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Foramen tympanicum prevalence in the population of southeastern of Brazil: a morphological study in computed tomography scans

T.M.C. Ribeiro **et al., Foramen tympanicum: morphological study**

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ABSTRACT

Background: The foramen tympanicum is located on the anteroinferior region of the external acoustic meatus and posteromedial to the temporomandibular joint in children between the first and the fifth year of life. It is considered an anatomical variation when it persists in adults. The aim of this study was to verify the prevalence as well as to characterize the foramen tympanicum in CT scans of the population from southeastern Brazil.

Materials and methods: A total of 78 CT scans of dry human skulls were used, which were selected randomly regarding the ages, ranged from 15 to 100 years, and composed a total of 20 female and 58 males. The foramen tympanicum was identified in the images of the axial plane and confirmed in the images of the coronal and sagittal planes. The largest diameter (in mm) was obtained. The descriptive statistics (in %), Fisher's

test and chi-square test ($\chi 2$) were performed to compare the prevalence of foramen tympanicum between sexes and sides. The probability value ≤ 0.05 was defined as a level of significance. Descriptive statistics were performed to verify the mean diameter of the foramen on the right and left sides of the skulls.

Results: The prevalence of foramen tympanicum was higher in females (P = 0.0070), bilaterally, as the absolute values of females were lower in relation to males. Fisher's exact test showed that the prevalence of foramen tympanicum was significantly higher in females (45%) than in males (15.52%). On the right side, the mean axial diameter was 2.23 mm (range 0.93–3.75 mm). On the left side, the mean axial diameter was 2.22 mm (range 0.9–3.61 mm).

Conclusions: The knowledge of anatomical variations is extremally valuable for an accurate diagnosis, treatment plan and prognosis and a thorough preoperative assessment.

Key words: temporomandibular joint, computed tomography, anatomy, foramen tympanicum, Huschke's foramen, tridimensional morphometry

INTRODUCTION

The foramen tympanicum (FT), also known as Huschke's foramen, is the bone communication between the external acoustic meatus and the temporomandibular joint (TMJ) found during the development of the tympanic part of the temporal [1; 2]. The FT is located on the anteroinferior region of the external acoustic meatus and posteromedial to the TMJ in children between the first and the fifth year of life. This is considered an anatomical variation when it persists in adults [3]. Topsakal et al. [2] defined the FT as being a variable deficiency in the floor of the bony part.

The formation of FT occurs after birth, when the tympanic ring becomes the tympanic bone and has the shape of a broken ring at its upper extremity. During its development, which occurs in a circular and superior direction through its ossification centers, the tympanic bone will merge with the petrous portion of the temporal bone forming the external wall of the tympanic cavity [4]. The next stage of development is the appearance of two tubers or prominences that grow against each other, until they

come together in the first year of life. The tympanic bone presents, because of the fusion of these two tubercles, an opening called the TF [5].

In adults, the presence of FT is associated with the spread of infections originating in the external acoustic meatus, which affect surrounding regions such as the TMJ and the parotid gland; tumors originating in the mandibular fossa of the temporal bone, which uncommonly reach the external acoustic meatus; cases of spontaneous salivary fistula in the external acoustic meatus; and complications in TMJ arthroscopy [3,6,7]. Finally, the study of FT morphology and prevalence in dry skulls and CT scans indicated a difference between the sexes [5].

The aim of this study was to verify the prevalence as well as to characterize the foramen tympanicum in CT scans of the population from southeastern Brazil.

MATERIALS AND METHODS

The research was analyzed and approved by the Committee of Research Ethics of the University of Campinas (Protocol number CEP-FOP-UNICAMP-CAAE 38866220.3.0000.5418).

Sample

A total of 78 CT images from human skull selected at random ranging in age from 15 to 100 years, 20 female and 58 males, and acquired by the Aisteion Multislice 4 CT System (Toshiba Medical Systems Corporation - Japan), for the protocol of the skull: 100 MA, 120KV, with cuts of 1mm.

The CT scans were obtained from skulls belonging to the Bone Collection housed at Piracicaba Dental School from the University of Campinas (UNICAMP). The skeletons belong to a contemporary Southeast Brazilian population, are of the actual population and surroundings, are in a good state of preservation, and were identified by death certificates.

