Ballet History

The discipline of ballet was first recognized in history in 1661 when King Louis XIV established one of five of the first dance academies. Académie Royale de Danse was founded to enhance the performance standard of dancing primarily in the ballet de cour, otherwise known as the non-leading roles in the performance, and the professional level increased respectively from demand. Out of this establishment resulted a formally designed notational system for ballet that is the foundation of ballet today. The beginning of movements, such as the five positions of the feet and the arms, and teaching methods began at Louis XIV’s institution because of the daily meetings among thirteen experts to create and improve ballet. His preference for clean technical movements resulted in intense training and invested studies into the most efficient training methods. The popularity of ballet increased, hence the four institutions that were built following Louis XIV’s (Needham, 2008).

Great aesthetic appeal in ballet was achieved through the long lines created with the entire dancers’ body. The creation of pointe shoes enhanced the long lines of the legs and increased the beauty associated to ballet movement. However, the underlying enhancement of the shoes resulted in high technical demand and rigor of training. In the early development of ballet, heeled shoes that limited technical ability where worn during performances. Marie Camargo debuted the first ballet slipper without heels at the Paris Opera Ballet in the 1730s and
this style was implemented everywhere. Further mobility and articulation led to the highest technical demand and work *en pointe* commenced. *En pointe* refers to dancing on the tip of the toes. The first full performance *en pointe* was performed in Italy in 1832 by Marie Taglioni called *La Sylphide*. Dancing *en pointe* with only a shoe of darned satin during the timeframe became insufficient and more support was needed. By the nineteenth century, pointe technique had developed immensely to involve even more intricate positions and jumps and therefore the shoe was altered to accommodate needs as they progressed (Hecht, 2005).

**Ballet Styles**

Different styles and methods of ballet arose as more institutions appeared around the world. The Cecchetti method could be seen in Russia, The Royal Academy of Dance (RAD) was created in London, and the Bournonville style was influenced in France. In the beginning of the twentieth century in St. Petersburg, Russia, the Vaganova Academy of Russian Ballet was established by Agrippina Vaganova. The Vaganova aesthetics focused on clean and simple mechanics of the human body and technique for proficient dancers (Rizzo, 2012).

Vaganova did not encourage flexibility of the dancer over the proper placement of classic positions (shown below in Figure 2) which, through strong self-discipline and accuracy, created long lines of beauty. Ballerinas added their distinctive interpretative qualities during performance and this was emphasized through her expression and her elaborate *port de bras*, or arm positions. Vaganova offered three styles of *port de bras* shown at the top of Figure 1 that the dancer was allowed to choose according to preference and/or choreography. This style of classical ballet has developed into a neoclassical form because of the progression in various teaching methods and style of movements (Rizzo, 2012).
Figure 1. The Vaganova style follows the classic five positions illustrated in the bottom row. In addition, it offered various arm styles illustrated in the top row (Vaganova, 1946).

Specialization and one-to-one training has decreased in prevalence, but was once of utmost importance in this style. Vaganova’s unique method of rigorous technical training has put Russian ballet at the top level of performance (Rizzo 2012).

Vaganova Injury Demographics

With the safest approach to teaching, Vaganova dancers are at the least risk for injury. Classes are structured into lessons that address specific muscles and movements pending on age and level. The specificity of the lesson complexity to the dancers’ level is important to prevent injury due to lack of preparation. Younger ballerinas focus entirely on demi pointe, or on the balls of the feet, to build her stability along with her foundation of ballet knowledge. Repetition of tedious exercises in younger ballerinas results in the greatest technical precision when the dancer ages. Proper initial training limits the damaging movements that lead to injury later in a dancer’s career. The ballet class progresses in a fashion that allows for the muscles to strengthen and lengthen with the least amount of strain. Class begins warming the muscles with technical
exercise at barre. The most time is spent at barre because correct placement and turn-out is mastered here, which develops strength needed in order to proceed on to more advanced and demanding work. The time spent in centre rather than barre increases with age and ability. Once basic skills are mastered and become habit, combinations consisting of moving positions are presented and memorized in centre. Practice with combinations lead to variations, which consist of full ballet movements, transitions, and jumps. Adagio is followed by allegro in older age groups after barre to practice the speed and the mechanics of jumps. Difficulty and complexity of combinations and variations only increase as age increases because of the high demand in technique and strength (Vaganova, 1946).

