



**T.R.
ONDOKUZ MAYIS UNIVERSITY
INSTITUTE OF GRADUATE STUDIES
DEPARTMENT OF ANATOMY**

**COMPARISON OF THE ATTACHMENT ANGLE OF THE
COSTAL CARTILAGES BETWEEN THE SEXES ON THREE
DIMENSIONAL MODELS OBTAINED FROM THE COMPUTED
TOMOGRAPHY IMAGES**

Ph.D. Thesis

Ahmed Ibrahim ABDI

Supervisor

Prof. Dr. Bünyamin ŞAHİN

SAMSUN

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ACCEPTANCE AND APPROVAL OF THE THESIS

The study entitled “**Comparison of the attachment angle of the costal cartilages between the sexes on three dimensional models obtained from the computed tomography images**” prepared by **Ahmed Ibrahim ABDI** and supervised by **Prof. Dr. Bünyamin ŞAHİN** was found successful and unanimously accepted by committee members as PhD thesis of the Department of Anatomy, following the examination on the date 13/08/2021.

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2021

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ÖZET

BILGISAYARLI TOMOGRAFİDEN ELDE EDİLEN ÜÇ BOYUTLU MODELLERDE KIKIRDAK KABURGALARIN STERNUMA TUTUNMA AÇILARININ CİNSİYETLER ARASINDA KARŞILAŞTIRILMASI

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Amaç: Bu çalışma, Karabük Üniversitesi Hastanesi Radyoloji Anabilim Dalı merkezinden alınan bilgisayarlı tomografi görüntülerinden elde edilen üç boyutlu modeller üzerinde kıkırdak kostaların cinsiyetler arasındaki bağlanma açısının belirlenmesi ve karşılaştırılması amacıyla yapılmıştır.

Gereç ve yöntemler: Çalışmamızda 31'i erkek, 32'si kadın toplam 63 kişiye ait tomografi görüntüsü kullanılmıştır. Görüntülerin uygun düzlemlere getirilmesinden sonra, ImageJ yazılımında kıkırdak kostaların sternum'a bağlanma açıları ölçülmüştür.

Bulgular: 1., 2., 3., 4., 5., 6., ve 7. kıkırdak kostaların sternuma tutunma açılarının ortalaması erkeklerde sırasıyla 63,02; 82,23; 92,97; 109,48; 124; 134,75 ve 13,75; ve kadınlarda 62,16; 85,65; 97,59; 97,59; 129,59; 137,38 and 138,29 olarak ölçüldü. 1. kıkırdak kostanın sternuma tutunma açısı erkeklerde kadınlara göre daha büyüktü. Diğer altı kıkırdak kostanın sternuma tutunma açısı ise kadınlarda erkeklerden daha büyük bulundu.

Sonuç: Araştırmada erkek ve kadınlar arasında kıkırdak kostaların sternuma tutunma açıları arasında farklılık olduğu, kadınların birinci kaburga kıkırdağı hariç, kostal kıkırdak ortalamalarının erkekler göre yüksek olduğu bulunmuştur. Kıkırdak kostaların sternuma tutunma açılarının cinsiyet tayininde etkili bir veri olduğu görülmektedir.

Anahtar Kelimeler : kostal kıkırdak, bilgisayarlı tomografi görüntüleri, sternum.

ABSTRACT

COMPARISON OF THE ATTACHMENT ANGLE OF THE COSTAL CARTILAGES BETWEEN THE SEXES ON THREE DIMENSIONAL MODELS OBTAINED FROM THE COMPUTED TOMOGRAPHY IMAGES

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Aim: This study aims to determine and compare the attachment angle of costal cartilage between the sexes on three-dimensional models obtained from the computed tomography images collected from the Radiological department center in Karabük University hospital at Karabük.

Material and Methods: The number of study sample was 63, males were 31, while females were 32. The data collected CT scan images from the archival system of the radiology department center in Karabük University hospital at Karabük. First, images were opened with Horos software, saved as DICOM, then another software known as ImageJ, used during measurement.

Results: In this study, variation of the size of costal cartilage angles were found. In addition, the angle of costal cartilages increases from the first to rib seven. The average mean of degrees of C 1 (M 62.58), and (83.96, 95.32, 113.12, 126.84, 136.08 & 138.17) with standard deviation (± 7.89 , ± 10.33 , ± 10.99 , ± 10.31 , ± 10.08 , & ± 9.54), in C 2 - C 7 respectively. The costal angles increased as an order of the costal numbers from C 1 to C 7. The First Costal cartilage angle of male was more in size than females, but other remained costal cartilage angles (2nd, 3rd, 4th, 5th, 6th & 7th), females had a large average mean when compared to males.

Conclusion: The study found a difference in attachment angles between males and females. Females have high angle mean of costal cartilages than males, except only the first costal cartilage. The recommended information was to make further study determination abnormality related to angles of costal cartilage and sternum.

Keywords: costal cartilage, dimensional models, computed tomography images, sternum.

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ABBREVIATION OF TERMS

CPR	Cardio-pulmonary resuscitation
CVA	Costovertebral angle
CCs	Costal cartilages
CXR	Chest radiography
CT	Computer tomography
MRI	Magnetic resonance imaging
3D	Three dimensions
NIH	National Institutes of Health
CD	Compact Disc
DICOM	Digital Imaging Communications in Medicine
RECs	Research Ethics Committees
IRBs	Institutional Review Boards
PC	Personal Computer
ANOVA	Analysis of variance
SPSS	Statistical package for social science
ICC	Intra-class correlation
SA	Sternum Angle
ML	Manubrium length
BL	Body length
MW	Manubrium width
TV	Thoracic Vertebra
SSPS	Special Soft Programs
FS	Forensic Sciences
TC	Thoracic Cage
SS	Synovial syndesmosis
TV	Thoracic Viscera
VAN	Vein Artery Nerve
CR	Clinical Relevance
CT	Subcutaneous Tissue
RM	Respiratory Mechanism
ICS	Intercostal Spaces
CC	Caput Costae
SAPHO	Synovitis, Acne, Pustulosis, Hyperostosis, Osteitis
MA	Morphological Analysis

ITA	Internal Thoracic Artery
SD	Standard Deviation
SSD	Statistically Significant Differences



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1. INTRODUCTION

Bone is active tissue found in all living things, including humans, that can change its composition due to the pressures to which it is subject. Bone comprises, like other connective tissues, of cells, fibers (Snell, 2011). The irregular, short, long, flat bones are the major categorized bones related to their general appearance, and long bones form via the mixture of membranous and endochondral bones. In contrast, the process of flat bones occurs via membranous bones (Clarke, 2008). Soft tissue assistance, preservation, phosphate and calcium storage, and red blood cells housing are significant functions of the bones in the body (Florencio-Silva et al., 2015). An expert may accurately determine sex When 90% of the skull or 95% of hip bones are present (Lynnerup, 2001). Bone mass is smaller in females than in males, and this sex distinction had regarded as a primary determinant of osteoporosis and fractures in females. Recent findings show that women have lower spine body size throughout adults and adulthood. But comparable thick spine bone relative to man corresponding age, degree, length, and weight (Gilsanz et al., 1997).

The pelvis and skull bones are the most critical areas used in identifying an individual's sex. First, it is the morphological evaluation of among sex in skeletons. The women's pelvis is well-developed for the fetus's easy exit. The ischio-pubis arm is curved outwards to facilitate the exit of the newborn head, and the angle of the pubis is wider accordingly (Bytheway and Ross, 2010). In contrast, females' sub-pubic is concave, whereas males' sub-pubic is convex, the pubic arm is broad. In addition, females have a large, oval pelvic cavity, but males have a heart-shaped, smaller pelvic cavity (Bytheway et al., 2010).

Gender analyses based on adult individuals' skeletal findings who have completed their secular development are morphologically conducted examinations (Mays and Cox, 2000). There are general variations in the skull and pelvis skeletal findings in adult men and women. The observations of these bones had evaluated by dividing them into five groups. Characteristics graded in groups determined with numbers 1 to 5 ("very feminine, female, uncertain, male, very masculine") are classified (Steyn and İşcan, 2008). Unfortunately, some skulls cannot define this scale, and an "uncertain" evaluation makes for such samples. The main reason for this situation can show to be the inability to reveal approximately morphological data or metric values due to the sex size difference (Steyn et al., 2008). In traditional metric

or non-metric and metric examinations, determinations are taken from quantitative differences, and statistical analyses perform (Bidmos et al., 2010). The differentiation of gender according to Human skull or other bones was essential in many fields of anthropology and paleontology (Evans et al., 2008). In such circumstances, descriptive statistical analysis performs using metric measures or gender determined by mathematical operations using the table created according to the weight coefficients of the morphological features (Brothwell, 1981; Olivier, 1969). Gender determination makes the rate of 80% from the cranium, 90% from the head and mandible, and 80% from the pelvis (Scheuer, 2002). (Pretorius et al., 2006) reported that incisura ischiatica differs by 90%, ramus by 95%, and orbital by 52% in South African black people in terms of gender. In the differentiation of gender, 90% from skull, 95% from pelvis, 98% from skull + pelvis, 95% from long bones + pelvis, 90-95% from skull + long bones, 80-90% from long bones alone (Pretorius et al., 2006).

There are several variations between men and women, such as hormonal and skeletal physiology, which corresponds to what is known as sexual dimorphism. Identifying male and female disparities in skeletal remains can be helpful from many points of view for medical scientists (Papaloucas et al., 2008). In addition, the remains of the bones are of significant importance for identifying the gender of forensic anthropology and in areas of physical science (Scheuer, 2002). Nevertheless, several researchers have indicated that using additional postcranial bones or combinations can produce similar (Tunis et al., 2017). The hip bone, which has various gender-related anatomical characteristics, is the best approach for establishing sex from adult skeletal remains (Schwidetzky et al., 1980). Various sex determination approaches have been proposed, depending on either inspection of specific sections of the hip bone, like the pubic bone, or together (Phenice, 1969). Ischium spines in the female pelvis are small in appearance and broader. The male pelvis especially has a higher loop in the sacrum and a smaller pubic arch. Whereas the women's pelvis is thicker when evaluated between the ischium stalks, the biacetabular distance between women and males in all populations is not substantially distinct. This discrepancy is due in part to the broader male femoral head that outwards changes of hip articulation. Whether gender morphological variations lead from obstetric limitations (Lewis et al., 2017).

The human lower limb and foot research in forensic identification highlights the enhanced probability of retaining tibia and Foot for mass disasters, terrorist attacks,

wars, explosions, high-impact transport accidents, and mass killings. A dead person's identity is the cornerstone of forensic analysis. Therefore, the primary objectives of any forensic anthropologist are to reconstruct an autobiography composed of a set of biological characteristics, such as gender, stature, and age (Ahmed, 2014). Manubriosternal is a flat bone in which the rib cage forms. It composed of cancellous bone, filled with hemopoietic blood cells throughout life. Superiorly, the sternum body articulates to the manubrium (Holcombe et al., 2017c). In comparison, the lower end articulates the xiphoid process. The complete sternum length in men is around 17 cm and less than that in women, the gender proportion among manubrial and mesosternal lengths (Changani et al., 2014). Even in sophisticated skeletal destruction, the sternum continuity maintains (Ekizoglu et al., 2014). The xiphoid process's caudal end is related to the diaphragm's medial tendon and the heart's lower border. As a prospective diagnostic process, radiologists should be conscious of these differences. Unfortunately, these sternum differences seldom record in the African population, and information from Kenya is absent (Hemed et al., 2014). The Sternum is the skeleton with congenital anomalies, and scientists often use differences to determine sex. Sternal changes and anomalies lead from an impaired and inadequate fusion of the ossification center (Ateşoğlu et al., 2018).

The sternal angle, a junction between the body and manubrium of the sternum, is significant in the anatomy of the chest (Chukwuemeka et al., 1997). Radiographical inspection on the sternum in anterior prominent determines the softness of the compact and the less mineral density, as well as the ribs, vertebra column. The sternum is usually seen at birth as four or five separate portions or calcification centers in the lateral view. An ossified xiphoid process found in about 68% of older patients in conventional medical imaging is relatively uncommon in young patients (Restrepo et al., 2009). The xiphoid is mostly cartilaginous in younger but almost complete ossified at age 40. The xiphoid is mostly definitely entirely calcified at the age of 60 and over. The needle must be placed directly underneath the xiphoid to perform pericardiocentesis safely, and the heart is just a few fingerbreadths below (Clemens et al., 2011). The ribs are composed of 12 pairs of elastic arches. Their amount may increase or decrease by the lack of the twelfth ribs. Ribs comprise highly vascular medullary and mass quantities of blood cells embedded in a thin layer of cortical bone (Standring et al., 2008b). The length of the ribs increases from the first to the seventh

of ribs then decreases to the twelfth. For the lateral end of their cartilage, the anterior, costal, rear has a narrow curved depression (Ray et al.. 2016). A slight angular bend in the dorsal portion of the ribs, identified as the costal angle, is commonly termed in the center ribs (Smereczyński et al.. 2017b).

A rib grows from the costal phase of a thoracic vertebra and reached endochondral calcification (Patil et al.. 2014). There are significant gender variations in both the rib cage quantity and configuration. Females are disproportionately lower than men in the rib cage size. Primarily, at distinct lung sizes, the trans—sectional area, the anterior-posterior anterior, and the lateral sizes are smaller. A specific association between the rib cage trans—sectional area and the height of the diaphragm dome also shows the distinct thoracic configuration in women (LoMauro and Aliverti, 2018). Costae make up major of the bone skeleton of the thoracic wall. It has 12 pairs of ribs that are flat and long. It has two sections, bone, and cartilage (Dyce et al.. 2009). On the lateral side of the bodies of the thoracic vertebrae and the transverse protrusions, there are articular faces that articulate with the ribs. Today, some successful results in terms of gender had obtained in humans with many methods. However, some variations have been revealed, especially in morphometric and macroanatomical aspects. Despite all this, there are still huge difficulties in gender determination (Sulaiman et al.. 2015).

The costovertebral angle (CVA) situated below the rib cage in the 12th rib. It is the 90-degree angle produced between the rib curve and the spine. Gender discrimination makes with the help of some features determined on the sternal surfaces of the ribs. In 1955, it first described the differences between males and females in costal cartilage calcification (Sulaiman et al., 2015). However, costal cartilage is a primary structural component of the thorax that contributes to its stiffness and strengthens the chest wall by connecting the area between the sternum and the ribs. Therefore, costal cartilage radiography is helpful and convenient for measuring an individual's age and gender (Holcombe et al.. 2017a). The primary modifications in aging costal cartilages are calcification and ossification (Rejtarová et al.. 2004). The costal cartilages appear to ossify externally in adults, lose their pliability and become fragile (Standring et al.. 2008a). Random calcification foci indicate a moment that should not be regarded as a disease in costal cartilage at smaller concentrations (Smereczyński et al.. 2017a). Recognition is the cornerstone of any forensic inquiry.

