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THE INFLUENCES OF ECCENTRIC FORCES ON THE TIBIA BONE WHILE STANDING IN THE FLAT FOOT CASE

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Abstract *The most important fact is that the intensified stress on the tibia bone which is caused by the eccentric force which induces the foot to flatten, can lead to fractures. However, the value of this stresses is conditional on the concentrated load with the distance from the center of the tibia bone where the distance is contingent on the slop of the toe bone center.*

In the study, we systematize the flat foot level which is influenced by the effect of the eccentric force on the tibia bone, into, the Natural pronation, Supination, Over pronation and Over supination.

Keyword - *eccentric force, flat foot, tibia, stress, core section*

Introduction

Especially, the flat foot (pes planus) is generally defined as a condition where the longitudinal arch of the foot disintegrates, there is not a clinically or radiologically conventional universal definition. Furthermore, the flat foot which we frequently encounter in the routine of the outpatient practice, will be more accurately witnessed as a consequence of laxity of the ligaments in the foot. Specially, the posterior tibialis which is actually there to maintain the talonavicular joint but can be degenerated due to variety of reasons like tendon tearing or tendinosis. Nevertheless, each flat foot case is not indistinguishable to each other. Moreover, Staheli divides the flat foot into 2 sections as the physiological, and pathological flat foot [1, 2, 3]. See fig.1

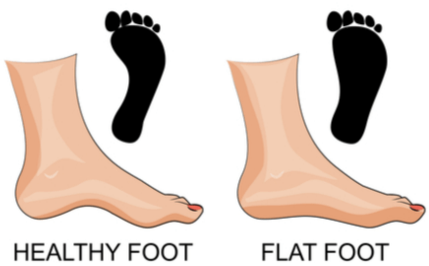


Fig .1. the comparison between healthy and flat foot

In fact, tibia (fig.2) is one of the two bones in the leg which is enormous and strong and it is positioned beneath the knee. It has a prism shaft with the anterior, posterior and lateral border and surfaces. The upper part of the tibia bone comprises of two condyles- tibial plateau, which articulates with the condyles of the femur which is the thighbone. Moreover, the tibial tuberosity connects with the ligament of the patella.

Additionally, tibia confederates the knee with the ankle bones, which means that the lower section of the tibia bone articulates with the ankle joint and with the talus which is the ankle bone. At the lateral side, there is a fibular notch, where the fibula and tibia form the tibiofibular joint. Indeed, tibia is constructed next to the fibula on the medial side of the leg, closer to center-line.

It is important to highlight that the tibia is affiliated to the fibula by the interosseous membrane and forms a type of joint called “syndesmosis” which has a limited motion.

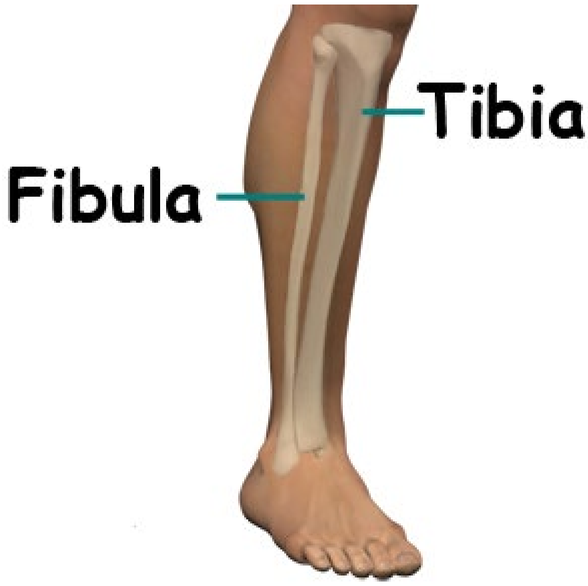


Fig. 2.- Tibia bone

Main part of study

The concentric and eccentric effect on the axial loading on the foot:

