Literature Review

Brief history of footwear

In ancient Mesopotamia and Egypt, sandals were a status symbol often only worn by authority or soldiers. The earliest instances of shoes have been found dating back over 10,000 years. These consisted only of a thin sole held on with a tie to protect the sole from sharp objects, such as dried lava crossings or sharp coral while fishing (Froncioni, 2006). Members of the Tarahumara tribe of Mexico wear similar sandals fashioned out of rubber from old tires. This is a relatively new innovation, as tires were developed within the last century. The Tarahumarans ran barefoot prior to the rubber sandals; however, many reportedly still prefer to run barefoot to this day. Native Americans often wore moccasins, a leather thin-soled shoe that was for tribe identification and warmth (Robbins, 2011).

The first athletic shoes were not created until the mid 1800's. The first major user of running shoes was Jesse Owens in the 1936 Olympics, wearing a pair of ADIDAS, founded by Adi Dassler in the early 1920's. Adi's brother, Rudolph became the founder of PUMA after a familial disagreement. NIKE was started in 1971 by Phil Knight and has become the most recognized symbol for a major athletic brand throughout the world (Kirschbaum, 2005). Humans have been running for millions of years; the amount of time since the invention of the modern day running shoe is roughly a minute by comparison. (Lieberman, *et al.* 2009).

The human body and running

It is a growing theory that humans were evolved to be distance runners. In sprinting, humans grade out poorly compared to many four legged mammals whom gallop or sprint at velocities much greater than that of even the worlds most elite humans. Humans do not just sprint, however, they participate in endurance running as well. Being closely related to primates,

homo-sapiens distance themselves from other primates in their ability to run. Most primates are limited to running minimal distances at higher speeds. From an anatomical view, humans have also evolved with several key distinctions from their primate counterparts. The achilles tendon length in humans is much greater than in primates. Shorter muscles with longer tendons add in a spring effect that can conserve energy while running, known as the stretch shortening cycle. The iliotibial tract is also elongated comparatively also. Humans also have an increased percentage of slow twitch muscle fibers in their legs; this could be from a mutation during evolution of the ACTN3 gene (alpha actin skeletal muscle isoform 3). (Lieberman, 2004)

The human foot is an engineering marvel, with the ability to withstand forces much greater than the individual's body weight, and tread over pebbles or rocks without injury. The glabrous skin (hairless skin) found on the soles of one's feet, is more resistant to cuts than the rest of the body's skin containing hair. The medial and lateral longitudinal arches are crucial to human endurance running due to their ability to absorb shock, conform to the ground, and propel forward. The muscles of the foot, when relaxed, create a flexible surface to contact the ground. The foot becomes rigid at toe off to assist in energy transfer.

Wearing shoes sometimes causes atrophy in the muscles of the foot and can cause the arch of the foot to go flat. A shod arch, when weight bearing at rest, has been shown to have muscle inactivity, with the shoe supporting the weight instead of the musculature of the foot. (Robbins, 1987) In a 1992 study of 2300 children (age 4-13 years) from India, children who wore shoes compared to children who were habitually barefoot had an 8.6% rate of instance of flat feet compared to only 2.8% respectively (Bhaskara Rao, 1992). A flat arch cannot function correctly when the foot lands: the arch is supposed to flatten to absorb the shock, which cannot happen when already flat. This intrinsic atrophy also limits the muscular involvement during toe

off, and leaves the plantar fascia as the only way to control the arch. This may cause inflammation of the plantar fascia near the insertion at the calcaneus. After stopping usage of shoes, there is evidence that the intrinsic musculature can recover from the atrophy and return to normal function. (Robbins, 1987)

The foot, from a neurological standpoint, is adept to processing instantaneously the sheer and vertical forces from landing. Wearing shoes can inhibit this ability and the body's reaction to the ground. The added cushioning can create a false sense of security where the body thinks the force is less than it actually is. With the raised heal of shoes, one is forced to land on the heal first instead of the preferred forefoot (Lieberman, 2009). It is estimated that 75% of shod runners are heal strikers (Hasegawa, 2007). Landing on one's heal also creates a greater force sent up the leg and lower back. The repeated stress of thousands of strides per run may help explain high injury rates, as two out of every three runners each year will suffer an injury (Romanov, 2003). The body not being able to fully understand the forces acting on it also increases one's risk of an ankle sprain (Warburton, 2001). Adding irregularities to the insole of a shoe to simulate barefoot conditions showed better receptivity to the amount of actual force being applied at heal strike (Froncioni, 2006). Walking on a balance beam with soles of different rigidity and thickness also affected balance. Soles that were thin and hard were the highest scoring. The hard sole does not absorb the shocks of walking or running allowing your body to properly adjust for the ground (Robbins, 1992).

Role of manufacturers

Shoe companies, like any business, are out to make a profit. Running shoes are no exception to this. The technology put into shoes is often what dictates the cost of the shoe. Whether or not the increase in cost is beneficial though remains to be seen. Advertising has been

proven to play a role on an individual's perception of the quality of a shoe. If a sole was said to be more absorptive to shock, the individuals were less likely to try to land softer. Where as when the individuals wore the same shoe but were told that it was a poorly designed shoe and it had a higher risk of injury, they stepped down much softer during the trials as a way to protect their body from the shock (Robbins, 1997). In 2007, a study from the United Kingdom tested three shoes from three different major manufacturers in price ranges of *less expensive*, *average*, and *more expensive* for comfort and plantar pressure. Low and medium priced shoes performed as well as their more expensive counterparts (Clinghan, 2007). In light of all this, shoe manufacturers have been more about profit than the health of the consumer. Joseph Froncioni, M.D., had a short conversation with Gordon Valiant, director of the research center for Nike in Beaverton, Oregon (Froncioni, 2006). The conversation had Dr. Froncioni asking about shoes being bad for runners and a cause of injury, and if Nike had research to prove otherwise. It should be noted that Dr. Froncioni is an orthopedic surgeon looking for answers for patients, not a reporter trying to dislodge Nike as a shoe manufacturer. Mr. Valiant refused to answer any of his questions about shoes being a cause of injury (Froncioni, 2006).

Lately, there has been a push to appease the barefoot runners of the world from the major manufacturers. In the past few years, numerous minimalist shoe designs have been released on the market. The first shoe made to mimic barefoot was the *Nike Free* released in 2005. This style still has a raised heal (although reduced) and was the first major push in the right direction. Also in 2005, Italian manufacturer *Vibram* released the *Fivefinger*. The Fivefinger is a shoe that has zero padding and is just a thin rubber sole, with individual toe pockets instead of a single large toe box.

The Vibram Fivefinger has been shown to possibly mimic barefoot conditions in running economy, kinematics and ground pressure distribution (Squadrone, n.d.). Runners who wear shoes such as the Fivefinger's may be more likely to employ a forefoot strike, as opposed to a heal strike common in shod runners. A forefoot strike (even on hard surfaces such as cement) generates less collision forces than shod individuals. This forefoot strike employs a shorter stride length with a higher cadence. Runners who heal strike may increase hip internal rotation torque by as much as 54%. In the hips and shoulders, we create joint stability by externally rotating, not internally. Wearing running shoes compared to barefoot conditions also increased knee varus and knee flexion torque by 38% and 36%, respectively (Kerrigan, 2009). Heal strikers may also face impact forces 1.5-3 times their body weight in the initial 50ms of heal strike (Lieberman, 2009). The heal cushion in shoes is added to decrease these forces but it has been shown that there is a chance it is increasing the force instead. These forces possibly may lead to the increased rate of chronic injury (Hart, 2006).