By assessing the properties of all the bones when the entire skeleton is accessible, it is relatively simple to determine the sex correctly (Darwish et al., 2017). They investigated bone examinations performed in forensic sciences based on identifying distinctive markers such as pathology, age, gender, biodiversity, and height findings with metric analysis for identification purposes after determining whether it belongs to humans (Gleiser and Hunt, 1955). There are analyzes made with technological and art-based applications used today, techniques such as two- and three-dimensional digital animations and resurfacing.

Today, thanks to special software programs, a development in which three-dimensional photocopies and scans find an application area mentions. There are analyzes and medical examinations made by participating in a 4th or even a 5th dimension (Rogers, 2005). A significant problem encountered, especially in forensic sciences, is identifying the cranium fragments whose information is unknown and the postcranial ossa are missing (Krishan, 2006). The integrity of skeletal remains can be affected by many distinct variables. Gunshots, necrosis, traumatic injury, and geographical factors (Ekizoglu et al., 2014). An essential component of any medico-legal inquiry is determining gender from human bone fragments (Gupta et al., 2014). The aims were comparison the attachment angle of costal cartilages among the sexes on three-dimensional models obtained from the computed tomography images. The two specific aims were categorized first is to determine the angle size of costal cartilages of seven ribs and sternum and second is to compare the angles size of costal cartilage and gender, for determination of difference.

2. GENERAL INFORMATION

2.1. Anatomy of the Thorax

Thoracic anatomy information is essential for the thoracic surgeon. Knowledge of intrathoracic anatomy and diaphragm level is depending on superficial landmarks. Which would helpful for interventions such as tube thoracostomy. In addition, understanding the musculature of the chest wall is vital for the restoration of muscle flaps (Sayeed and Darling, 2007). The chest bones are an osteocartilaginous structure covering and guarding the thoracic organs and facilitating mechanical ventilation (Ward, 2005). The thoracic features have visco-elastic, and the thoracic consist of the thoracic spine, sternum, and osteochondral ribs (Carrier et al.. 1992). The thorax is the region located between the diaphragm and root of the neck. Above its borders are the T1 vertebra, the first ribs, and the superior edge of the manubrium stern in front (Jost et al.. 1978; Moore et al.. 2014). the thorax is space encircled by the bony of a costal cage (Cook and Weinhaus, 2015). This region houses and supports the thoracic viscera. It links to the neck through the superior aperture and divides from the abdomen inferior aperture by respiratory muscle (Bastir et al.. 2013; Hussain and Burns, 2020).

The thoracic skeletons make the thoracic cage (Kani et al.. 2019). The thoracic cage is an ellipsoid space rounded from superior to inferior and bean shaped in the transverse sections. Encircle the thoracic cavity in the central space called the mediastinum and containing the heart and the great vessels. Once intact, the thoracic wall is stiff and flexible on all three anatomical planes due to synovial syndesmosis developed among the ribs and the sternum in the front and back of the vertebral column (Gandhi, 2019). The bottom is the 12th thoracic vertebra at the back, the 12th and 11th bone and cartilaginous ribs, the anterior-outer 8th, 9th, 10th cartilaginous ribs, and the arcus costarum formed by the union with the 7th cartilaginous rib. In addition, there is a region consisting of the lower edge of the corpus stern in front (Singh, 2011).

The thoracic wall consists of the bone and cartilage structures surrounding the essential organs related to respiration and circulation, the muscles adhering to and surrounding these structures, fascia, and the skin covering all these structures together (Moore and Dalley, 2018). Therefore, it is vital to know the anatomy of the thoracic wall and its constituent structures in the correct diagnosis and treatment of the region. The systems forming the thoracic wall are the bone and cartilage formations that form

the thoracic skeleton and the muscles starting from this skeleton (Plagenhoef et al., 1983). Therefore, when examined, the structure of the thoracic involves both bones and cartilages. In addition, it seems that 12 thoracic vertebrae are joining the structure of the vertebral column at the back, the sternum in the front, and the bone and cartilage ribs extending between them (de la Pared Torácica and y Mama, 2006).

The thoracic viscera divide into three spaces, one on each side, the central mediastinum, and two bilateral pulmonary areas. The mediastinum is the central area comprising the heart and large vessels. At the same time, the pleural spaces constitute the two pulmonarias (Bastir et al., 2013; Hussain et al., 2020). The upper mediastinum is vertically between the manubriosternal junction up to the upper thoracic aperture and horizontally from the sternal angle to the T4 and T5. The upper mediastinum structures include large vessels, trachea, thymus, and lymphatic tissues (Richardson et al., 2015). The lower mediastinum further split into three regions; a mediastinum with the pericardium and its components, the main blood vessels. The anterior mediastinum is an area of behind the sternum and Infront the pericardium. The superior border of the diaphragm to the lower border of the superior mediastinum contains the thymus gland and lymph nodes. Finally, the posterior mediastinum, which is among the pericardium Infront and anterior part of the thoracic vertebra behind, is composed of the structures like esophagus, thoracic duct, and Azygos venous system (Whitten et al., 2007). Calcification of the cartilaginous ribs does not have a pathological meaning. The cartilage part of the 1st rib starts to be calcified after the age of 20. Unilateral or bilateral cervical rib joints with the seventh cervical vertebra are common congenital anomalies (O'Rahilly et al., 1980). The thoracic vertebral column seems in the middle and straight-upright on the posterior-anterior chest radiograph. Right or left curvatures are pathological (El-gendy et al., 2021).

2.2. The bones of Thoracic Skeleton

2.2.1. Sternum

The sternum is a flat cortico-cancellous bone with no medullary space and is transverse-sectionally triangular. It seems to have three well-defined portions: the superior end of the manubrium, a middle portion body, and the inferior end of the xiphoid. The sternum encircles the thoracic space by connecting to 10 pairs of left and right ribs. The superior seven true ribs have directly articulated two upper parts of the sternum. The following three consider false ribs because their costal cartilages attach indirectly to the middle part of the sternum, the seventh pair of costal cartilages. The lowest two pairs of ribs are termed floating ribs. A rigid cortical bone shell that surrounds the sternum is more vascular trabecular bone. The manubrium seems to have depressions between the clavicular attachment and has the thickest cortical wall (White and Folkens, 2005; Whitehouse, 1975).

Clinical relevance of the sternum is also apparent throughout cardiopulmonary resuscitation methods. Sternum fracture is a common consequence of successful compressive cardio-pulmonary resuscitation (ACD - CPR) of the thoracic site, artificial respiration, and heart massage. Fractures caused through this process can cause severe cardiac injury that often leads to the death of the patient (Baubin et al., 1999). In addition to osteoporosis, the main factors lead to fractures. It is perceived to be considerably thinner than the male sternum and thus more vulnerable to fractures (A Stini, 2003). They consist of three parts: manubrium sterni, corpus sterni and processus xiphoideus. The sternum is composed of a well-blooded trabecular bone structure and is approximately 17 cm long (Bardeen, 1905). There is pronounced stenosis at the level of the manubriosternal joint where the manubrium and corpus parts meet. After this joint, it expands again, and after the fifth cartilage joins with the rib, it continues by narrowing down again. The manubrium sterni section is at the third and fourth thoracic vertebrae (Bongiovanni and Spradley, 2012), as shown in following Figure.2.1.

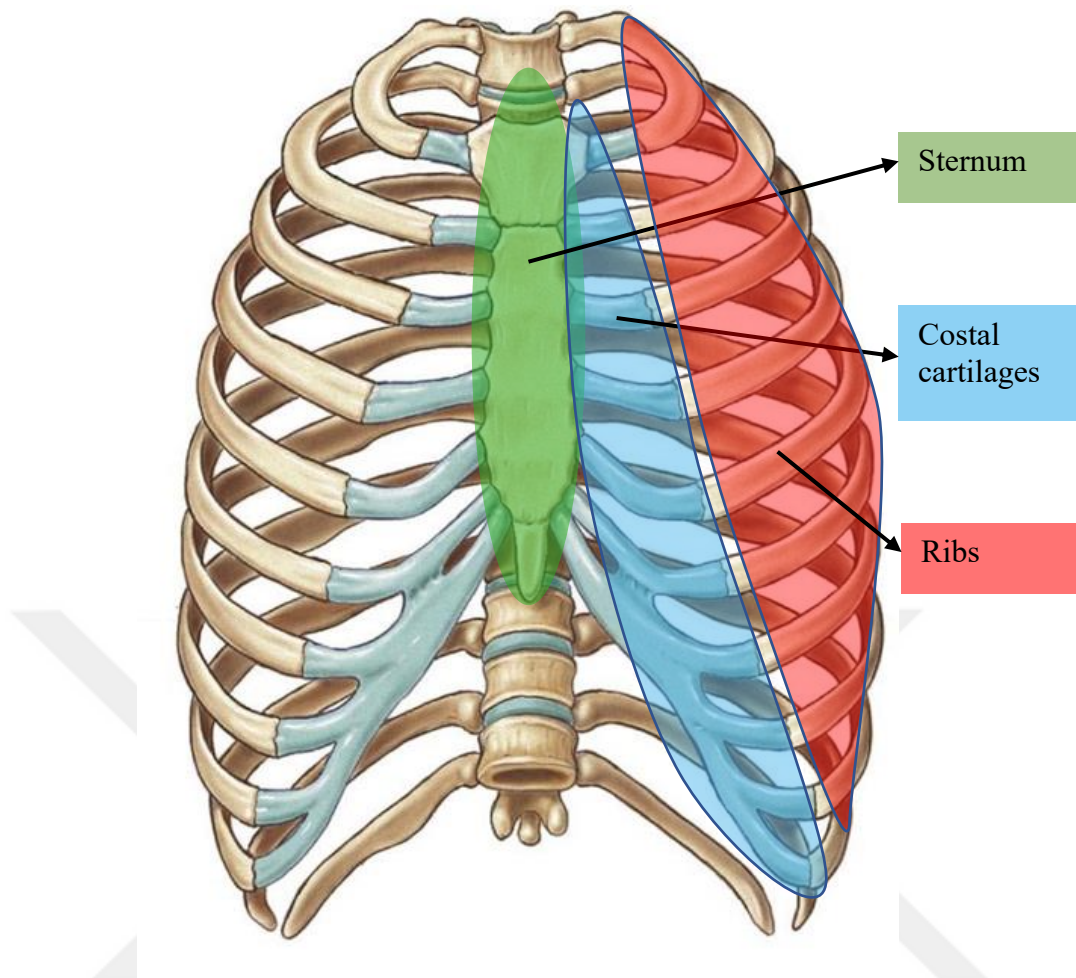


Figure 2.1. The skeleton of the thorax (Moore et al., 2018)

The upper border is the incisura clavicularis, two notches on the sides where the clavicles sit. In the midline, the incisura jugularis, behind which the jugular veins pass, is located. On the lateral side, the incisura costalis I, where the head of the first rib sits, belongs entirely to the manubrium sternum. In contrast, the upper half of the incisura costalis II, where the second rib locates, is also in the manubrium (Bongiovanni et al., 2012). The part of pectoral major and Sternocleidomastoideus muscles are attached to the front of this part, the sternotiroides and sternohyoideus muscles attach to the back. It locates at the level of the thoracic vertebrae. The part where it articulates with the manubrium is at the lower edge of the fourth thoracic vertebra. An obtuse angle forms the rearward-facing sternal angle or Louis angle (García-Parra et al., 2014). This level feels with palpation from the front, the sternum, manubrium, and corpus parts, and the second cartilage articulates with the rib. The xiphoid process is the smallest part of the sternum. When in the cartilage structure in young people, it ossifies as time passes and completes its ossification towards the 40. The abdominal muscles are instead attached

to this part (O'Neal et al., 1998).

Sternum Area: This region represents by the location of the sternum. The incisura jugularis superficially limit middle manubrium sterni at the top, incisura clavicularis on the sides, the base of the xiphoid process, and rib notches on the lateral edge the sternum, which are the joints of the cartilaginous ribs on the sides. And it extends deeply to the pleura (O'Neal et al., 1998).

Topographic layers of this region:

- a) Skin,
- b) Subcutaneous tissue,
- c) Superficial aponeurosis,
- d) Superficial muscle layer,
- e) Bone layer,
- f) Deep muscle layer (Jit et al., 1980).

a) Skin: The skin in this area is thick, hairless in women, and hairy in some men; It is also rich in sebaceous glands.

b) Subcutaneous tissue: It is a thin layer containing little fatty tissue. It has vertical muscle fibers between the sternocleidomastoideus and m. rectus abdominis.

c) Fascia layer: This layer consists of the apo-neurosis (fascia pectoralis) of the pectoralis major and tightly adheres to the sternum in the middle.

d) Superficial muscle layer (subfascial layer): Under the superficial aponeurosis, fibers belong to three muscles that insert into the sternum. These muscles: m. sternocleidomastoideus, m. rectus abdominis and m. pectoralis major, M. sternocleidomastoideus consists of sternal and clavicular two heads. The sternal head (caput sternale) starts from the upper part of the anterior face of the manubrium sterni, primarily to the lateral half of the linea nuchalis superior. The clavicular head starts from the upper side of the medial 1/3 of the clavicle and adheres to the outer face of the processus mastoideus (Jit et al., 1980).

e) Bone layer: The bone layer contains the joints between the sternum and the parts of the sternum and the joints made by this bone with the clavicle and ribs. Sternum: The sternum length is about 17 cm in men and less in women (White et al.,

2005).