When a beam, or long bone in the human body, is weighted with an external force parallel to its long (i.e., central) axis, the external force is known as an axial loading force. Axial loading force is divided into two categories, concentric and eccentric axial loading forces.[4]. Afterward, when an external axial compression loading force impersonates directly, in line with the central axis of a structure, the compression force will induce only compression of the beam, or long bone, without having any bending moments (see illustration on left). Otherwise, if the external axial compression loading force is offset from being in line with its central axis, it will incite an eccentric axial loading force (see illustration on right). Together with the eccentric axial loading, the externally-acting compression force will provoke a bending moment on the column, or long bone, which is disputed by the internal molecular structure of the beam, or long bone. Therefore, the internal aversion to deformation of a structure is known as stress. However, if the beam or long bone is tending to become more convex on one surface, this surface of the beam or long bone will have an aggrandized tension stress. Also, if the beam or long bone is gravitating to become more concave on one surface, this surface of the beam or long bone will have a magnified compression stress.

In the example (fig.3) below, the eccentric axial compression loading force compels the beam to tend more, to bend the beam, so that it alters more convex on the right side of the beam, and becomes more concave on the left side of the beam.

Subsequently, this creates an increment on the tension stress on the right-hand side of the beam and it also inflates in the compression stress on the left-hand side of the beam.[4]

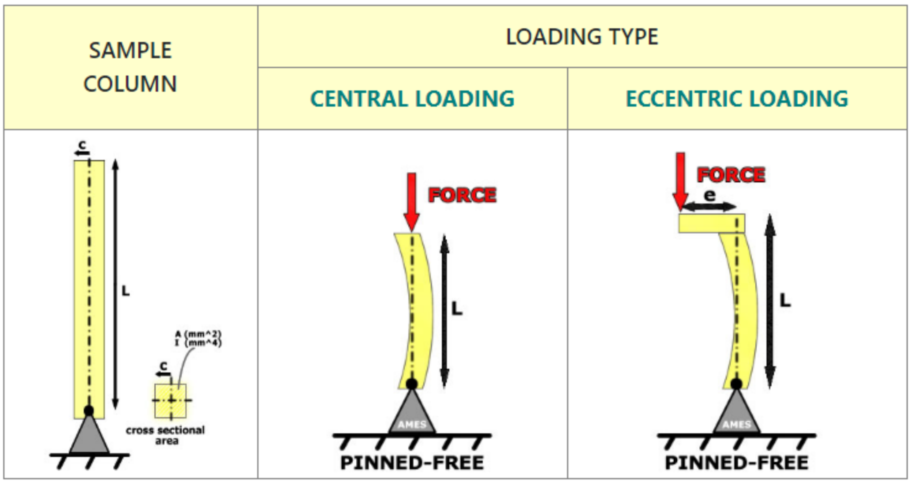


Fig. 3. Example of the affection of the eccentric axial compression loading force on column

For instance, the eccentric force which acts on the tibia bone and leads to **flattening** the foot which can lead to the loss of the medial longitudinal arch, is regarded as the most important highlighted fact. For this reason, the elevated stress on the tibia bone can cause a higher risk to get fractured and effects the triceps surae.

It is important to highlight here, if there is a dysfunction of the foot, it will fail to keep its normal structural support with the recasting of the shape.

Coupled with it, the value of these burdens relies on the concentrated load including the distance from the center of the tibia bone whereas the distance subordinates on the slop from the toe bone center.

In the study, we tabulated the flat foot level into four sections as natural pronation, supination, over pronation and over supination. Aside from that it is important to stress out that this classification counts on the effect of the eccentric force which conducts on the tibia. fig .4.