The research considered CTs of the skulls that presented the anatomical structures of the temporal bone preserved and intact, without macroscopic deformities. CT scans of individuals with any any signs of bone remodeling in the temporal region were excluded, as well as individuals with implants, plates and screws or any other metallic artifact in the referred region.

FT evaluation using 3D reconstruction

The Mimics software v. 21.0 (Materialise, NV, Belgium) was used to produce the segmentation of the images on each CT scan. The FT was identified in the images of the axial plane and confirmed in the images of the coronal and sagittal planes. Then, in this same software, 3D reconstruction was performed to visualize and to confirm the presence of the FT (Figure 1).

After locating the structure (Figure 1), the Mimics software v. 21.0 (Materialise, NV, Belgium) was used to measure the largest diameter (in mm). Each FT was evaluated by a single evaluator previously calibrated. The evaluator was trained to determine the presence of the FT and which was evaluated according to its anatomical characteristics observed on CT scans. After training, the measurement was performed using the distance measurement tool, marking the outermost voxel of both ends of the FT, in the axial plane of the computed tomography (Figure 2).

Statistical analysis

The data were tabulated in the Office Excel (© Microsoft 2021). The descriptive statistics (in %), Fisher's test and chi-square test ($\chi 2$) were performed to compare the prevalence of FT between sexes and sides. The probability value ≤ 0.05 was defined as a level of significance. Descriptive statistics were performed to verify the mean diameter of the FT on the right and left sides of the skulls. All data were analyzed using the GraphPAD Prism v.8 software (San Diego, CA, USA).

RESULTS

In this study, 58 (74.36%) male and 20 (25.64%) female skulls were observed. FT was determined in 18 (23.1%) of 78 skulls (they had FT on at least one side of the head). The sample's mean age was 55 years (range, 19 to 100 years) for females and 54.41 years (range, 15 to 87 years) for males.

The chi-square test showed a relationship between sex and FT ($p < 0.05$). The chi-square test showed that the prevalence of FT was higher in females ($P = 0.0070$), bilaterally, as the absolute values of females were lower in relation to males. Fisher's exact test showed that the prevalence of FT was significantly higher in females (45%) than in males (15.52%) (Figure 3).

The FT was bilateral in 14 (17.95%) skulls, 7 in males and 7 in females. For the unilateral, we did not find the right side for both sexes. We found the FT on the left side,

unilaterally, in 2 female skulls and 2 male skulls. On the right side, the mean axial diameter was 2.23 mm (range 0.93–3.75 mm). On the left side, the mean axial diameter was 2.22 mm (range 0.9–3.61 mm).

No correlation between location or sex and diameter of TF was found by unilateral analysis of variance ($p > 0.05$).

DISCUSSION

Studies in CTs scans indicated this is an extremely important exam for visualizing anatomical structures, such as FT [5,8]. According to Çetin et al. [9] radiological studies, mainly using CT scans, bring contributions to demographic data and dimensions of an anatomical bony feature from a determined population. In a recent study, Topsakal et al. [2] highlighted the importance of visualization and of the anatomical knowledge of certain anatomical structures, as the FT, to perform the endoscopic ear surgery. They related that the minimal invasive technological developments such as robot assisted or image guided ear surgery claim to be less invasive or more anatomical structures preserving.

Hashimoto et al. [10] believe that there is a difference in prevalence of FT between males and females. From these results, we were interested in investigating if the visualization of FT in CT scans of dry skulls would be feasible and its prevalence in a sample of Brazilian nationality.

In agreement with Akbulut et al. [1], the present study showed the prevalence of FT of 23.1%. In other studies, the prevalence was approximately 12% [5, 8, 10]. In a recent study, Deniz et al. [8] examined 200 cone-beam computed tomography images (400 ears) in a Turkish sub population. The authors noted size and location (unilateral and bilateral) of the present FT and found that the prevalence of the FT was significantly higher in females (8%) than in males (3.5%) as well as in the present study in a Brazilian sub-population that the persistent FT was significantly higher in females (45%) than in males (15.52%). The literature explained that the female predominance of FT might have been based on growth and development differences of temporal bone between sexes [11].