At the side corners where the manubrium and corpus meet, there is a second rib notch. The corpus sterni expands downward and on its sides from top to bottom, respectively III-VII. There is a rib notch for each of the costal cartilages. The body length of the sternum in adults is approximately twice that of the manubrium (Steele and Bramblett, 1988). It consists of four segments and ends at the level of the disc between the T8-T9 vertebrae. Processus xiphoideus articulates with the lower end of the body. The lower end of this protrusion is at the 10th or 11th chest vertebra level and is variable in shape, thickness, and size (Quigley, 2001). Although the lengths of the manubrium and the body show gender differences, no racial difference is observed. Anomalies of the sternum such as depression (pectus excavatum or funnel chest), protrusion (pectus carinatum or pigeon chest), mixed disorders, absence deformities, union or nonunion disorders can be encountered (Cobben et al., 2014)

Sadler stated that abnormalities such as pectus excavatum and pectus carinatum caused abnormalities in the formation and growth of ribs. The sternum contains blooded trabecular bone surrounding the thick compact layer between the medulla containing red bone marrow (Quigley, 2001). The hinge-like nature of this joint allows the joint to move during breathing. In this area, it is possible to count the ribs by detecting the angulus sterni with palpation. This angle and plane between mentioned vertebrae divide mediastinum to lower and upper parts. Again, this point coincides with the bifurcation point, where the pulmonary artery divides into right and left branches. Other significant anatomical formations corresponding to the level of Angulus sterni are Right and left pleura just below this level are in direct contact with each other. Right and left brachiocephalic veins to combine to form the SVC (Kimmerle et al., 2008). In addition, the tracheal bifurcation and the place where the ductus thoracicus cross the front of the vertebral column locates at this angle level. Angulus sterni is an important anatomical landmark as it guides all these anatomical formations. This joint ossifies in advanced ages. Provides elasticity during breathing.

Articulatio xiphosternalis: It is a synchondrosis type joint between the sternum body and the xiphoid process. Between the corpus sterni and the base of the xiphoid process there is a depression (fovea xiphoidea) at the disc level between T9 and T10 (Nagy, 2013). The joint faces cover with fibrous cartilage, and there is disc between the faces. The disc that prevents the clavicle from slipping inwards attaches to the first

rib cartilage below and above the clavicle. The disc divides the joint cavity into two internal and external spaces and acts as a cushion against impacts from the upper limb. The joint is functional of the sellar type (Marino, 1997). The joint capsule supports by lig. Sternoclaviculare anterior from the front, lig. Sternoclaviculare posterius from the back, lig. interclaviculare crossing the incisura suprasternalis from above. The capsule is thin above and below. Outside league at the bottom. Supported by costoclaviculare. This joint connects the upper limb to the trunk (Eliopoulos et al., 2007). These joints are supported from the outside by ligaments called lig. sternocostale radiatum. The fibers of the ligaments are attached inner side, one side front and back of the sternum, surface of cartilages outside. With the mixing of the beams of m. pectoralis major and m. transversus thoracis. These bonds contain many elastic fibers. Joints also have internal ligaments (Eliopoulos et al., 2007).

f) Deep muscle layer (anatomical structures on the inner surface of the sternum) attached to the sternum at the sides of the midline on the posterior aspect of the sternum. Transversus thoracic or m. sternocostalis. These link to the cartilages of the 2-6th ribs. They pull down the lower part of the thorax. Thus, they act as an expiratory in breathing. The endothoracica locate on the inner surface of this muscle layer, and the parietal pleura locate on the inner face of this fascia (Radoinova et al., 2002).

2.2.2. Costae

Twelve pairs of elongated bones make up a large part of the rib cage's anterior, lateral, and posterior walls. The ribs, which play a vital role in the respiratory mechanism, also protecting many vital organs in the rib cage. Although ribs articulates thoracic vertebrae at the back, only the first 7 of them are directly connect to the sternum in the front (Jacobs, 1992). The sternal ends of the 8th, 9th, and 10th ribs are attached to the cartilaginous rib and sternum numbered 7 through joint cartilage (Tobias, 1985). The sternal ends of the 11th and 12th ribs do not attach to the sternum and end freely, so the last two ribs are called costae fluctuantes (swimmer ribs). The slopes and lengths of the ribs are different from each other (Tobias, 1985). The slope of the 1st rib is the least, while the 9th rib is the most inclined. The 1st rib is the shortest, while the 7th rib is the longest. Since the 3rd-9th ribs have no distinct features, they are called distinct ribs. The other ribs are called atypical ribs. The most important of these is the first rib (costa prima) and, as previously mentioned, the shortest and most curved rib (Pfeiffer et al., 1995). However, two separate grooves by a protrusion

upper face, v. subclavia sits groove at the front, and a. subclavia sits in the back. The space between the ribs is called the intercostal space (*spatium intercostale*). Intercostal spaces name according to the number of the upper rib (Lau et al., 2008). as presented in below Figure 2.2.

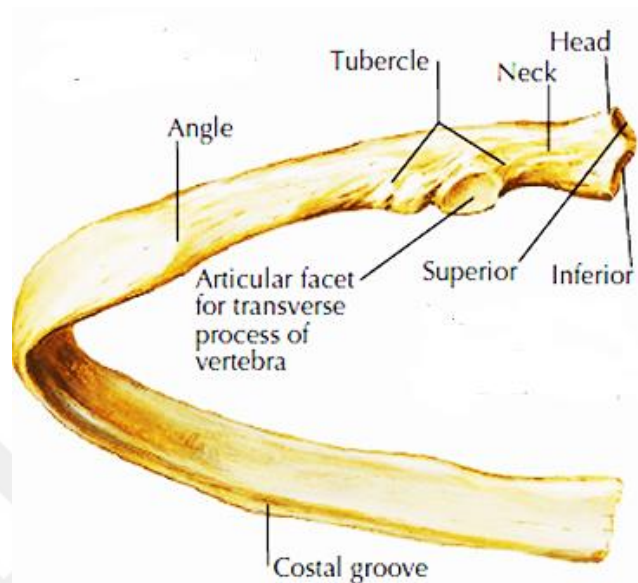


Figure 2.2. Typical features of the Sixth rib (Netter, 2014)

The area under the 12th rib is called the subcostal area. The back ends where the ribs attach to the vertebrae are called *extremities vertebralis*, and the ends where the ribs attach to the sternum are called *extremitas sternalis*. The sternal end contains hyaline cartilage that ossifies with age, and this is called *cartilago costalis* (cartilage rib). The medial ends of the 7th and 10th cartilage ribs form the *arcus costarum* (costa arc) with the sternum. In addition, there are sections called *caput costae*, *collum costae*, and *tuberculum costae* at the rear ends of the ribs. *Caput costae* is the part of the rib where it joins with the vertebrae. The 2.5 cm section from the *caput costae* is called *collum costae*. Finally, there is a groove called *sulcus costae* on the lower edge of the inner surface of each rib facing the lungs. In this groove, the intercostal vessels and nerve bundle follows (V., A., N. and *intercostalis*). Where the *collum costae* ends, the rib body begins and there is a protrusion called the *tuberculum costae* at this junction and the back. This protrusion, which found in all ribs except the 11th and 12th ribs, joins the *process transversus* of the vertebrae. Although the ribs are parts of the rib cage, they can sometimes seems as rudimentary in the neck area. That is called the *costa cervicalis* (cervical rib, cervical rib). In this case, may compress many important structures in the region. The ribs can rarely seems in the lumbar region; this is called the *costa lumbalis* (lumbal costa, lumbal rib) (Lau et al., 2008).

The ribs are generally 12 pairs of bones and costal cartilage structures that make up a large part of the thorax skeleton for articulating with the sternum or with each other to costal cartilage parts on the back vertebrae in the front. Their number may be more in the presence of cervical or lumbar ribs and less if the 12th pair does not develop. Since the first seven pairs of cartilage structures directly articulate with the additional sternum, they are called true ribs (Guo et al., 2007). True ribs, ribs one to seven, are fixed to the thoracic spine and sternum via costal cartilages that restrict spine mobility (Horton et al., 2005). The eighth and 10th ribs join the structure of the seventh cartilaginous rib and establish a connection with the sternum, leaving the ends of the 11th and 12th ribs exposed.

For this reason, these costae are called swimming costae. As a common variation, 35% -70% of the 10th rib may not merge with the sternum in the swimming costa in different races. A typical costa has front and rear ends and a stem extending between the two (Guo et al., 2007).

Extensions at the rear ends of the vertebrae that articulate with their bodies are called bonnet ribs. The front faces of the bonnet costa are adjacent to the pleura and the sympathetic chain in the lower ribs. There are also protrusions called tuberculum costa, which are more prominent in the upper ribs joining with the transverse protrusions of the vertebrae. These tubercles not seem in swimming ribs (Rejtarová et al., 2004). On the lower edge of the inner surface of all ribs, there is a groove called the sulcus rib, through which neurovascular structures follow. Musculus intercostalis interni attaches to this groove and separates the bone and neurovascular structures. Musculus intercostalis intimi attaches to the lower sharp edge of the rib and therefore to the lower edge of the rib. In contrast, the muscular intercostalis intimi is attached to the upper edge of the groove on the inner surface of the rib (Rejtarová et al., 2004).

2.2.3. Costal Cartilages

Costal cartilages serve to extend the hyaline cartilage ribs forward and contribute to the elasticity of the chest walls. Costal cartilages are located only at the anterior ends of the ribs and provide the medial extension (Sandoz et al., 2013). Costal cartilages are the link between the ribs and the sternum. Costal cartilages thus form the last part of the ribs that connect to the sternum through them. Costal cartilages thus form part of the anterior human rib cage (Yoganandan and Pintar, 1998). Costal cartilages are hyaline cartilage that is both compressive and elastic in terms of flexion

compared to bony ribs and bony sternum. In early adulthood, the cartilage gradually begins to calcify and then ossify, which further decreases the elasticity of the chest with age. Costal cartilages are the link between the ribs and the sternum. Costal cartilages make up the last 3-9 cm of ribs that connect to the sternum. The cartilages of the six upper ribs are attached to the sternum by ligaments, the ligament by the sternocostal radiatum (Yoganandan et al., 1998). It is attached to the lower part of the sixth and seventh rib bone through the xiphoid process, a ligament, costoxiphoid ligament.

Costal cartilages form part of the anterior rib cage. The boundaries between the bony ribs and cartilaginous tissue are usually partially evident from the outside as they are usually slightly thickened. Together with the spine and sternum, the ribs form the bony skeleton of the chest (Holcombe et al., 2017a). The ribs exit the spine and run forward along with the lungs, mainly towards the sternum. In the case of ribs, a distinction makes between "real ribs," "false ribs," and "free ribs." A person has a total of twelve ribs. Seen from above, the "true ribs" are the first seven ribs and are attached directly to the sternum via the costal cartilage. The three ribs below, namely eight to ten ribs, are connected only indirectly to the rib cage via the articulation interchondrals, with the costal cartilages of the upper seven ribs (Holcombe et al., 2017a). The last two lower ribs' costal cartilages are very short or absent and therefore not attached to the sternum. The chest surrounds the two lungs and separates from them only by the pleural space, and the space is a very narrow body cavity filled with 5-10 milliliters of serous fluid. That reduces the friction between the rib cage and the lungs. Since the anterior ribs cover with hyaline cartilage, the chest has slightly elastic properties. These elastic properties are crucial to the freedom of movement of the chest. The primary function of the costal cartilage is to provide the flexibility of the rib cage. Because costal cartilages also form part of the chest, they also protect the underlying lungs and heart (Lau et al., 2011).

The costal cartilage makes up of hyaline cartilage. Hyaline cartilage is more throughout the body and can often found in joints. Compared to bony structures, cartilage is flexible in compression and bending. If you put pressure on the cartilage, it can initially bend and withstand pressure. When the pressure removed, the cartilage quickly returns to its original position thanks to its flexibility. Bony structures have little of these properties and will break soon if the same pressure is applied. Therefore,

the costal cartilage is essential for the flexibility of the rib cage, which is especially important when breathing. In addition, the costal cartilage of the second to sixth ribs is the starting point for musculus thoracicus transverses, which pulls inward from the inner part of the sternum (Lau et al., 2011).

Costal cartilages usually allow forward movement of the ribs by providing flexibility to the chest wall. There are usually 12 pairs of cartilages associated with the rib cage. Seven typically connect ribs to the sternum or breastbone, while the following three are mainly located between the ribs. It connects the last two lower ribs with the abdominal wall. These are a type of hyaline cartilage made partially from flexible collagen fibers and usually supports and protects bones from movement forces (Holcombe et al., 2017c). This type of connective tissue is found in the rib cage, consisting of the same material as cartilage in the nose, joints, and respiratory tract. There usually are two surfaces in each costal cartilage. The anterior surface usually positioned forward, running up the ribs; it attaches to a large ligament and muscles in the former case. A connection between the sternum and the large pectoral muscle provides by the first six or seven cartilages. In contrast, others connect the ribs to other abdominal muscles (Holcombe et al., 2017a).

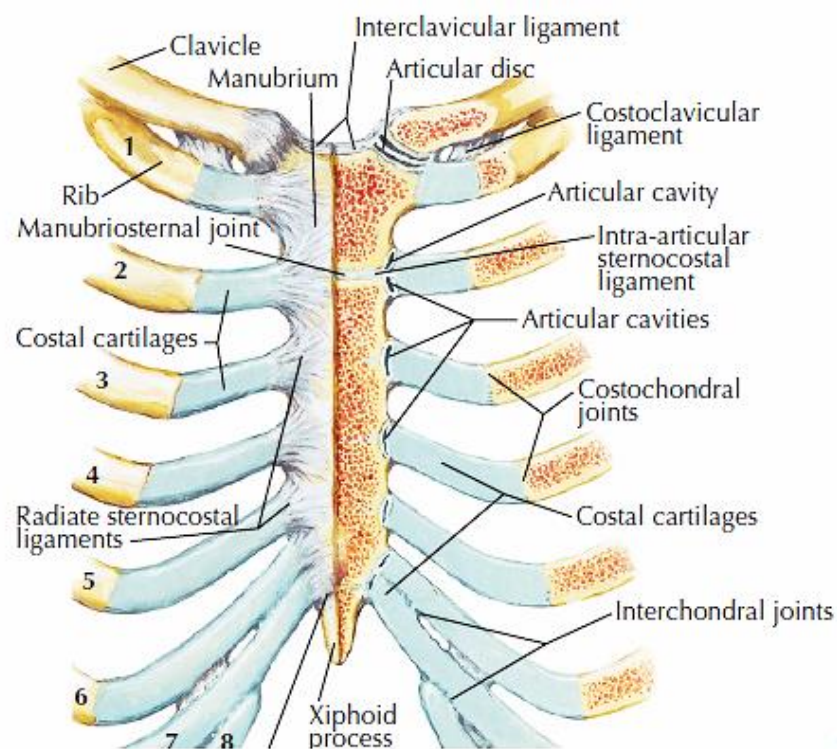


Figure 2.3. Costal cartilages ,Ribs (Netter, 2014)

2.2.4. Vertebrae

Like a typical vertebra, Thoracic vertebrae consist of an overall body called the corpus vertebra in front, and an arch part called the arcus vertebra at the back. The part of the arcus vertebra attached to the body is called the pedicle, and the posterior part is called the lamina (Semionov et al., 2019). The bodies of the thoracic vertebra, which are 12 in total, expand as the load to bear increases as they descend. The longest part of the medulla spinalis follows within the thoracic part of the canalis vertebralis formed due to the fusion of the foramen vertebral, which are the holes between the corpus and arches of the thoracic vertebrae (Sundaram and Feng, 1977). Apart from these structures, there are seven distinct protrusions in a thoracic vertebra, four of which are joint protrusions, just like other vertebrae. In addition, there are two transverse protrusions laterally from the junction of this peduncle and lamina. In addition, there is a spinous process extending from the midline to the back, two upper joint protrusions that allow it to articulate with an upper vertebra, and a lower joint protrusion that allows it to articulate with a lower vertebra (Donley and Loyd, 2018). The body parts of all thoracic vertebrae connect by symphysis-style semi-movable joints formed by placing disc structures called discus intervertebral between them. In addition, the arcus parts are in contact with each other, the joint zygapophyseal, which are synovial joints that form between the upper and lower joint protrusions.