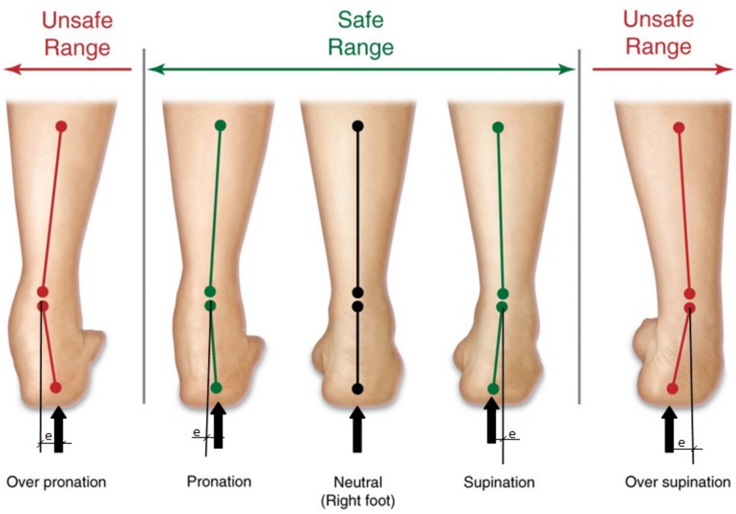


Fig.4- Four-point model of the influence of eccentric force on the foot

Materials and method

When a structural member or bone (tibia) is subjected to a compressive axial force(fig.5), it's referred as a compression member or a column. Besides, compression members are inaugurated as the tibia bone. In short, they transmit weight of an object above it to a lower one and during this transmission, they are compressed.

Particularly, if a long slender bar is loaded, it will contort before it yields. In this case, if the force is sited in the centroid of the cross section or in the core section of the tibia then the engendered stress will be only a compression stress without influencing the tibia bone, due to the nature of contorting.

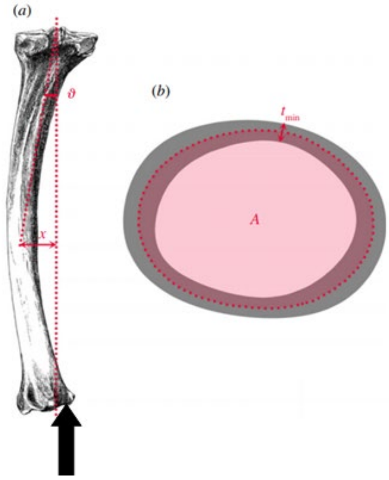


Fig.5- The influence of the eccentric axial compression loading force on tibia [5]

Furthermore, the core section(fig.6) is a small area around the center of gravity of the cross section. In addition, the core of the cross section is depicted by the fact that any compressive longitudinal force exerted inside, it incites compression stress at all points of the cross section. Compared to the force which is positioned outside of the core section of the tibia bone, where the tibia is under the complex - type of deformation, it will have a greater compression and also bend at the same time.

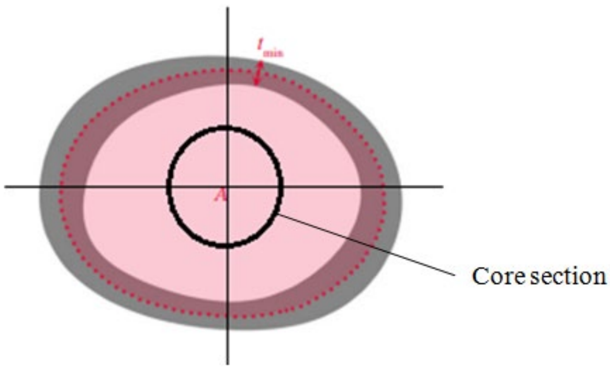


Fig.6- The Core section of tibia

The geometrical properties of cross-sectional area of tibia are shown in fig.7.

To determine the companied stress on tibia, in this study, we used the equation which is shown below [6].

ez and ey are the eccentricities of the application of force F.

In an arbitrary cross section at a given load, such internal force factors act like:

Nx, My, Mz.

