"Congenital Club Foot in the Human Fetus" (1980), by Ernesto Ippolito and Ignacio Ponseti [1]

By: Gandee, Katherine Keywords: congenital club foot [2]

In 1980, Ernesto Ippolito and Ignacio Ponseti published their results on a histological study they performed on congenital club foot in human fetuses. The researchers examined the feet of four aborted fetuses and compared the skeletal tissues from healthy feet to those affected by congenital club foot. Infants born with club foot are born with one or both feet rigidly twisted inwards and upwards, making typical movement painful and challenging. Ippolito and Ponseti studied how the connective tissues, such as the ligaments and tendons stretching across the foot and ankle, function to pull the affected foot out of place as the fetus [3] develops. Their findings helped researchers determine club foot?s potential causes and possible treatments by focusing on connective tissues.

At the time of their research, Ippolito was an orthopedic physician at Sapienza University of Rome [4] in Rome, Italy, and Ponseti worked at the University of Iowa [5] Hospitals and Clinics in Iowa City, Iowa. The authors examined four aborted fetuses, detailed the deformities they observed in the club feet, and compared the tissues from the club feet of the aborted fetuses to similar tissues from normal feet.

In affected feet, bones in the heel and below the ankle of infants with club foot are small and displaced inwardly. The deformed shapes and positions of the bones range in severity. Previous researchers hadn?t established how club foot was caused. With their study, Ippolito and Ponseti addressed how the different tissues of the skeletal system besides the bone tissues may affect congenital club foot.

The four fetuses the researchers examined were all male and did not have any congenital birth defects [6] other than club foot. The first fetus [3] was sixteen weeks old and had one very severe club foot. The other foot was normal and served as a control. The fetus [3] was aborted due to *abruptio placentae*, a rare condition in which the placenta [7] detaches from the fetus [3] prior to birth. The second fetus [3] was aborted at nineteen weeks following an automobile accident, and had moderate deformity in both feet. The third fetus [3] was electively aborted at seventeen weeks and had severe deformity in the left foot and mild deformity in the right foot. There was one control fetus [3] with no congenital birth defects [6] aborted at twenty weeks, also due to *abruptio placentae*.

To prepare the feet for observation, Ippolito and Ponseti first isolated the lower legs from the rest of the fetuses? bodies. They treated the feet with paraformaldehyde, which stabilizes the structural details of cells and tissues, then with ethylenediaminetetraacetic acid or EDTA, a chemical that removes minerals from tissues to make them easier to examine. The researchers then washed the feet with water and used alcohols to dehydrate the tissues. They finally treated each foot with chloroform, which homogenizes the foot?s tissues, and they then embedded the tissues in paraffin to preserve them. They cut each club foot in a different plane

to observe the deformity from different angles, and then cut each healthy foot the same way for direct comparison. The researchers stained each foot with chemicals to dye the tissues, a process that helped them differentiate the different types of tissues in the feet.

For the first fetus [3] they analyzed, Ippolito and Ponseti noted that in both feet many of the skeletal elements were made of tough, yet elastic cartilage, which is common in fetuses prior to the structures turning into rigid bone later in development. They found many differences between the affected right foot and the healthy left foot. The researchers also highlighted that the bones and muscles of the lower leg in the affected foot were small, underdeveloped, and disfigured. Additionally, they less than normal muscle and excessively thick and developed tendons throughout the affected leg and foot compared to the healthy foot. Ippolito and Ponseti also examined the blood vessels around the bones and noted disfigurement in their structures. They studied the tendons of the feet and noted that the tendons unfavorably stretched around the disfigured bones and, in some areas, pushed the bones into one another.

In the second fetus [3], Ippolito and Ponseti observed the affected feet in comparison to the healthy feet of the control fetus [3]. In the right club foot, the researchers found that the bones of the ankle and heel were not joined properly because the ankle was abnormally flexed such that the toes pointed downward. Where the bones were supposed to adjoin, Ippolito and Ponseti instead found connective tissues filling the space between the bones. The authors describe other areas, such as where the lower leg attached to the heel, where bones adjoined too closely with little room for necessary connective tissues in between. Where the bones were not supposed to touch, the researchers noted that nearby tendons extended to surround the bones. Additionally, the joint between the ankle and heel was especially deformed, whereas the joint connecting the ankle to the bottom of the foot appeared normal. Ippolito and Ponseti found missing a joint that normally functioned to connect the bones to the front of the foot. As with the first fetus [3], the researchers noted issues with displacement and excessive thickness of the tendons in the affected foot compared to the control.

Similar to the previous fetuses, in the third fetus [3], the researchers observed that bones caused the affected feet to curve abnormally inwards and downwards. They noted that the bones connected with one another rather well as long as the foot rested in the abnormal position. Additionally, in that fetus [3] there existed dense, fibrous tissues in unexpected areas of the affected feet.

Ippolito and Ponseti?s focus on connective tissues enabled them to describe and propose explanations for club foot. Additionally, the researchers concluded that because the fetuses they studied were at a very early stage of development, their observations informed researchers about the origins of club foot.

Ippolito and Ponseti concluded that congenital club foot is associated with looser joint connections between the ankle and front of the foot and too tight of connections between the ankle and back of the foot. The researchers hypothesized that the loose connection with the front of the foot could account for the foot?s inward tilt, and the tight jointing with the back of the foot could explain the rigid downward tilt of the foot. The authors also described the thick tendons in the club feet, especially on the insides of the feet. The short, thick tendons on the inside of the feet could gradually pull the foot inwards as the fetus [3] developed. With too few muscles in the lower leg, Ippolito and Ponseti argued that the tendons overwhelmed the muscles early in development.

Ippolito and Ponseti suggested that fetuses might develop club foot as a result of several primary factors. The factors include the foot?s tendons growing abnormally short and thick, which can pull the foot inwards. Also, the leg muscles do not fully develop, and the ligaments connected to the muscles do not stretch and pull the foot upwards properly.

They used their results to argue against researchers who hypothesized that that congenital club foot is a neurological problem, or that it results from external pressure on the womb [8] during development, because they ruled out such possibilities when selecting the fetuses they examined in their study. Furthermore, Ponseti and Ippolito ensured that the fetuses they examined had no other abnormalities besides congenital club foot, so that everything they observed could be attributed to the club foot and not to other possible or correlated disorders. The researchers suggested that congenital club foot is a genetic condition due in part to retraction of the connective tissues in the leg and foot.

Ippolito and Ponseti published their results in 1980?s "Congenital club foot in the human fetus [3]. A histological study." In the paper, they suggested that abnormal muscles, tendons, and ligaments in the club foot cause and perpetuate the deformity in developing fetuses. They argued that their findings supported the validity of the Ponseti method, a treatment for congenital club foot in which doctors stretched and cast the foot into a more normal position, as connective tissues in infants can be stretched into a new position fairly easily.

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