These joints are also called facet joints in the clinic (Donley et al., 2018). The spine consists of 33 or 34 vertebrae (vertebrae) lined up on top of each other. The adult spine consists of 26 independent bones due to the ossification and fusion of the sacrum and coccyx vertebrae. The 26 vertebrae connect by ligaments made of fibrous cartilage called the discus inter-vertebral (intervertebral disc). Of the spine length, which is 70 cm in an adult male and 60 cm in a woman, are discs and are vertebrae (Bastir et al., 2013). The first 24 vertebrae above the sacrum that make the Column vertebral are called presacral vertebrae (true, mobile vertebrae). The spine is in the shape of a straight column when viewed from the front and back. When viewed from the side, some curvatures seem. Forward curvatures, lordosis; backward curvatures are called kyphosis. There is lordosis in the neck and waist area, kyphosis in the chest and sacral region. Thorax vertebrae have 12 bones; their stems and protrusions are thicker than the cervical vertebrae. Each typical chest vertebra has ten joint faces. All thoracic vertebrae articulate with the ribs, with articular faces in their trunk and transverse

protrusions (Bastir et al., 2013).

2.3. Embryology of Thorax

2.3.1. Sternum

The formation of the sternum component occurs concurrently during embryogenesis, as it does for many other body structures, as they interact and alter each other series of events categorized into stages for ease of understanding. The aim of studying embryogenesis is to confirm that midline development defects will affect surgical partition and healing of the sternum. During the sixth week of the embryonic stage, the sternum starts to develop. Although sternal anomalies are most likely associated with the heart, a portion of the sternum (manubrium) has its origin in the neural crest (Weston et al., 2006). Within the embryo's initial mesenchyme, several frameworks in the precordial area emerge at the same time. The primitive manubrium has found in the midline. The top layer is emerging as a pre-sternum for the future shoulder girdle and cranially para-median supra-sternal masses that arise apart from the sternal mass condensations (Rodríguez-Vázquez et al., 2013). the sternal bands' roots seem as dense spots of mesenchyme ventral to the edges of the first and second ribs, which connect to the lateral aspects of the developing pericardial cavity at this point (Selthofer et al., 2006). The initial inter-clavicular mesenchyme meets the medial sides of the first ribs by inter-costo-clavicular mesenchyme in the seventh week (AR, 2014; Selthofer et al., 2006).

With its oval morphology, the inter-clavicular mesenchyme starts to take form in the primitive manubrium during the eighth and ninth weeks, with the appearance of the sterno-clavicular joints below the inter-clavicular ligament anlage and becomes associated with the inter-costo-clavicular mesenchyme of the first ribs (figure 2.5.) The paramedian sternal condensations then emerge as broad markings ventral to the second and first ribs, making connections and leading the sternal bands to form. The sterno-costal head of the pectoralis major then arises from the sternal bands and first ribs, but not from the primitive manubrium (Selthofer et al., 2006). The formation of the manubrium in the inter-costo-clavicular mesenchyme is most likely controlled by the somite origin of the first rib, causing a boundary to divide them. As a result, anatomy connects the first rib, and the manubrium varies from that of the other ribs to the sternal body, also in adults (Dorskocil, 1993). The primary ossification center in the clavicles progresses during the later mesenchymal phase. Like the body of the sternum,

the xiphoid process grows from a pair of mesenchymal tissue bands at the ventral end of the ribs' Anlagen. The sternal bands on either side of the midline form by the dense mesenchyme adjacent to the anterior ends of the ribs, which connect in cranial and caudal ways like a chain (Selthofer et al., 2006). The sternal bands distinguish them from the inter-costo-clavicular mesenchyme. These sternal bands form separately of the ribs before joining together later (standring, 2008).

Two cartilaginous sternal plates have lined the median plane fuse to create the sternum. The number and arrangement of ossification centers differ depending on the completeness and duration of the merging of the sternal plates and the mature bone's width—a sternal foramen results from inadequate fusion. In the fifth fetal month, the manubrium begins to ossify from one to three centers. The first and second sternebrae typically form from a single center that develops at the same time. The third and fourth sternebrae centers are often paired and occur in the fifth and sixth months. Nevertheless, one of the pairs may not occur until the seventh or even eighth month, and the fourth sternebrae center may be absent. After the third year or beyond, the xiphoid process starts to ossify (standring, 2008).

The embryological formation of the sternum is dependent on the chondrification of the bilateral sternal plates. Endochondral ossification, a method guided by various ossification centers, is used to ossify the sternal bone. Ossification occurs along the sternebrae, separate parts of the mesosternum (Ateşoğlu et al., 2018). Sternal ossification starts during the fifth month of prenatal. During the ages of 6 to 12, the ossification centers in each part of the sternal body merge to create a single ossification center. By the age of 25, the calcification and fusion of the sternal body parts usually are complete. Sternal differences and abnormalities occur from the failure of this developmental process (Yekeler et al., 2006).

Provided that median sternotomy is the most standard surgical method, the sternum has a significant clinical significance. The sternum is one of the skeleton sections that look differently on different images or examination sequences. On cross-sectional images of living objects, sternal variations observe by chance (Babinski et al., 2015). Males' sternums are 209 mm long, while females' sternums are 183 mm long. The manubrium's shape may be triangular, trapezoid, or quadrangular. The average manubrium measurements in men are [55 mm 68–37 mm 13 mm] (length, width, maximum-minimum thickness). Women have [52 61–33 mm 11 mm], while

men have [52 61–33 mm 11 mm]. The gladiolus has an average size [length, width, and thickness] of [110 mm 31 mm 10 mm] in males and [94 mm 27 mm 9 mm] in females (Kilian et al., 2013).

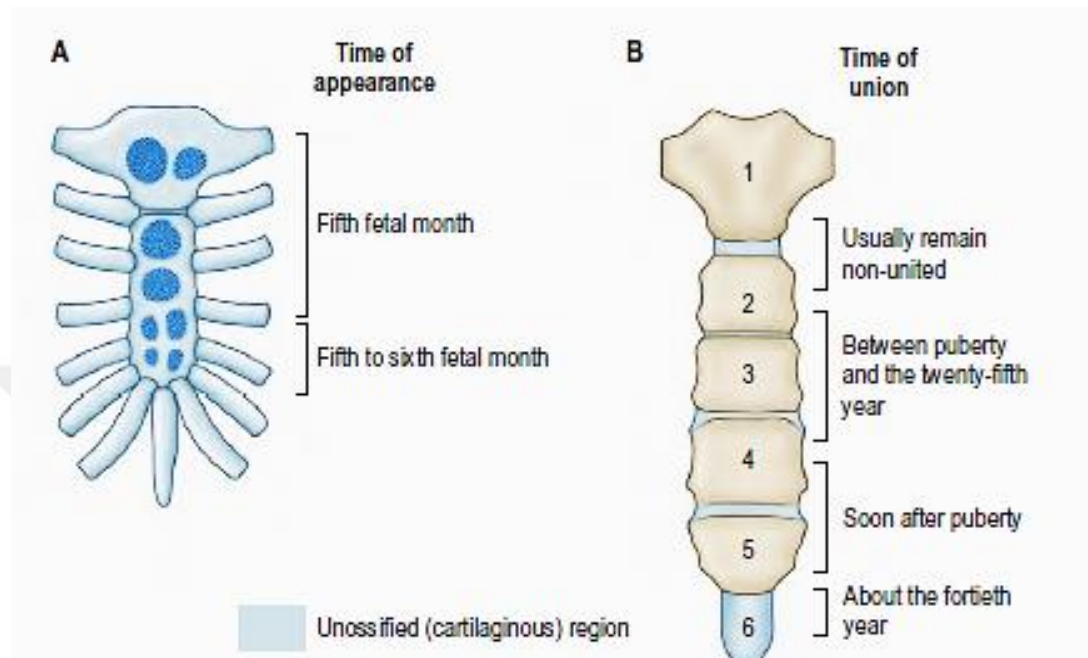


Figure 2.4. The ossification of the sternum. A, Before birth. B, After birth (standing, 2008)

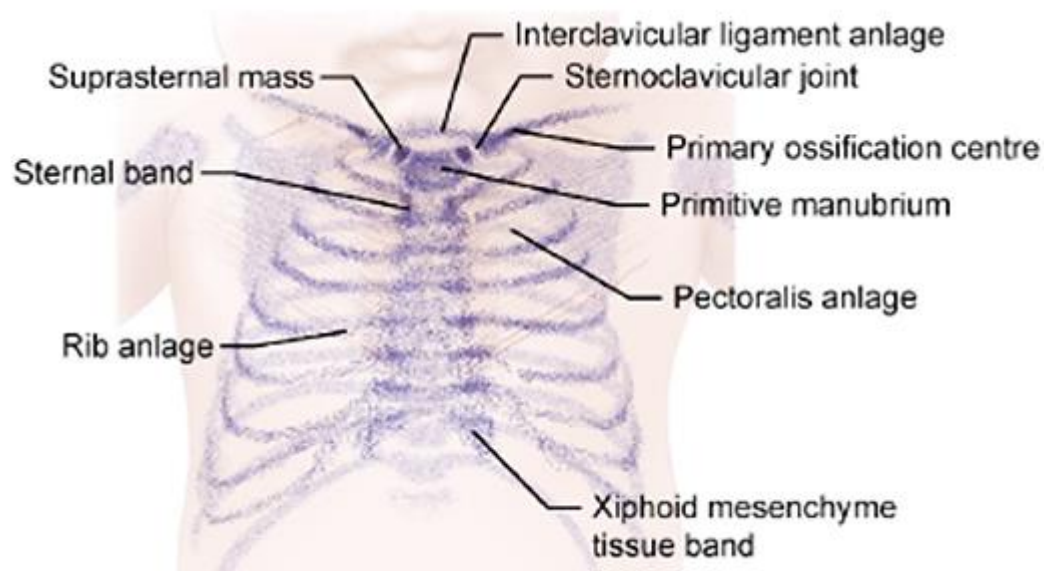


Figure 2.5. Postnatal development of the sternum during the early embryonic (Eighth and Ninth weeks (Gandhi, 2019)

2.3.2. Ribs

Twelve paired ribs develop from cartilaginous costal processes of the developing thoracic vertebrae. Secondary ossification centers of the ribs occur 15 years after rib formation starts at nine weeks (Larsen, 1998). By day 45, the first seven “true” ribs have connected to the sternum through their costal cartilages. The sternum does not communicate with the lower five “false” ribs. Rib changes in children may be isolated or occur in conjunction with other congenital disorders (Glass et al., 2002). In several patients, a frontal chest radiograph is used to measure the ribs.

On the other hand, routine chest radiographs are unreliable for rib detail, and focused rib views offer better detail. The over penetrated grid technique creates these views, with additional oblique views focused over the most critical field (Meschan, 1975). Computed tomography (CT) or magnetic resonance imaging (MRI) are the appropriate tools for assessing inflammatory or neoplastic tumors (Glass et al., 2002).

2.3.3. Costal cartilages

The thoracic skeleton makes twelve ribs on each side, which joins by costal cartilages to the sternum. Costal cartilages are bar-shaped hyaline cartilages that protect by a strong peri-chondrium that runs parallel to the connective tissue of the ribs, excluding the first, most inter-chondral, and most chondro-sternal joints have synovial spaces (Verma et al., 2015). The first costal cartilage joins the first rib and the manubrium to create a primary cartilage joint, a rare type of syn-arthritis typically replaced by bone after 25 years (Singh, 2011). Bilateral ossified first costochondral and chondrosternal joints report in the literature. Around the costal cartilage, such as the periosteum, perichondrium, and connective, sternocostal hyperostosis occurs (Singh, 2011). In addition, the costal cartilages ossify externally with time, diminishing their elasticity and stiffness (Verma et al., 2015). Costochondral defects at the top end of the thoracic cage may cause by problems in the division of bone tissue throughout early life formation. In addition, they relate to differences of location in neurovascular organs (Todd, 1912). In the first costal cartilage, mineralization and osteolysis are natural age-related alterations, not degenerative conditions (Kampen et al., 1995). Problems such as congenital rib abnormalities, which can be numerical or structural, may also be related. Super-numerary ribs and structural anomalies such as short ribs, bifid ribs or forked ribs, joined or linked ribs, and pseudo-arthritis of the first rib are instances of numerical problems (Anita et al., 2009).

According to Etter (1944), either of the first seven ribs can be bifid, and any two ribs from the first to the tenth can even have synostosis (Etter, 1944). The fusing of the ribs and the sternum may result in limited thorax movements throughout breathing, necessitating surgical treatment to ease the symptoms. Patients may experience various complaints as a result of direct or indirect impact on surrounding neurovascular systems. SAPHO syndrome can affect the costochondral and manubriosternal joints (Chigira and Shimizu, 1989). Sclerosis of the manubrium, calcification of the costal cartilage, and connective tissue edema can all be characteristics of Teitze's syndrome. It also can induce venous congestion in the upper limb because of bilateral pressure of the subclavian vein (Dihlmann and Dihlmann, 1991). The development of tiny osseous islands in the cartilage to perfect ossification related to the first rib and the sternum were among the age-related morphological alterations (Vinod Babu et al., 2014). In her analysis, Pushpa MS discovered that the first rib's grades of costal cartilage calcification as one gets older. Costal cartilage and articular calcification make the rib cage more resistant to movement. This more excellent resistance puts more strain on muscles, which could explain why you seem like you're working harder to breathe (Vaziri et al., 2010).