Nx = - F, My = ± F • eu, Mz = ± F • ez

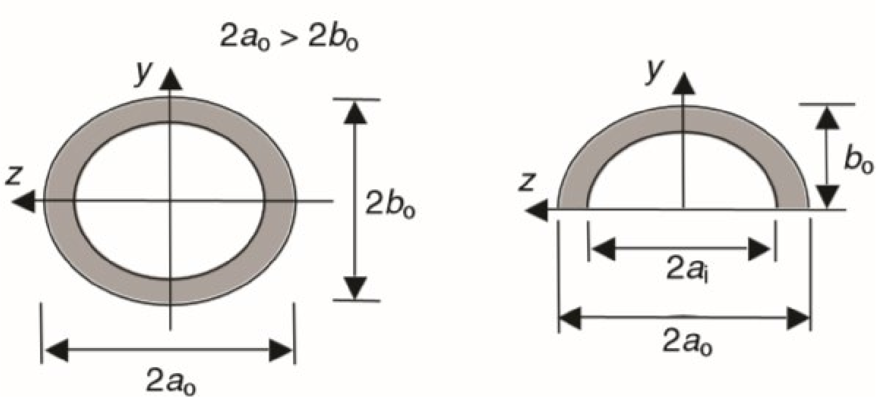


Fig.7. the geometric properties of cross section of tibia [6]

Therefore, the normal stress at an arbitrary point in the cross section will composed of axial compression stresses of force Nx, and stresses from pure bending are recited as the moments of My and Mz in both principal planes.

$$\sigma_A = \pm\frac{N_X}{A} \pm \frac{M_Z}{I_Z} \pm \frac{M_Y}{I_Y} \tag{1}$$

$$I = \frac{\pi}{4}\left(a_0 b_0^3 - a_i b_i^3\right) \tag{2}$$

$$A = \pi\left(a_0 b_0 - a_i b_i\right) \tag{3}$$

Where the $б_A$ is the combined stress which influences on the foot due to eccentric force

A- Aera of cross section of tibia. I- moment of inertia of tibia.

In fig 8. we can see all cases of the influence of eccentric force on tibia and the results which are impacted on the leg of the human body.

Results

Where the weight of the patients are from 80 -85-90-95-100 kg, the normal person with 80 kg, the result of the stress on tibia where we have a normal foot is 1,6 MPa , and for patient with 80 kg, minimum stress 1,25 MPa and maximum stress 1,94Mpa, for patients with 85 kg , minimum stress is 1,26 MPa and maximum stress 2,14Mpa, for patient with 90 kg , minimum stress 1,13 MPa and maximum stress 2,46Mpa. All these results are given in table .1

Table 1

Results of combined stress for all case in fig .8.

Case of eccentric force	maximum stress	minimum stress	Weight
natural person	1.6	-	80
pronation	2.4	1.55	85
supination	2.53	1.58	90
Over pronation	3.21	1.44	95
Over supination	3.34	1.53	100