Demographics of Dancer Injury Overall

Dance injury should be evaluated meticulously to properly rehabilitate the wound in an effective timeframe to keep the dancer away from training for as little time as possible. The dancer’s “off-season” is the most detrimental to training and to the muscles. The discipline of ballet is physically demanding in technical movements that require an above average joint range of motion and tendon flexibility for plantar- and dorsi- flexion movement. The overuse of targeted muscles and the long hours of training, seen in the professional level, are the primary components to the epidemiology of dancers. Professional ballet dancers’ demographics prove to have a low body mass index (BMI) and are considered underweight; this could contribute to the risk for injury specifically in the bones. The hyper mobility involved with the technique of ballet and the design of the pointe shoe do not complement each other in respect to the negative effect on the ankle and knee. Dancers, mainly professional ballerinas, usually ignore any pain in fear of hurting their career. Specific dance movement and muscle use must be considered in order to accommodate and treat dance injury (Shah, 2008).
Due to a significantly high joint range of motion, studies prove that dancers are more likely to develop patellofemoral pain syndrome. The classic “turn-out” in the simplest form of technique requires use of full rotation and extension of the hip and the knee; this is experienced on top of high ankle plantar-flexion range of motion in the ankle/foot joints when en pointe. One theory suggests a chain reaction of joints in the lower extremities where one joint corrects its position by causing a “false” position in a neighboring joint. This can be applied to dance, for example, when poor external hip rotation is compensated with anterior pelvic tilt and pronation of the feet. Repetitive training with incorrect form can cause serious injury due to the constant stress in neighboring joints. The increased stress in the ankle and hip in dancers only further damages the knee because of the joint chain reaction. Dancers with a high range of motion at the hips and ankles are more prone to patellofemoral pain syndrome of the knee. Ballet dancers who work en pointe have a high ankle/foot joint range of motion which makes them more likely to have this knee pain (Steinberg, Siev-Ner, Peleg, Dar, Masharawi, Zeev, & Hershkovitz, 2012).

The lower limbs of a ballet dancer are left at risk for musculoskeletal injuries because their shoes lack proper shock absorption. The pliability of the pointe shoe allows thorough technique, but it decreases the support of the shoe because it degrades quickly with use. The significant plantar flexion when en pointe requires extreme strength of the intrinsic muscles of the foot and of the ankle to withstand the intense pressure through the box of the shoe to the toes and the tendons. The turn-out causes an increased torque on the medial ankle and knee. Forced turnout can lead to rolling over the ankle and rolling in of the medial arch which can possibly cause bunions and arthritic conditions. Stress fractures are a particularly common injury seen in dancers because of the pressure and plantar flexibility combination (Kadel, 2006).
Anatomy of the Foot

The pointe shoe begins with ample foot strength and flexibility. Ballet movements require a shift in weight distribution on the bones of the feet and they are pushed beyond normal limits. These movements call for specific control of the bones, ligaments, muscles, tendons, and nerves making up the foot to coordinate for a large range of motions. The skeleton of a foot consists of the tarsus (three major tarsal bones), the metatarsals, and fourteen phalanges (Barringer, 1990).

The weight of the body is passed to the foot by the talus or ankle bone from the tibia and fibula of the leg to the calcaneus or the heel bone. There is dense cartilage found between these bones, but there is no muscle surrounding the ankle joint. The part of the heel that is visible is a protective bursa extended from the calcaneus and its below the Achilles tendon. This helps reduce friction and provide support to the ankle. The cuboid is found in front of the calcaneus and it forms a joint with the lateral cuneiform and navicular. The navicular connect the talus to the three cuneiforms. The three cuneiforms form a joint with the metacarpels in front of it. Figure 2 provides a diagram for these depictions below (Barringer, 1990). During average walking and running positions, the shock is mainly absorbed through the heel of the foot through the calcaneus joint to the talus bone in the ankle (Jorgensen & Bojsen-Moller, 1989).
Figure 2. The nature of the foot anatomy (Skeletal Systems, n.d.).

The bones of the foot create two arches - the inner longitudinal arch and the transverse arch which is formed by the convex arrangement across the forefoot. Depending on the original nature of the foot, these attributes could benefit or harm the dancer by the size of the arch. The term *instep* refers to the inner surface in contact to the longitudinal arch. It is made up of the calcaneus, talus, navicular, the three cuneiforms, and three metatarsals. Long ligaments maintained by muscles hold the arch position of the foot. The spring ligament that is attached to the plantar or sole surface of the navicular supports the talus bone. Short and long plantar ligaments run under the entire foot and between the metatarsals along with four short layers of the major intrinsic muscles.

These muscles are responsible for the weight-bearing, propulsion, and shock absorption. Movement solely for the feet without contact to the floor requires the use of the Achilles tendon and muscles located at the back of the calf and back of the knee. The flexibility in the Achilles
tendon is also important for positions that bend at the knees, specifically in preparation for jumps (Barringer, 1990).

Figure 3. The bone alignment while in position *en pointe* (Dance-Related Ankle, n.d.).

When dancing *en pointe*, one must not buckle under their own weight and strength must come from the foot before the shoe. Figure 3 demonstrates the anatomy when working *en pointe*. Complete control of the intrinsic muscles allows for the anatomical progression and articulation through each metatarsal of the foot. This requires strength in the foot as well as the calf muscles and sustainment of muscles of the hip like the gluteals, hamstrings, and quadriceps while articulating other movements (Barringer, 1990).