2.4. Sex difference in the thorax

2.4.1. Sternum

The sternum, broad triangular bone in the center of the chest, surrounds the heart and major vessels in the middle mediastinum. Its lower end, the xiphoid process, is associated with the diaphragm's central tendon and the inferior border of the heart (El-Busaidy et al., 2014). The sternum is a flat bone that runs vertically across the thoracic cage's median and anterior segments (we lost this area the reference). Sternal variations and anomalies are congenital anatomical abnormalities caused by a defective and incomplete ossification center fusion (Akin et al., 2011). Order on their radiograph, helical computed tomography (CT), or magnetic resonance imaging (MRI) manifestations, the dynamics of sternal differences in living subjects have been identified (Akin et al., 2011). According to morphometric analysis, females and males have proportionally similar sternum structures (Selthofer et al., 2006). Until after 30 years of age, the sternum's morphology reveals significant changes in shape and form throughout childhood and young adulthood, as active growth and ossification are occurring. However, there are significant parametric variations in different absolute

values between males and females (Weaver et al., 2014). Manubrium thickness finds to be 8.1 ± 1.6 mm in females and 9.2 ± 1.5 mm in males. found the mean thickness of manubrium for females and males 8 ± 1.6 mm and 9.2 ± 1.5 mm, respectively. Female and male corpus sterni thicknesses got to be 8.1 ± 1.3 mm and 9.2 ± 1.5 mm, 7.9 ± 1.5 mm, and 8.5 ± 1.5 mm, respectively. The thickness of corpus sterni between 2 and 3, between 4 and 5 sternebrae in female and male got 8.1 ± 1.3 mm and 9.2 ± 1.5 mm, 7.9 ± 1.5 mm and 8.5 ± 1.5 mm, respectively. Individuals' xiphoidal endings may have anatomical differences. These morphologies are essential since they misinterprets as fractures throughout imaging (Ateşoğlu et al., 2018). Manubrium length uses to determine sex from the sternum. Females had a maximum length of 40.44 mm, while males had a minimum length of 36.56 mm. As a result of this analysis, it can be concluded that in the population of central Delhi, if the manubrium length is less than 36 mm, it belongs to a woman, and if it is more than 41 mm, it belongs to a (males)men. Despite the statistically significant p-value (0.003) (Table 1), the duration of the mesosternum cannot be considered a reliable criterion for sexing the sternum due to the large proportion of males and females with overlapping events (Gupta et al., 2014). Determination of sex from sternal bone in central Delhi population. Males had significantly greater sternal measurements than females, including manubrium length (ML), sternal body length (BL), manubrium width (MW), and sternal body width (Franklin et al., 2012).

The sternum's asymmetry, breadth, and thickness can raise the risk of suture material movement via the sternum during median sternotomy (El-Busaidy et al., 2014). Due to its high width and subcutaneous place, the sternum is a popular site for bone marrow biopsy. As fatality rates were widely published, the sternal thickness is a critical factor in this procedure (Inoue et al., 2010). The sternum was largest at the third intercostal notch in the current analysis. That reflects past findings. In males and females, the widest portion of the sternum got at the sixth and fifth intercostal notches (Selthofer et al., 2006). In the current study, the sternum was widest at the third intercostal notch. That differs from previous findings. Selthofer et al. (2006) reported the widest segment of the sternum at sixth and fifth intercostal notches in males and females, respectively. The length of the entire sternum in mm of male sternum except xiphoid It has been determined that 80% of the measurement value in terms of is above 149 mm, and in women it is below this value. Almost all bones of the body were

evaluated by many researchers in terms of gender determination (Brothwell, 1981; Olivier, 1969).

2.4.2. Ribs

The sternum, twelve thoracic vertebrae, and twelve pairs of ribs, including their costal cartilages, constitute the skeleton of the chest wall. These twelve ribs meet dorsal with the vertebral column and anteriorly with the sternum through costal cartilages. The first chondro-sternal joint considers to ossify as early as 15 years of age, and it is the primary cartilaginous joint (McCormick and Stewart, 1988). Through shoulder girdle (movement) motion, it brings stability to the sternoclavicular joint. The chondrosternal joints, which range from the second to the seventh, are synovial joints that allow the chest wall to move quickly. The presence or absence of the twelfth pair of ribs will raise or decrease the number of ribs. The true ribs are the first seven pairs attached to the sternum (by) via costal cartilages.

The remaining five are the false ribs (From eighth to twelfth, these ribs are false). The eighth to tenth rib cartilages typically connect the suprajacent costal cartilage, while the eleventh and twelfth ribs are referred to as 'floating' ribs because their anterior ends are free. The length of the ribs increases from the first to the seventh then decreases until the twelfth. The ribs have two ends; a middle part is called the shaft. The lateral end is cartilage; the anterior, costal, end has a slight concave depression. The shaft is convex on the outside and grooved on the inside at its pointed lower border, which contrasts by its rounded upper border (Ray et al., 2016). At the vertebral end, the typical ribs have a tubercle neck and shaft. A transverse ridge separates two articulation areas on the head of the ribs. The body of the corresponding vertebra articulates with the bottom and wider facet (Ray et al., 2016).

2.4.3. Costal cartilages

The costal cartilages are hyaline cartilage flat bars that run from the anterior ends of the ribs and play an important role in thoracic stability and elasticity. Alkaline phosphatase is a chondrocyte-secreted enzyme that hydrolyzes alkaline phosphates into free phosphate ions. The latter reacts with soluble calcium in the tissue fluid to form calcium phosphate in the cartilage tissue matrix. Calcification is the term for this procedure. Only when the costal cartilages have calcification are they evident on radiographs. After puberty, the costal cartilages are vulnerable to calcification (Vastine

2nd et al.. 1948). The prevalence of costal cartilage calcification rises with age, from around 6% in the third decade to 45 percent in the ninth (Teale et al.. 1989). Costal cartilage radiography is efficient and helpful for determining an individual's age and sex. Individual differences in the presence of first costal cartilage calcification on chest radiographs use to identify individuals (Banerjee, 1992).

Male and female variations in costal cartilage calcification were reported in 1955 in research that focuses on endocrine effects on hyaline cartilage calcification (Ray et al.. 2017). Costal cartilage ossifications tend to increase with age. A peripheral form of ossification predicts male sex with 99.6% accuracy, whereas the presence of a central type of ossification predicts female sex with 100% accuracy. In several situations, particularly in women, identifying ossification patterns may aid in age estimation (Rejtarová et al., 2004). Unless they are calcified, the costal cartilages are not apparent on radiograms. The major processes that happen in (developing) aging costal cartilages are calcification and ossification. Costal cartilage calcification links to various pathological conditions, including arterio-sclerosis, nutritional status, metabolic, and endocrine changes, in previous studies. Costal cartilage calcification variations among males and females report since 1955 (McCormick and Stewart, 1983).

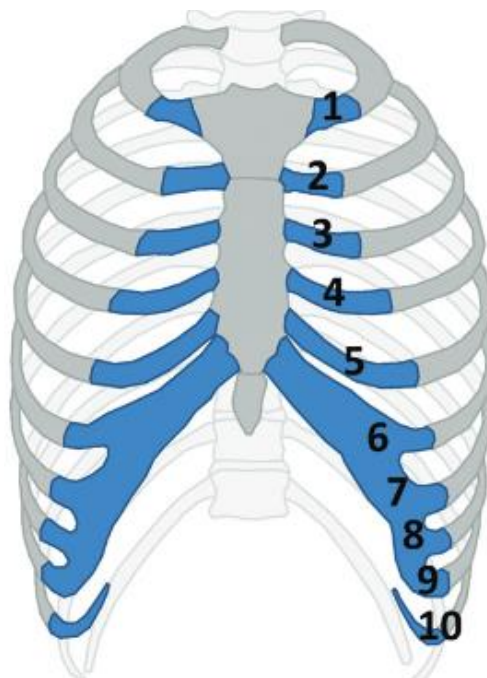


Figure 2.6. The anatomy of CCs (Nummela et al.. 2018)

2.4.4. Supply of thorax

The internal thoracic arteries, which run along the lateral edges of the sternum deep to the costal cartilages, give the majority of blood to the anterior thoracic tissues. In addition, two venae comitantes at the region of the third intercostal gap create accompanying internal thoracic veins that lie medial to the arteries and drain the area via many tributaries (Negri et al., 2002). These intercostal veins travel together with the nerves between the intercostal muscle and the innermost intercostal muscle. The vein, artery, and nerve are placed in ascending order from superior to inferior (Donley et al., 2018). Direct sternal branches without collaterals or collaterals arise from the internal thoracic artery as a single trunk that splits or trifurcates into the sternal branch, anterior intercostal, and anterior perforator (Puri et al., 2007). Those branches emerge from the internal thoracic artery's anterior-medial surface individually or from small trunks 0.5–12 mm long (Rigaud et al., 1998). The way they branch into the intercostal areas to deliver blood to the sternum classifies differently (Berdajs et al., 2006). Females have more sternal and perforator branches to feed the breast tissue, while men have more sternal and intercostal branches (Itezerote et al., 2017).

In contrast to the lower section of the sternum and xiphoid, the upper four intercostal areas have the most collaterals (86%) (de Jesus and Acland, 1995). The presence of a posterior intercostal continuation separate from the internal thoracic artery may assist in the maintenance of certain sternal blood circulation (Gupta et al., 2002). In addition, many sternal arteries subdivide and tri-furcate before entering the sternum, creating an arterial arcade beside the sternum after forming anastomosis (Openshaw et al., 1984). The sternum receives lots of good blood due to this arterial configuration (Gupta et al., 2002). When the internal thoracic artery elevates off its usual position, there is a possibility that flow to the sternum will be impaired (Seyfer et al., 1988). The posterior intercostal veins drain into the azygos or hemiazygos veins, while the anterior intercostal veins drain into the internal thoracic or musculo-phrenic veins. The thoracic wall's lymphatics flow into the parasternal and intercostal lymph nodes. The high thorax's para-sternal lymph nodes and intercostal lymph nodes empty into the broncho-mediastinal trunk. In contrast, the bottom thorax's intercostal lymph nodes flow into the thoracic duct (Berdajs et al., 2006). The 11 intercostal and subcostal nerves, which emerge from the anterior rami of spinal nerves, are the main sources of the nerve supply of the chest wall. A dermatome and a myotome supply by

each intercostal nerve (Clemens et al., 2011).

2.5. Image Analysis

The image analysis methods create to allow quantitative analysis of microscopy data. The essentials of image analysis are covered, comprising program setup, data input, image analysis capabilities, and analysis techniques for getting data from microscope data using ImageJ. In addition, the book includes step-by-step instructions for assessing subjects in a fluorescence image and collecting data from two-color tissue images obtained by bright-field imaging (Hartig, 2013).

2.6. CT Imaging and Reconstruction of the Images in CT Imaging

A range of imaging modalities use to scan the thorax, comprising chest radiography (CXR), computer tomography (CT), and magnetic resonance imaging (MRI) (Wehrli et al., 2007; Well et al., 2007). Reconstructed CT images in three dimensions (3D) from axial scans may be helpful (Alkadhi et al., 2004). In analyzing the thoracic cage's three-dimensional shape. In contrast to lateral chest X-ray images, the current employed CT plain and reconstructed photographs of the thorax to analyze the structures. The thorax in the sagittal perspective was employed to analyze the structures because it gives better visibility of the sternum and vertebral column. The current review research used an axial segment of the thorax at the xiphisternal level to analyze the form of the thoracic cage as it ages. Various investigators had used CT axial scans to estimate the chest's thoracic index and radiological marker by classifying the antero-posterior diameter by the lateral diameter at three thoracic levels the manubrio-sternal junction. The diaphragmatic dome and the midpoint among these two different levels (Howatt and DeMuth, 1965; Joshua et al., 2014; Kangarloo, 1988; Scammon, 1927; Takahashi and Frost, 1966). Chang et al. conducted 3D reconstructions of multi-slice CT scanned in pediatric participants after Ravitch thoraco-plasty and measured the volume of ossification in the costal cartilage by eliminating the bony thoracic cage correct software window settings (Chang et al., 2007). Automatic segmentation and reconstruction of the ribs and ossified sternbrae were performed on each transversal plane using Avizo software (V5, VSG, USA), with further manual corrections at the boundaries of the sternbrae margins. The costal cartilages were manually segmented to analyze both their form and their connection with the sternum.

2.7. ImageJ and Its Use

ImageJ is a commonly used image analysis program in the biological sciences and beyond. ImageJ attracts non-programmers, amateur programmers, and experienced developers equally due to its ease of use, recordable macro language, and flexible plug-in structure. Allowing such a wide range of contributors has resulted in a vast community comprising biological and physical fields (Rueden et al.. 2017). Wayne Rasband of the National Institutes of Health (NIH) created ImageJ, an image processing platform frequently referenced (Schneider et al.. 2012). Since its beginning in 1997, ImageJ had shown to be helpful in a wide variety of technical undertakings and projects, especially in the natural sciences (Arena et al.. 2017)



3. MATERIAL AND METHODOLOGY

This methodology consisted of the way and strategies demonstrated to compare attachment of the angle of costal cartilages with the sternum. This part has also covered research design, study population, testing procedure used, data collection, and data analysis methods. Furthermore, it also presents theoretical and actual epistemological directions of comparing the angle measurements of costal cartilages.

3.1. Study Design

The study has conducted to descriptive study based on generally quantitative research to compare measuring angles of costal cartilages with the sternum. These measurements, including costal cartilages of males and females, comprise the following costal cartilages, C 1, C 2, C 3, C 4, C 5, C 6, C 7. Therefore, this study Design has directly connected to the correlation or comparison of male-female costal cartilages angle attachment with the sternum.

3.2. Sample Methods

The sample size is the subset of the population study, which is they have selected the different patients visited in Karabük university hospital. They had referred with a suspicion of multiple chest illnesses for radiological imaging. The patients' data of CT scans gained with the permission of assistant Professor Zülal Öner, which done this thesis, applied to the non-interventional clinical research ethics committee of Karabük University. CT scan data retrieved from the archive system databases. The total number of the study population was 73 of took CT scan, but 10 CT scan was not clear images, then we have got finally get 63 sample size out of 73. The sampling procedure was non-probability sampling was selected particularly Purposive sampling (judgment) selected samples used with researchers' own decision (purposive).