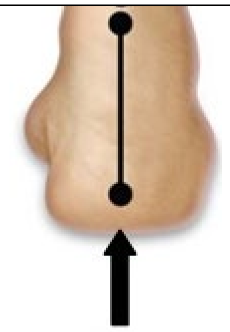
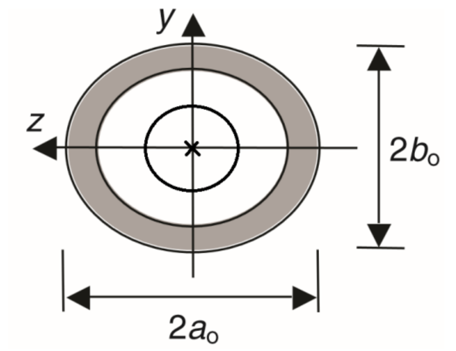
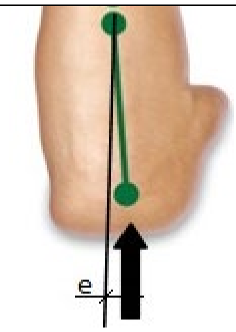
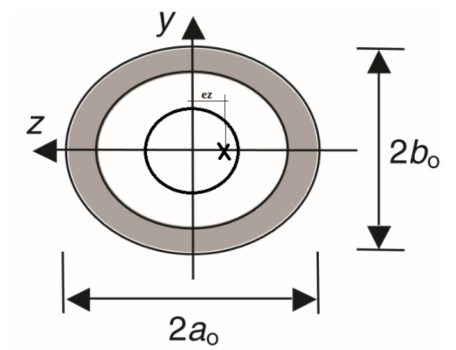
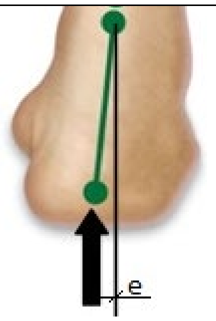
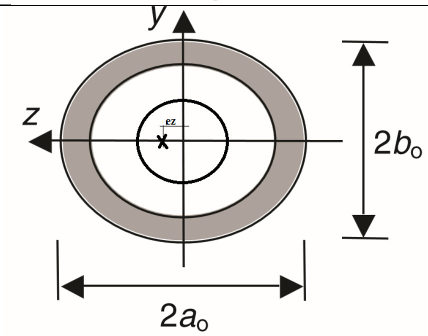
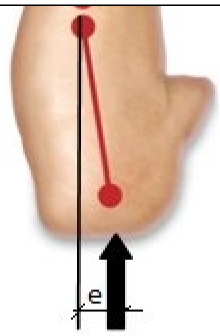
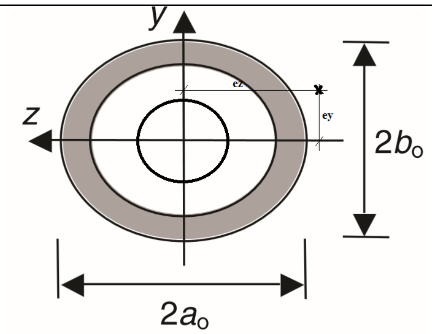
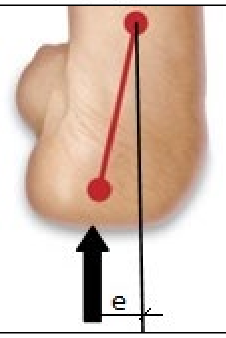
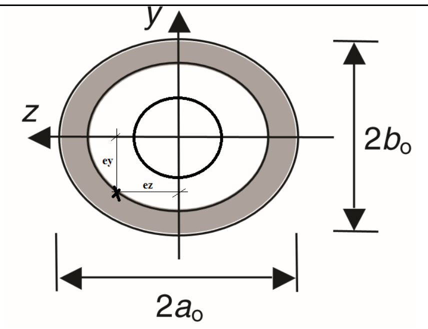
	natural			
	pronation			
	Supination			
	Over pronation			
	Over supination			

Fig .8. The cases of the influence of the eccentric forces on the foot

Conclusion

In conclusion the flat foot is a well-recognized condition among health professionals who treat the foot and ankle problems. However, it is represented by rearfoot eversion and a diminution in the height of the medial longitudinal arch. To summarize, the flat foot can be extant in a rigid or flexible form, which is congenital and affecting less than 1% of the population. In contrast, a flexible flat foot is an acquired deformity that affects up to 23% of the adult population. In this study, we highlighted, the stress which is initiated on the tibia due to the eccentric forces.

As a result, this study verified that the maximum stress value is measured and influenced by the mathematical model which is ratified for the calculation of aforesaid variable. Using the mathematical model of two points, which are both sited in the foot, the results in minimum and maximum values of stress which are aimed at determining the stress of occurrence of the highest subtler production over the course of the stance phase, the use of both mathematical models are satisfied. However, if the objective is to dictate the magnitude of maximum subtalar pronation, a variable that significantly influences the musculoarticular injuries in the ankle and knee region, the use of the four-point model is recommended due to the influence of the tibial inclination. Therefore, if bending moments are being composed in beams, or long bones, there is a way to abate the bending moments and the resulted tension and compression stresses which are acting on the walls of the beam, or long bone, is to attempt to make the external loading forces become more concentric and less eccentric relative to its central axis. Understanding the engineering concept of concentric and eccentric axial loading will concede the clinicians to perceive better, how the foot orthoses can help to aid in the healing process and how to intercept the medial tibial stress syndrome and medial tibial stress fractures.

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