Pointe Shoe Dynamics

The pointe shoe must be able to adjust to the dancer’s range of motion while providing as much support as possible. Inside the tip of a modern day pointe shoe, there is a hardened box or block made from densely packed layers of fabric, paper, and burlap cemented together with some form of super glue. The box creates a flat platform for the dancer to stand on. It extends over the phalanges and encases the toes. The length of the front of the box is called the vamp. The upper is located at the inner lining of the box. An outer sole of leather makes contact with the floor and
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provides support for a sturdy instep with a piece called the shank, reinforcing the inner portion. The upper is commonly lined with cotton for a more appealing feeling (Barringer, 1990).

The beginning of pointe work did not call for the use of any toe padding. The foot, typically covered in tights made of a light mesh material, made direct contact with the inner lining of the shoe. In the 1860s, ballerinas who performed in St. Petersburg would usually not wear any toe pads at all. Toe pads have developed with time to further cushion the toes in the box. Maria Peptipa, a particularly non-graceful dancer, inserted a block from an old pointe shoe into her shoes due to her weak feet and began the appearances of toe padding. This only benefitted the following ballerinas who worked en pointe because easier articulation was achieved and technical quality of company dancers improved. The pain of no toe pads, however, did not stop prima ballerinas at the time (Vazem & Dimitrievitch, 1986).

Recent toe pads have developed to be able to mold and conform to every dancer’s foot. There are toe pads made entirely out of a silicone rubber compound, which will melt to conform under high temperatures, but will re-solidify and remain in that shape. These provide great cushion qualities (Woodle, 1992). Other more traditional toe pads still exist where they are cotton or lamb’s wool based. Some combine the two materials of rubber and cotton for cushioning (Freese, 2005).

Recently Improved Pointe Shoe Models

The Bruckner shoe was meant to redistribute the dancer’s weight and ground force reactions from dancing en pointe to the entire foot rather than just the toes receiving the full impact. This design helps with the unnecessary pressure caused from the slope of the toes being perpendicular with the floor while en pointe that can lead to discomfort, buckling, or sickling, which is the leaning of the medial arch to one side on flat foot. The shell of the shoe is comprised
of the box and the shank which are molded together to become one unit for strength and support. The box is formed from high temperature plastic of polyethylene or polypropylene to maximize the shoe’s durability. The shank is formed from carbon-graphite fiber (a flexible plastic) to translate the forces through the upper foot or it is formed from durable leather. The shell is designed to accommodate an average dancer with the asymmetric design of the second toe being longer than the first by building up the shell on the outer side to increase contact of the phalanges and metatarsals with the toe box; this will allow for ground forces to travel up the foot and a more even distribution of pressure. The airy foam lining along the shell fills in excess space when the dancer’s foot is in the shoe (Bruckner, 2005).

![Figure 4](image)

Figure 4. These are some modern day brands and the shoe they produce (Different Types of Pointe, n.d.).

The Gaynor Minden pointe shoe (seen in Figure 4) contains a lining of dynamic foam on both sides of the box and the platform that is 1/16 to 3/16 of an inch thick. The open-celled polyurethane foam compresses less than 2% at room temperatures and compresses less than 10% at roughly double the room temperature. The foam provides fast resiliency and support because it compresses during the flat standing position and expands when standing en pointe. Further
research into materials could improve these rates for less compression when temperature increases. The inner face of the lining in the shoe is pleasant for the foot rather than typical coarse muslin materials that chafes and cause blisters (Minden 1998).

The goal for the most innovative pointe shoe requires modifications to the box, the platform, the shank, and the quarter of the shoe. In Colucci and Klein’s model, a lining of memory foam along the box provided interior support and decreased pressure. The shank of the shoe was made into a gradient of supportive material to relieve more pressure in high impact areas, like the metatarsals and the heel. The elastic quarter was also modified to allow the foot to rise up slightly higher en pointe with greater ease (Colucci & Klein, 2008).

Materials

To optimize the design for a shock-absorbent pointe shoe, viscoelastic properties were examined for materials. The elasticity of a material determines its resistance to force and deformation. Elastic materials can return to their original shape after a force is applied and non-elastic materials have a stronger tendency to remain deformed. Viscosity is the resistance and/or ability to flow. Highly viscous materials are mainly solids or hard materials. Viscoelasticity is a property that considers the characteristics of a deformation. Each behavior described depends on different things. Elastic behavior will conserve energy and momentum upon impact, and viscoelastic materials tend to dissipate the force of impact over a dependent time interval. Viscoelasticity can be used to isolate vibration, decrease noise, and absorb shock (Difference Between Elastic and Viscoelastic, n.d.).

Modern attempts to improve materials included a carbon-graphite fiber shank rather than a durable leather shank. The carbon fiber holds the properties of high strength to weight ratio, high fatigue resistance, and high tensile strength. Combined box and shank designs have tested to
provide better support. Previous boxes have been out of polyethylene or polypropylene plastics for high temperature durability (Bruckner, 2005). Other shoe designs have contained an inner lining of dynamic foam made of polyurethane such as ethylene vinyl acetate (Minden, 1998). Gradient shanks of material have also been designed to relieve pressure in high stress areas (Colucci & Klein, 2008).
References


The Difference Between Elastic Materials and Viscoelastic Materials -