3.3. Ethical approval

This study must eventually involve humans as participants required for significant medical development. Even after approval has been gained, the researcher maintains the ethical values essential to secure study subjects(Bain, 2017). All academic studies should be proposed to and authorized by an ethical committee, according to the guidelines. Before the study begins, the study design must report to an institute for review, debate, guidance, and acceptance. As a result, getting ethical

approval should be an ethical reflex for investigators, particularly in healthcare. Study subjects in proper research accept risks. That requires the research effort to seek the maximum level of appreciation for the sacrifices made by others in the interest of science (Munung et al., 2011). Many Research Ethics Committees (RECs), or Institutional Review Boards (IRBs) in other areas, are multidimensional in a form to adequately determine the different parts of the field of study under review (Tijdink et al., 2014). RECs could help bring these problems to the attention of the study team. Getting ethics approval is essential in doing scientific research (Ana et al., 2013). NECs are responsible for maintaining a database of smaller RECs, identifying their field of competence, and monitoring institutional capacity (Bain et al., 2018). In the Hippocratic tradition, medical ethics and ethical concepts have been applied and discussed for decades. Still, ethical human research guidelines, preservation ideas, policies, regulations, and protocols have only recently been established and slowly embraced or modified (Artal and Rubinfeld, 2017).

This study used images of Associate Professor Zülal Öner, which done her study applied to the non-interventional clinical research ethics committee of Karabük university and approval with official document numbered 6 -19 on date 5-7-2017. And we obtained written permission from Dr. Zülal Öner for our research. After the approval of the ethics committee, the total cases were 63, 31 males and 32 females. The images have obtained from the radiological imaging center of the radiology department in Karabük University. The images had used for thoracic computed tomography (CT) images of 2 mm section thickness. Images were taken from Karabuk University on Compact Disc (CD). Radiological images initially opened through Horos V2. Horos is an open source, user friendly and reliable application for radiological imaging. Images of individuals with congenital deformities such as Kyphosis and Scoliosis and individuals with a history of thoracic surgery were not included in the study.

3.4. Collection Procedure

It is essential to start that our raw data of scan photography from the archival system of image databases had processed to get the visible image that can open in Personal Computer (PC) using software Horos for MAC. The raw data of CT scan from an archival program of the database were processed using a system defined as Horos, which has DICOM medical image viewer for MAC.as shown a Figure. 3.1.

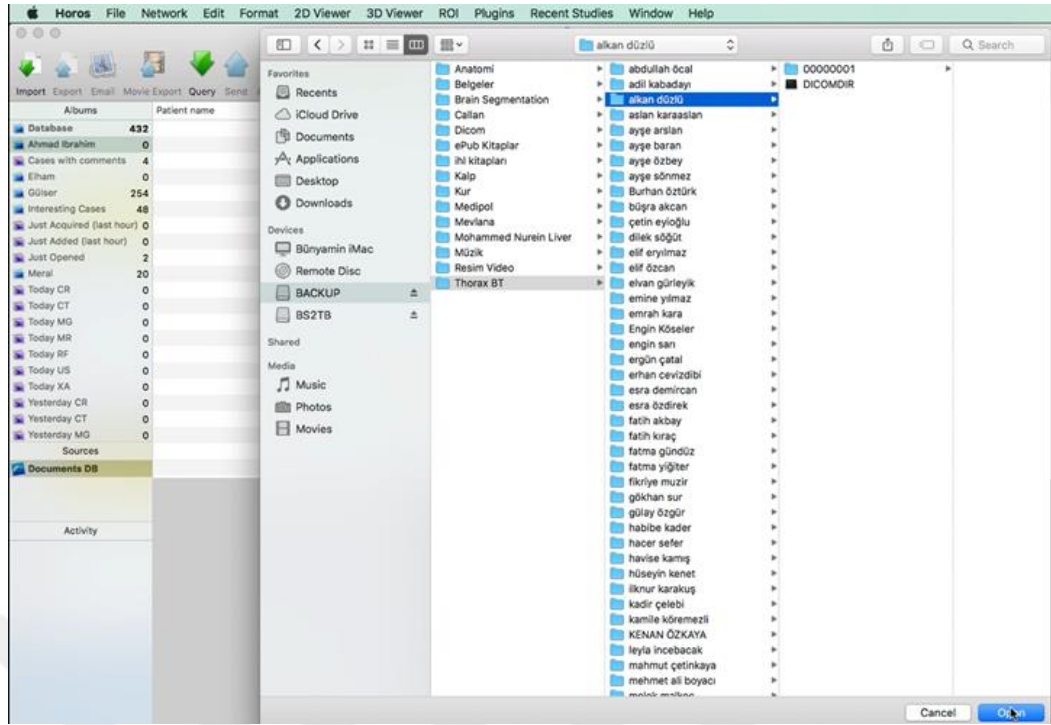


Figure 3.1. Horos software produces 3D medical imaging

The selected file is opened and copied in the case of imported images saved in the folder. The backup and BT chest images had chosen after opening the file, or the images have open as copy files. The section images have then opened in various thicknesses, for example, localizers 5 mm and 2 mm, and the section technique of 2 mm thickness have selected. Finally, the images were exported in DICOM format and saved in a folder, as shown in Figure 3.2.



Figure 3.2. The section with a thickness of 2 mm had used to export the image.

There were three different cross-sectional images in the opened 3D viewer tools, and the images with the proper thickness have selected to export. The re-orientation of the images has adjusted to the spine process of the vertebral column. The three adjusted images had carried to MPR. 3D MPR the radiant DICOM Viewer has a 3D MPR tool used to reconstruct pictures in any plane (oblique). That can aid in designing anatomical images that would be impossible to achieve using only basic images (Beraud et al., 2009). three prepared lined images had adjusted after the visual images had pressed. The sternum was located by moving the midline a little down and up; the sternum and spinal column were all in the same plane, which seems to be the sagittal plane. The single image had been prepared and processed, as presented in figure 3.3.

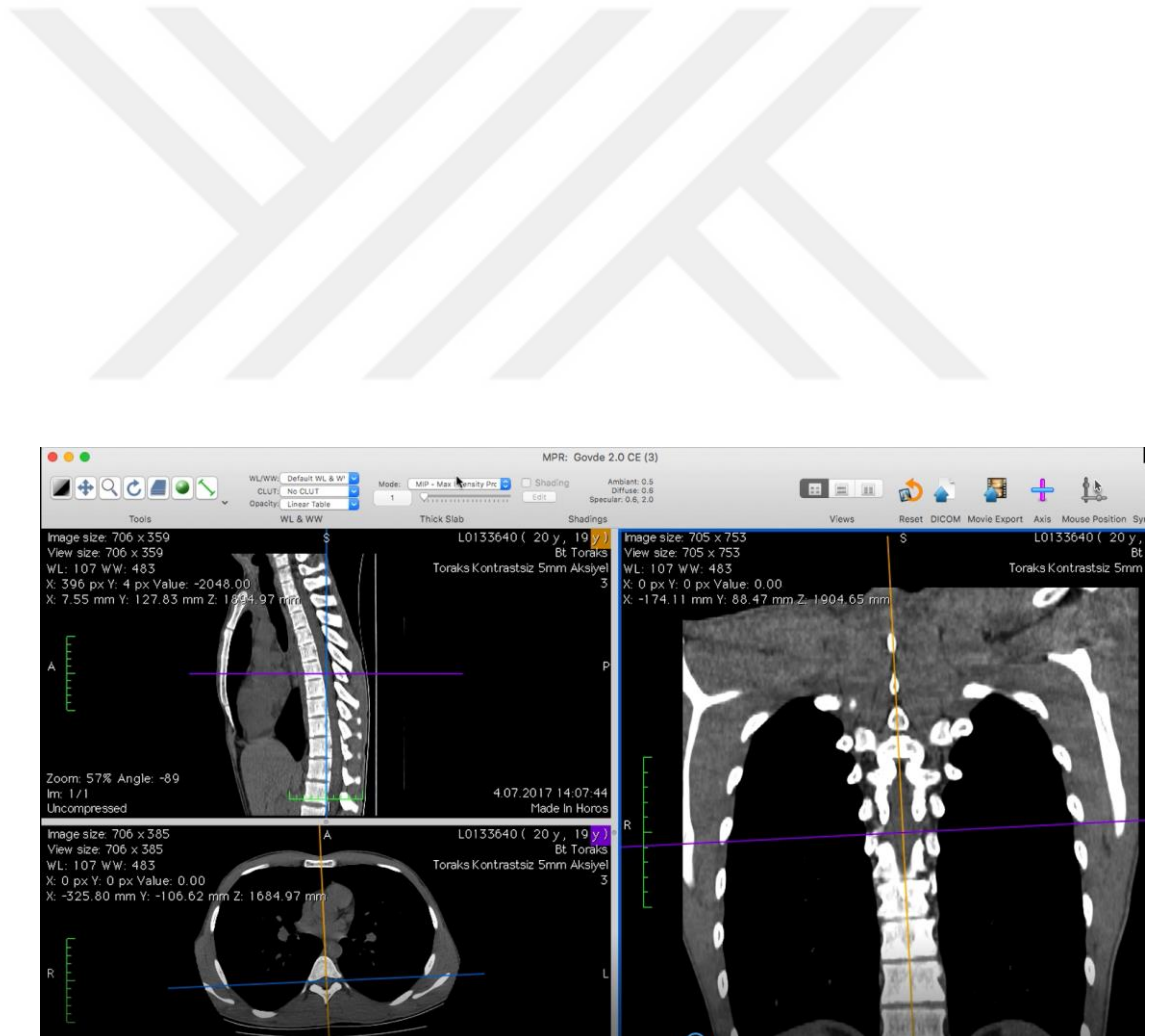


Figure 3.3. Adjusted images through Horos software procedure

Different images had adjusted for each perspective. The adjusted lines on the spinous process of the vertebra column in coronal view. The sternum and vertebrae

column has done the same line in the transverse view and sagittal view. On the same line, the manubriosternal angle will be to the area between T4 and T5. After adjusting whole section view images, the section techniques optimized, and the borders in the sagittal view have shifted forward. In contrast, the costal cartilages in the coronal view have made more visible, as shown in figure 3.4.

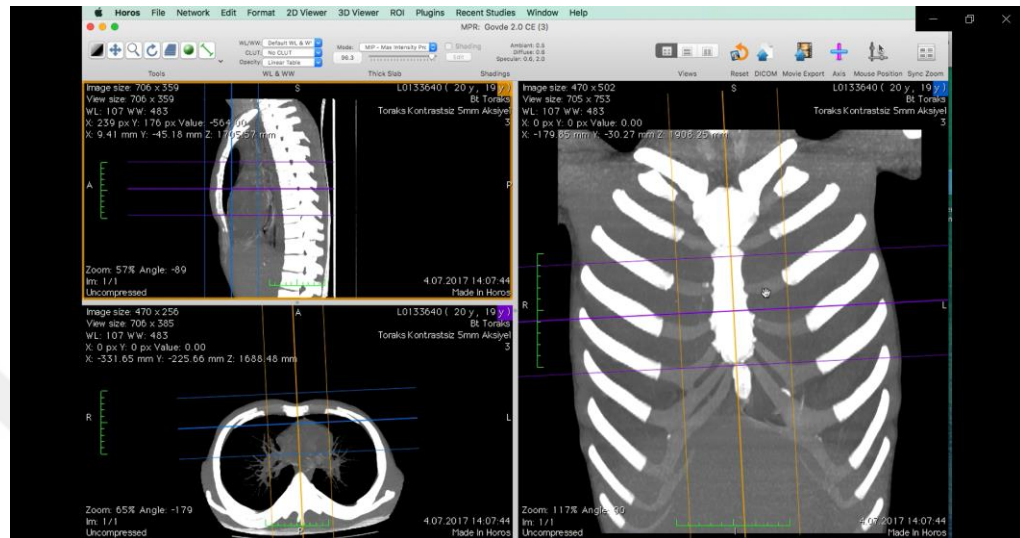


Figure 3.4. Adjusted Different views of images

The adjusted images have exported, and the second procedure started to make image analysis. A slightly reoriented section view was created first, with the lines straightened and perpendicular to the center of the sternum, then reoriented. Finally, exported images have taken with the coronal view to measure the angle of the costal cartilages, as presented in below figure 3.5.

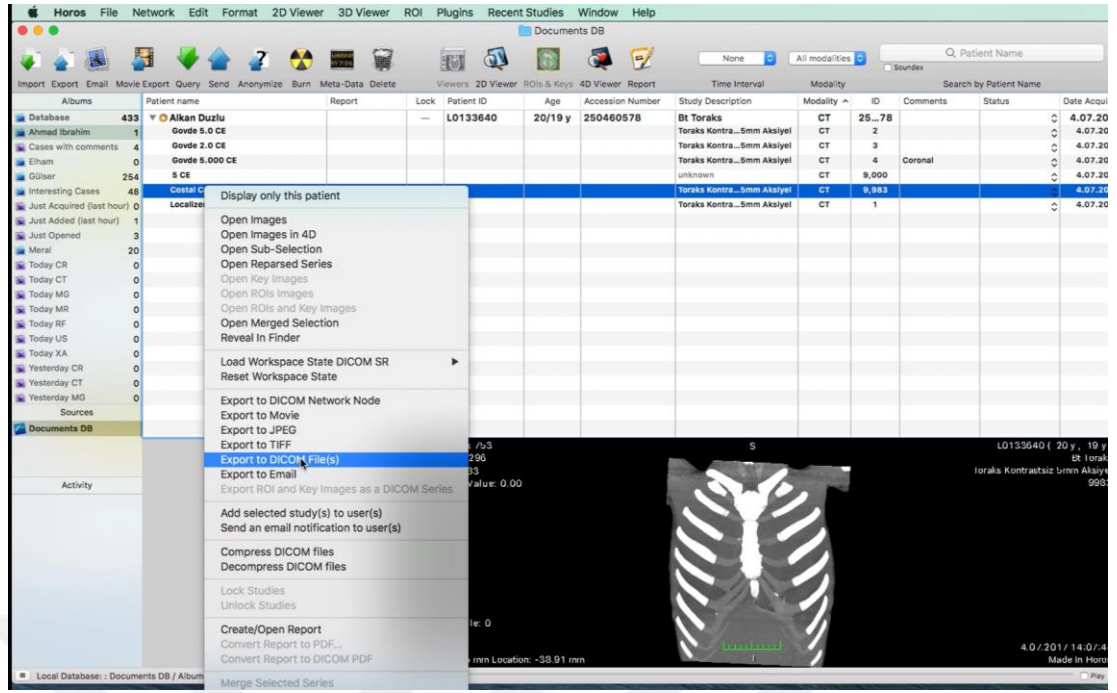


Figure 3.5. The Exported view section via Horos software

3.4.1. Processing of ImageJ Analyzer

The ImageJ analyzer is the second procedure used to analyze the exported images. After prepared and exported the ImageJ processing protocol using image different Dicom files. By taking some steps to examine and measure the angle of the costal cartilages, the cross-sectional view was adjusted primarily for the set measurement, as shown in figure 3.6.