In relation to the results about side prevalence, Deniz et al. [9] determined FT on the right side in 4% of patients and FT on the left side in 7.5% of patients ($p < 0.05$). This was bilateral in 2.5% of patients. In the present study, FT was bilateral in 14 (17.95%) skulls, 7 in males and 7 in females. For the unilateral, the results showed the FT on the left side, unilaterally, in 2 female skulls and 2 male skulls. Deniz et al. [9] explained that the relationship between the side and FT can be responsible for mastication habits and genetic factors of study populations. And it is possible to suggest the existence of the corporeal principle of laterality, with one side being more prevalent than the other.

The clinical implications related to the persistence of FT are widely discussed in the literature and the most current are otitis, infectious arthritis, herniation of the disc and fistulas in the external acoustic meatus. TMJ arthroscopy is an exam for diagnosing pathologies in the region, which is performed by a rigid optical fiber with a diameter varying between 1.7 and 2.7 mm [6, 10, 11]. These studies also showed that severe ear complications can develop during TMJ arthroscopy, due to the lack of preoperative detection of the presence of FT. This could happen because of the similarity between the mean diameter commonly found in FT and the diameter of the optical fiber used during the examination.

Our findings showed that the mean axial diameter for the right side is 2.23 (in mm) and for the left side is 2.22 (in mm), corroborating with the literature. In addition, Ertugrul and Keskin [12] concluded that the dimensions of the FT were generally larger in females than in males.

Although computed tomography is an expensive method, high-resolution imaging tests have proved to be a better technique for identifying the presence of FT when compared to conventional radiographs [6]. For instance, in a population with a prevalence of FT of 14.9%, the prevalence was higher in studies on cadavers (21.2%) than on radiographs (8.8%) [9]. Hence, the use of software with the capacity for three-dimensional reconstruction, improved the visualization of the structure of interest in our study (i.e., the FT). On the other hand, it is important to consider that FT with a diameter of less than 1mm may not be visualized in a computed tomography with a slice of 1mm thickness [13].

CONCLUSIONS

In conclusion the prevalence of FT in CT scans of dry skulls in a Brazilian population sample was 23.1%. Additionally, persistent FT was significantly higher in female (45.0%) than in male (15.5%) sex. Further, this study showed that the mean axial diameter for both sides were approximately 2.2 mm. The knowledge of anatomical variations is extremally valuable for an accurate diagnosis, treatment plan and prognosis and a thorough preoperative assessment.

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REFERENCES

1. Akbulut N, Kursun S, Aksoy S, Kurt H, Orhan K. Evaluation of foramen tympanicum using cone-beam computed tomography in orthodontic malocclusions. J Craniofac Surg. 2014;25(2):e105-9. doi: 10.1097/SCS.0000000000000440.

2. Topsakal V, Kachlik D, Bahşi I, Carlson M, Isaacson B, Broman J, Tubbs RS, Baud R, ten Donkelaar HJ. Relevant temporal bone anatomy for robotic cochlear implantation: An updated terminology combined with anatomical and clinical terms.Translational Research in Anatomy. 2021; 25: 100138. doi: 10.1016/j.tria.2021.100138.

3. Lacout A, Marsot-Dupuch K, Smoker WR, Lasjaunias P. Foramen tympanicum, or foramen of Huschke: pathologic cases and anatomic CT study. AJNR Am J Neuroradiol. 2005 Jun-Jul;26(6):1317-23.

4. Pękala JR, Pękala PA, Satapathy B, Henry BM, Skinningsrud B, Paziewski M, Tubbs RS, Tomaszewski KA. Incidence of Foramen Tympanicum (of Huschke): Comparing Cadaveric and Radiologic Studies. J Craniofac Surg. 2018 Nov;29(8):2348-2352. doi: 10.1097/SCS.0000000000004784.

5. Prowse SJ, Kelly G, Agada F. Temporomandibular joint herniation and the foramen of Huschke: an unusual external auditory canal mass. J Laryngol Otol. 2011 Dec;125(12):1279-81. doi: 10.1017/S0022215111002295.

6. Melgaço CA, Penna LM, Seraidarian PI. O forame de Huschke e suas implicações clínicas. Rev Brasil Otorrinol. 2003; 69(3): 406-413.

7. Moreno RC, Chilvarquer I, Hayek JE, Seraidarian PI. Anatomic and radiograph study of the persistence of Foramen of Huschke. Braz J Otorhinolaryngol. 2005 Sep-Oct;71(5):676-9. doi: 10.1016/s1808-8694(15)31273-8.

