral, rotation, and knuckling.

***References***

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1. Electronic mail: zswain@udel.edu [↑](#footnote-ref-1)