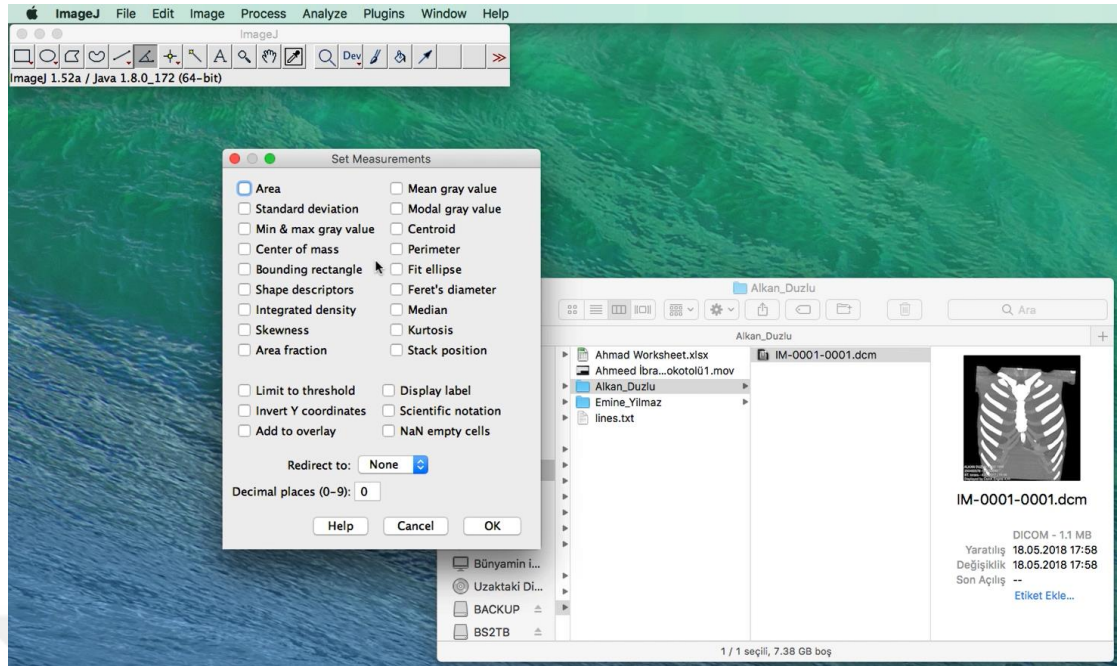


Figure 3.6. The adjusted image through the set measurement

After this adjustment, the window started analyzing the exported image, opened the ImageJ, and selected the exported image under the opened ImageJ processing procedure for more adjustment. The analyzed image, the ImageJ, was selected for well preparing the images. Another procedure called window level was perfecting for more visible and more measured attachment of costal cartilages with the sternum, as shown in figure.3.7.

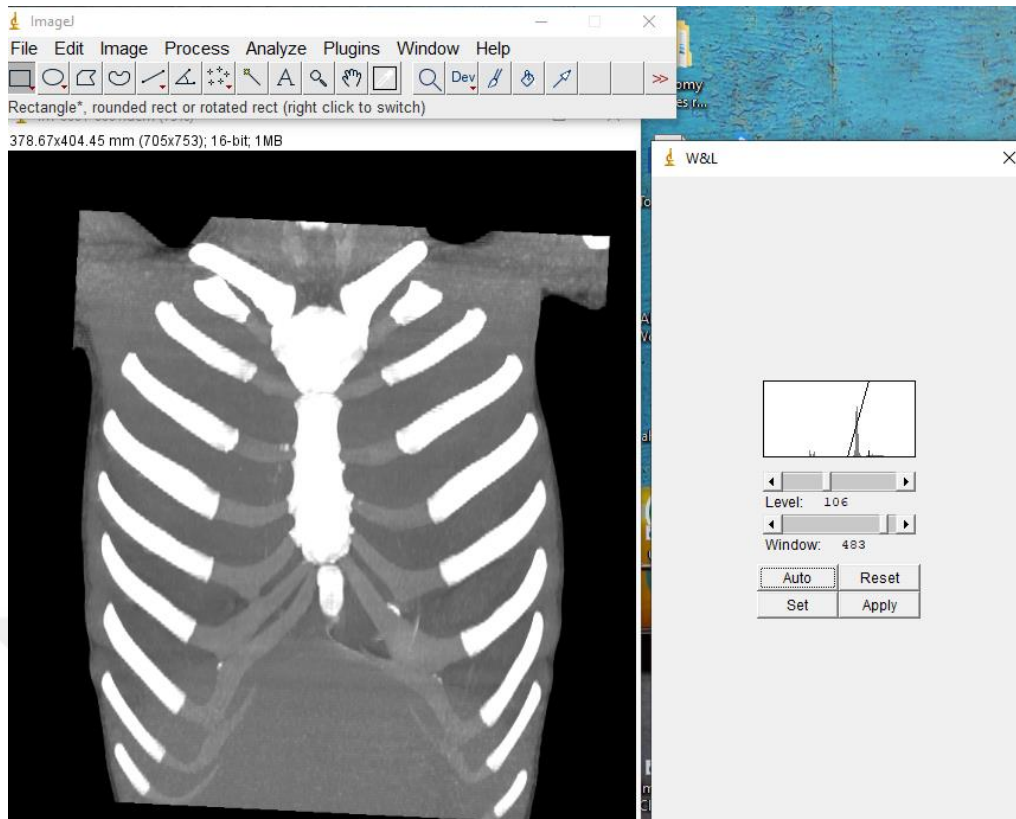


Figure 3.7. The adjusting of the image section by the window level

Before analysis and measurement, the image measured from the suprasternal notch of the manubrium to the junction between the body of the sternum and the xiphoid process line was straight the image has measured. The image opened by adjusting the view by tilting it to the left; then, the image rotated by selecting the transform and adjusting to the image and Figure 3.8. After adjusting the image through the rotation of the side, but shifted to the left is more perfecting, click the shortcut letter M of keyboard or select the measure of image process procedure.

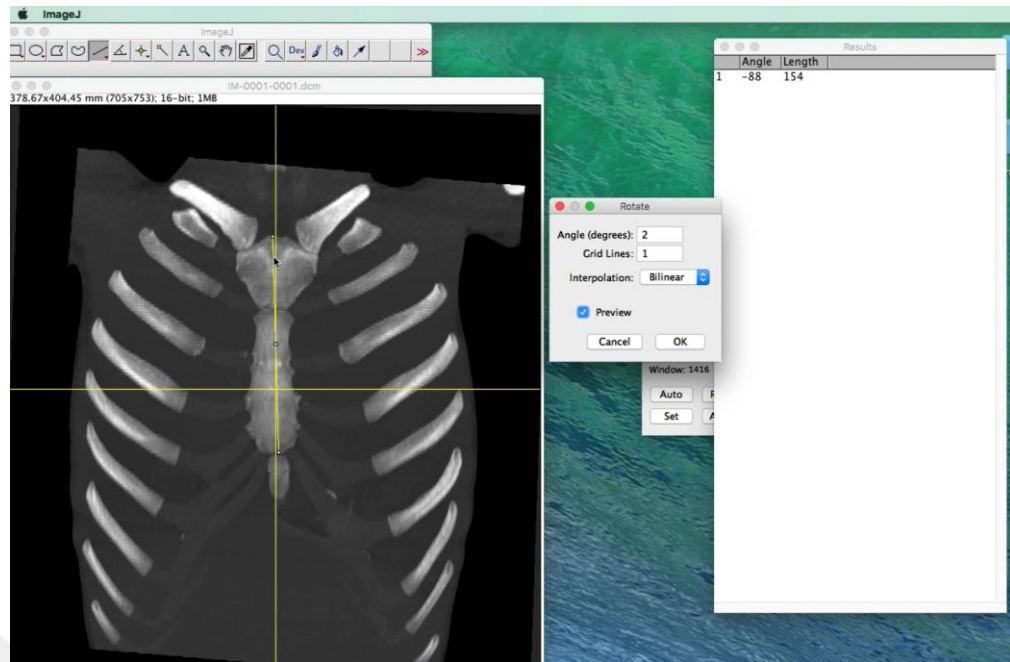


Figure 3.8. Adding the two positive points

When adjusting the image plugins and were selected text lines, the superimposed stated lines and the orientation of the lines were perpendicular to the sternum. The purpose of these lines was to measure the attachment of the costal cartilages with sternum correctly, as shown in following figures 3.9. and figure 3.10.

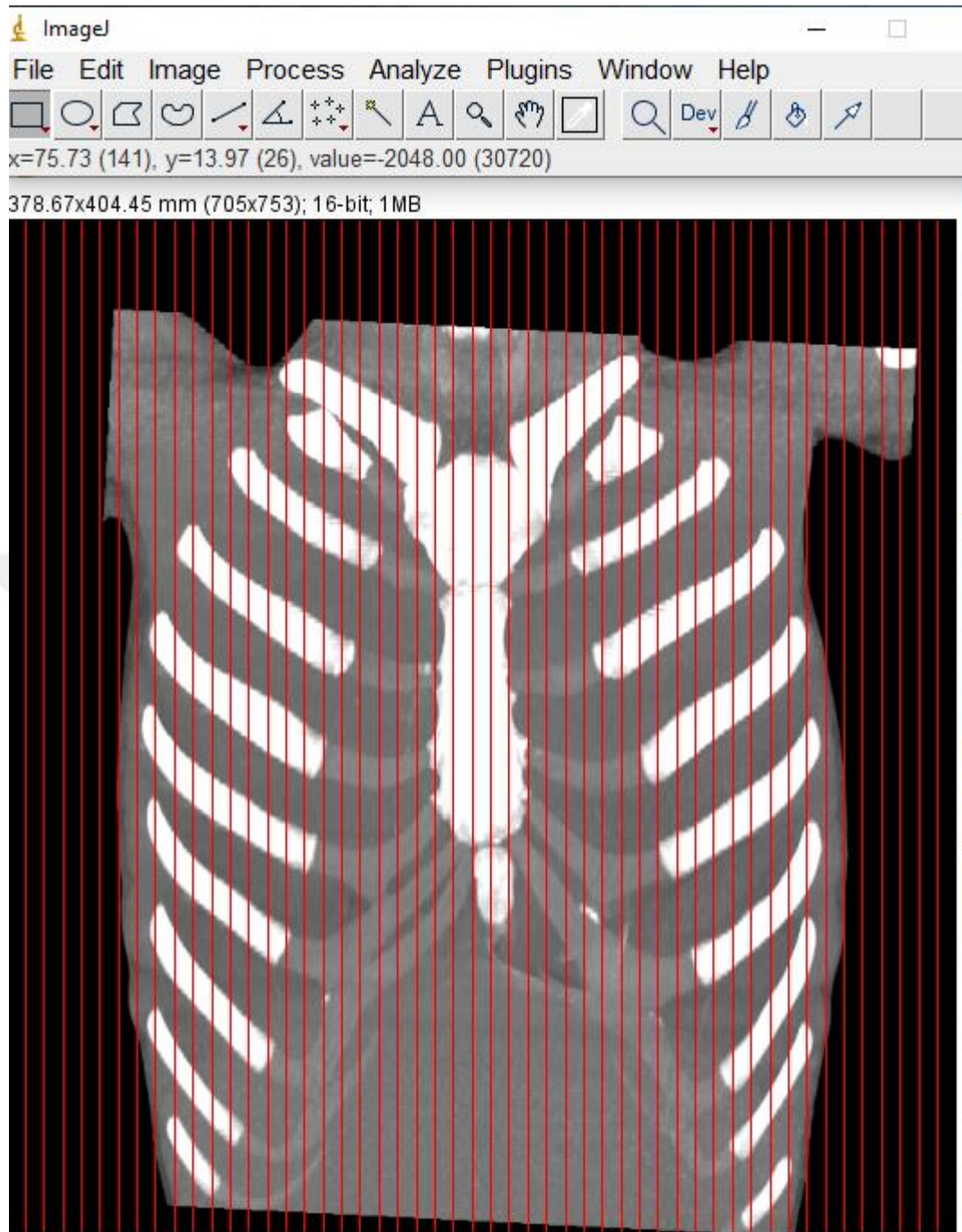


Figure 3.9. Superimposed Stated lines on Sternum, Ribs and Costal cartilages for Measuring the costal cartilages with sternum.

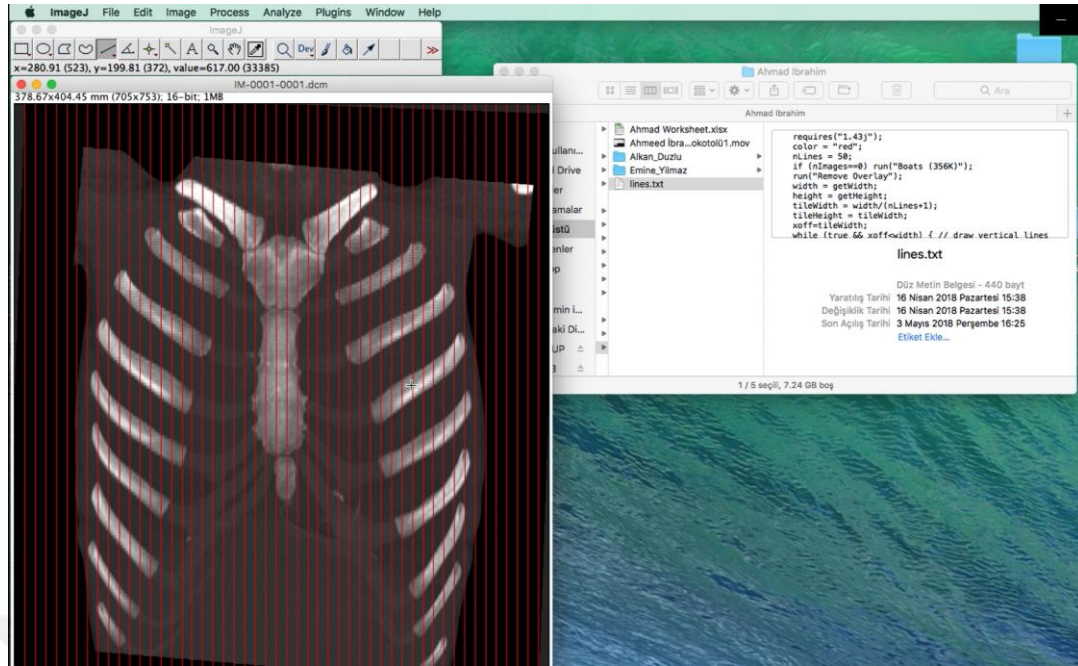


Figure 3.10. Superimposed Stated lines on Sternum, Ribs, and Costal cartilages for Measuring the costal cartilages with the sternum.