8. Deniz Y, Geduk G, Zengin AZ. Examination of foramen tympanicum: an anatomical study using cone-beam computed tomography. Folia Morphol (Warsz). 2018;77(2):335-339. doi: 10.5603/FM.a2017.0078.

9. Çetin H, Akkaşoğlu S, Çalışkan S. New approach to morphometric analysis of Huschke's foramen. Folia Morphol (Warsz). 2021 Jun 1. doi: 10.5603/FM.a2021.0056.

10. Hashimoto T, Ojiri H, Kawai Y. The foramen of Huschke: age and gender specific features after childhood. Int J Oral Maxillofac Surg. 2011 Jul;40(7):743-6. doi: 10.1016/j.ijom.2011.03.017.

11. Gonzalez PN, Bernal V, Perez SI. Analysis of sexual dimorphism of craniofacial traits using geometric morphometric techniques. Int J Osteoarchaeol. 2011; 21(1): 82–91. doi: 10.1002/oa.1109

12. Ertugrul S, Keskin NK. Relationship of age to foramen of Huschke and investigation of the development of spontaneous temporomandibular joint herniation. Int J Oral Maxillofac Surg. 2019 Apr;48(4):534-539. doi: 10.1016/j.ijom.2018.08.011.

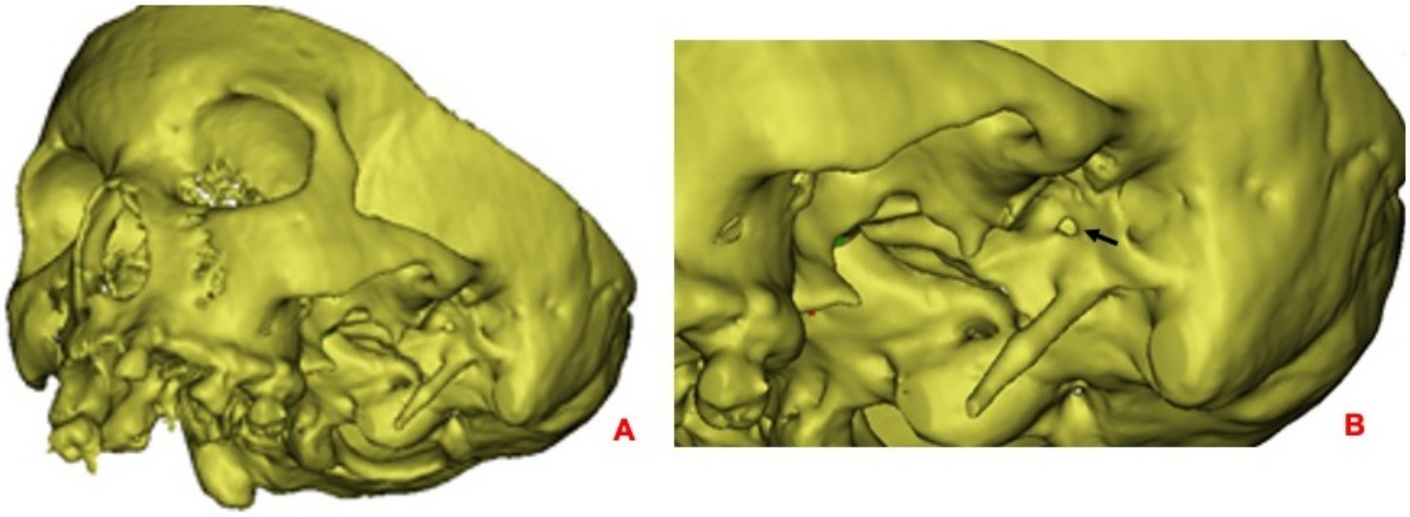
13. Park YH, Kim HJ, Park MH. Temporomandibular joint herniation into the external auditory canal. Laryngoscope. 2010 Nov;120(11):2284-8. doi: 10.1002/lary.21115.

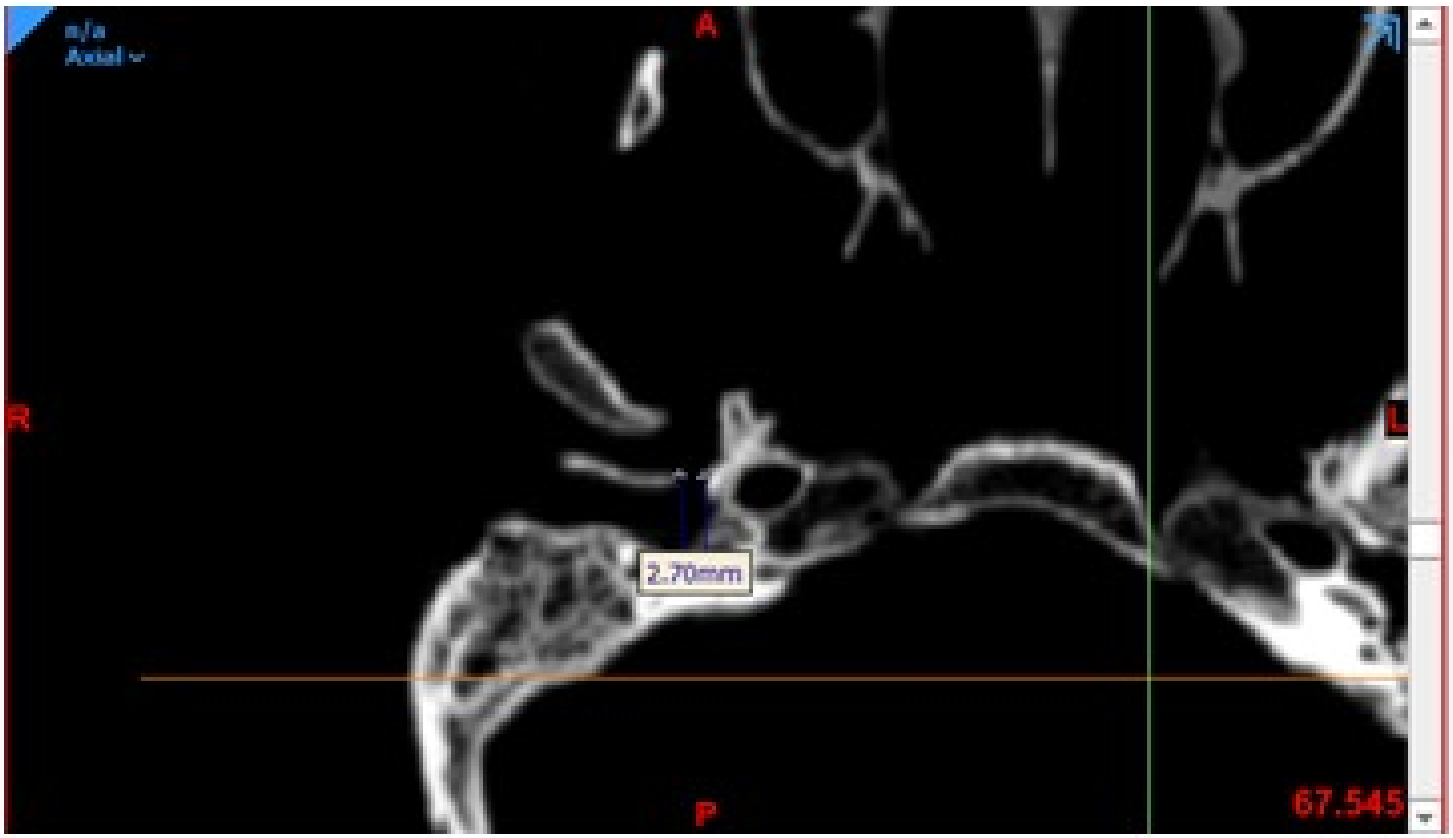
14. Iwanaga J, Singh V, Ohtsuka A, Hwang Y, Kim HJ, Moryś J, Ravi KS, Ribatti D, Trainor PA, Sañudo JR, Apaydin N, Şengül G, Albertine KH, Walocha JA, Loukas M, Duparc F, Paulsen F, Del Sol M, Adds P, Hegazy A, Tubbs RS. Acknowledging the use of human cadaveric tissues in research papers: Recommendations from anatomical journal editors. Clin Anat. 2021 Jan;34(1):2-4. doi: 10.1002/ca.23671.

Figure 1. A) 3D reconstruction of the CT scan of the skull in the Mimics software v. 21.0 (Materialise, NV, Belgium) in a lateroanterior view. B) The black arrow indicates the presence of the FT in a lateral view of the skull.

Figure 2. Computed tomography image of the axial plane of the skull, presence of FT indicated by the white arrow. The measurement was obtained using the Mimics software v. 21.0 (Materialise, NV, Belgium).

Figure 3. Prevalence of FT according to the sex.


A
B


n/a
Axial
A
R
L
P
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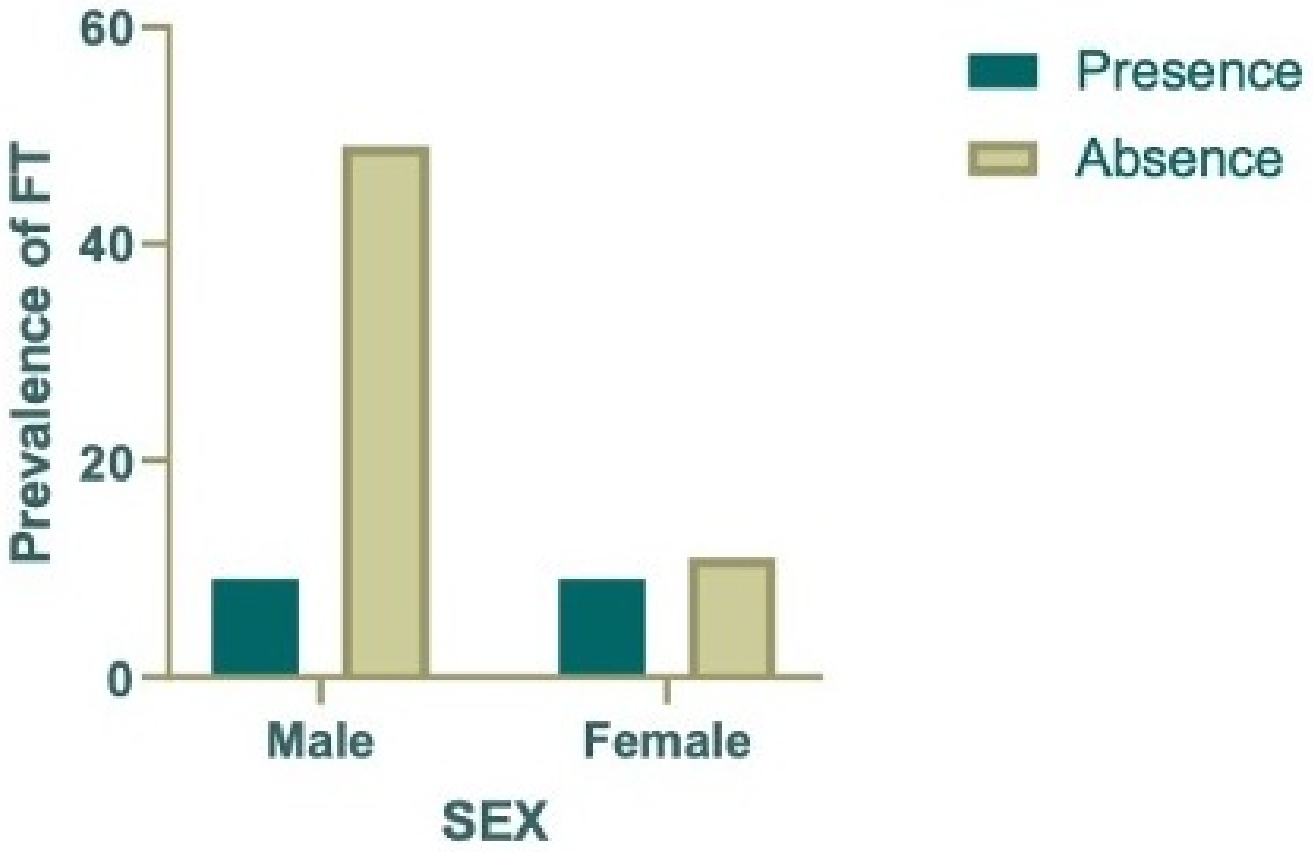
67.545


60
40
20
0
Prevalence of FT
Male
Female
SEX
Presence
Absence