3.4.2. Using available CT scan images, measuring the angle of the costal cartilages.

The costal cartilages' measuring angle determines the superimposed lines that are stated to the center of the sternum and used for ImageJ processing angle measurement. To start from the first to seventh costal cartilages, to measure the appropriate costal angle started the junction of costal with costal cartilage or middle of costal cartilage and crossing to the middle of articulation of costal cartilages with the sternum. This line was crossing two to three perpendicular lines. After adjusting measurements with ImageJ angle measuring, the results were put in an excel worksheet by a direct click of the M keyboard or measure of ImageJ processing procedure as shown in figure 3.11.

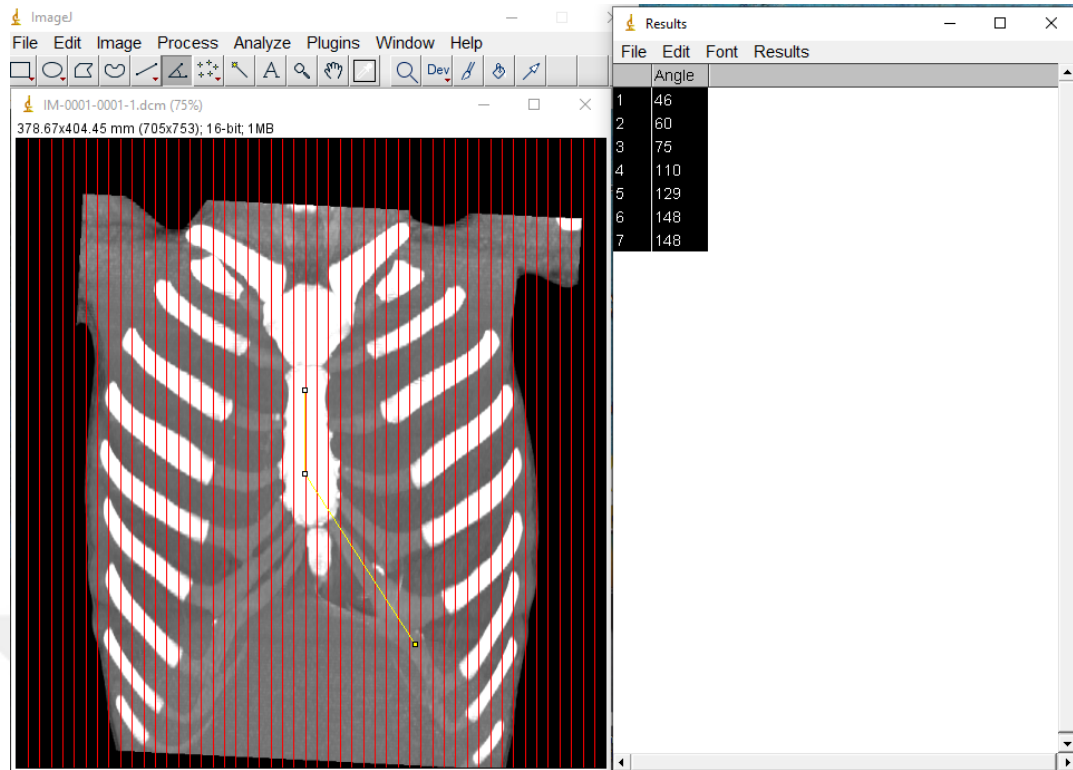


Figure 3.11. Angle measurement of costal cartilages using perpendicular state lines on an image

During the angle measurement of the costal cartilages, the measurements were repeated three times in each image. In addition, the angle measurements of the costal cartilages with the sternum were done and repeated three times for each mean. These measurements were copied to the Excel worksheet for both men and women, as presented below in figure 3.12 and figure 3.13.

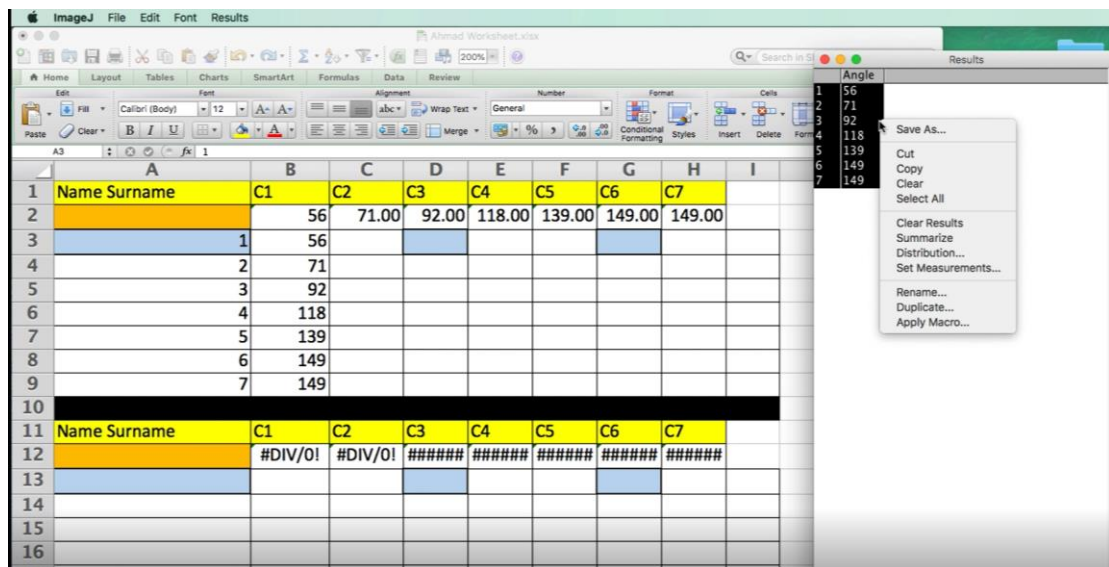


Figure 3.12. The angle measurements of the costal cartilages in the excel worksheet

a	Name Surname	C1	C2	C3	C4	C5	C6	C7	
	Alkan Duzlu	60.3333	73.67	86.67	114.00	136.00	145.67	147.33	
	1	63		1	64		1	54	
	2	78		2	70		2	73	
	3	84		3	86		3	90	
	4	111		4	115		4	116	
	5	136		5	137		5	135	
	6	146		6	145		6	146	
	7	148		7	147		7	147	

b	Name Surname	C1	C2	C3	C4	C5	C6	C7	
	Elif Ozcan	60	95.67	101.67	113.67	128.33	138.00	137.67	
	1	57		1	63		1	60	
	2	98		2	95		2	94	
	3	102		3	101		3	102	
	4	113		4	116		4	112	
	5	128		5	129		5	128	
	6	138		6	138		6	138	
	7	139		7	135		7	139	

Figure 3.13. Findings of angle measurements for a) male and b) female

3.5. Statistical Analysis

Data expressed for descriptive statistics such as mean and standard deviation using frequency and percent with tables and graphs. The sample size was (N=63) CT scan images were taken for patients who visited radiological department in Karabük university hospital. So, the male was 31, while female 32 out of 63, that means each had percentage of 49.3% to 50.7% respectively. The independent sample t-test has used to compare the standard distribution data between groups, and two-way repeated-measures ANOVA has used. Categorical variables have presented as a count and percentage, and Pearson correlation coefficient between variables. In addition, the Intraclass-correlation coefficient has been calculating as repeated measures. A P-value <0.05 was considered significant. Analyses have performed using SPSS version 22 (IBM SPSS Statistics 22, SPSS inc., an IBM Co., Somers, NY).

3.6. Limitations of this Study

The first limitation of this study was not Quantify the Causality, but the study only measured attachment angle of costal cartilages with sternum and comparison both sexes. Secondly unknown collected date of the images, this image was collected from archives of Karabuk University hospital with unknown time scope. Instead, only retrieved images were measure the angle of costal cartilages between sex. Also, the sample size of this study was (n = 63), it might be considered relatively small. Therefore, the need for future research to work on a large sample.

4. RESULTS

In this study, the prediction was there is no difference in attachment angle of costal cartilages in males and females. So that, the independent variable was attachment angles of costal cartilages. In comparison, the dependent variables were gender (male and female). These findings had collected for measurements of the first seven costal cartilages attachment with the sternum. Male and female with sample size 63 were obtained of images in Computed tomography (CT) in three dimensions and then measured the angles. The data analysis has divided into different parts based on measurement of costal cartilage angles to the sternum by counting seven ribs, three times each. 1. Initial costal angle measurement (C 1, C 2, C 3, C 4, C 5, C 6, and C 7). 2. Reanalysis costal angle measurement (RC 1, RC 2, RC 3, RC 4, RC 5, RC 6, and RC 7). 3. Correlation of costal angle measurement with gender (C 1, C 2, C 3, C 4, C 5, C 6, and C 7). 4. Reanalysis correlation costal angle measurement with gender (RC 1, RC 2, RC 3, RC 4, RC 5, RC 6, and RC 7).

4.1. Initial costal angle measurements (C 1, C 2, C 3, C 4, C 5, C 6, and C 7).

The initial measurements of costal cartilages and measurements had analyzed in the first seven costal cartilages (C 1, C 2, C 3, C 4, C 5, C 6, and C 7). As mentioned early, first used retrieval of data from archival system to Horos, ImageJ processing analyzed and then data analyzed in SPSS to present in tables and figures. The measurement of Costal cartilage of ribs angle with the sternum was done three times to each rib.

Table 4.1. findings presented intra-class correlation about angle measurements of costal cartilages from C 1 to C 7 and following findings of intra-class correlation values for repeated measurements of costal cartilages with not respect of gender and intra-class correlation indicates us following measurement scale, for instance. If, the result of Intra-class correlation (ICC) is valued less than 0.5 is poor, ICC value is between 0.5 – 0.75 it is moderate, the value ICC is between 0.75 – 0.9 it is good. Lastly, if the value of ICC is greater than 0.90, indicating excellent reliability (Koo and Li, 2016). First C 1 intra-class correlation is 0.779, indicates the reliability was “good”, the second from (C 2, C 3, C 4, C 5, C 6 & C 7) their intra-class correlation were 0.947, 0.973, 0.980, 0.974, 0.989 & 0.994 respectively, all these intra-class

correlations indicate “excellent reliability”.

Also, the tables have the average of each three repeated cases; for example, every Initial costal cartilage (C 1) has three times testing to remove data biases. So as table presented; the C 1 average was 62.58 with a standard deviation of ± 7.89 . Other costal cartilage (C 2 – C 7), All had average mean (83.96, 95.32, 113.12, 126.84, 136.08 & 138.17) with standard deviation (± 7.47 , ± 10.33 , ± 10.99 , ± 10.31 , ± 10.08 , & ± 9.54), respectively. That indicates the angle of the first costal cartilage was less than other costal cartilage angles; their difference was the space of angles for increased size according to levels of costal cartilages from C 1 to C 7. Below listed table 4.1.

Table 4.1. Distribution of quantitative variables from initial C 1 to C 7 and their intraclass correlation coefficient

Variables	Intraclass correlation coefficient	Mean $\pm$ SD (degree)	Minimum (degree)	Maximum (degree)
C 1_1	0.779	62.78 $\pm$ 7.5	47.00	80.00
C 1_2		62.41 $\pm$ 9.01	43.00	91.00
C 1_3		62.68 $\pm$ 8.55	44.00	55.00
C 1 Average		62.58 $\pm$ 7.89	45.00	81.33
C 2_1	0.947	83.52 $\pm$ 7.21	69.00	97.00
C 2_2		84.7 $\pm$ 8.4	71.00	106.00
C 2_3		83.71 $\pm$ 7.85	68.00	100.00
C 2 Average		83.96 $\pm$ 7.47	69.67	99.33
C 3_1	0.973	94.97 $\pm$ 10.37	68.00	122.00
C 3_2		95.81 $\pm$ 11.25	66.00	124.00
C 3_3		95.17 $\pm$ 10.16	68.00	123.00
C 3 Average		95.32 $\pm$ 10.33	67.33	123.00
C 4_1	0.980	112.75 $\pm$ 11.55	89.00	136.00
C 4_2		113.08 $\pm$ 11.24	91.00	136.00
C 4_3		112.65 $\pm$ 11.08	85.00	135.00
C 4 Average		113.12 $\pm$ 10.99	89.33	135.67
C 5_1	0.974	126.87 $\pm$ 10.28	99.00	149.00
C 5_2		127.06 $\pm$ 10.52	103.00	149.00
C 5_3		126.70 $\pm$ 11.17	104.00	148.00
C 5 Average		126.84 $\pm$ 10.31	102.00	148.67
C 6_1	0.989	136.21 $\pm$ 10.16	109.00	162.00
C 6_2		135.98 $\pm$ 10.18	110.00	163.00
C 6_3		136.1 $\pm$ 10.27	111.00	163.00
C 6 Average		136.08 $\pm$ 10.08	110.00	162.67
C 7_1	0.994	138.33 $\pm$ 9.54	119.00	165.00
C 7_2		138.37 $\pm$ 9.49	118.00	166.00
C 7_3		137.87 $\pm$ 9.73	118.00	164.00
C 7 Average		138.17 $\pm$ 9.54	118.67	165.00

Source: primary data

The figures below were presented the initial costal cartilages measurement from C 1 –C 7. Figure 4.1. The data explained the means of each costal cartilage angle attachment with the sternum, which presented as graphs determine the distribution of data with a comparison of normal distribution. For example, the result of C 1 repeated (C 1-1, C 1-2, C 1-3) has a mean between 62.78, 62.68 & 62.41 respectively, which have a similarity of data, and predicting better percentage with connecting maximum of 80.

As the first figure, all other figures (Figure 4.2.- Figure 4.7) have presented the mean as a central tendency. The spread of data for normal distribution has increased according to the number of costal cartilages increases; for example, C 1 is less than C 2 concerning the number of means, lower and upper bound (minimum and maximum). That indicates the last costal cartilage angle was high as comparison to other costal cartilage angles, below list figures.

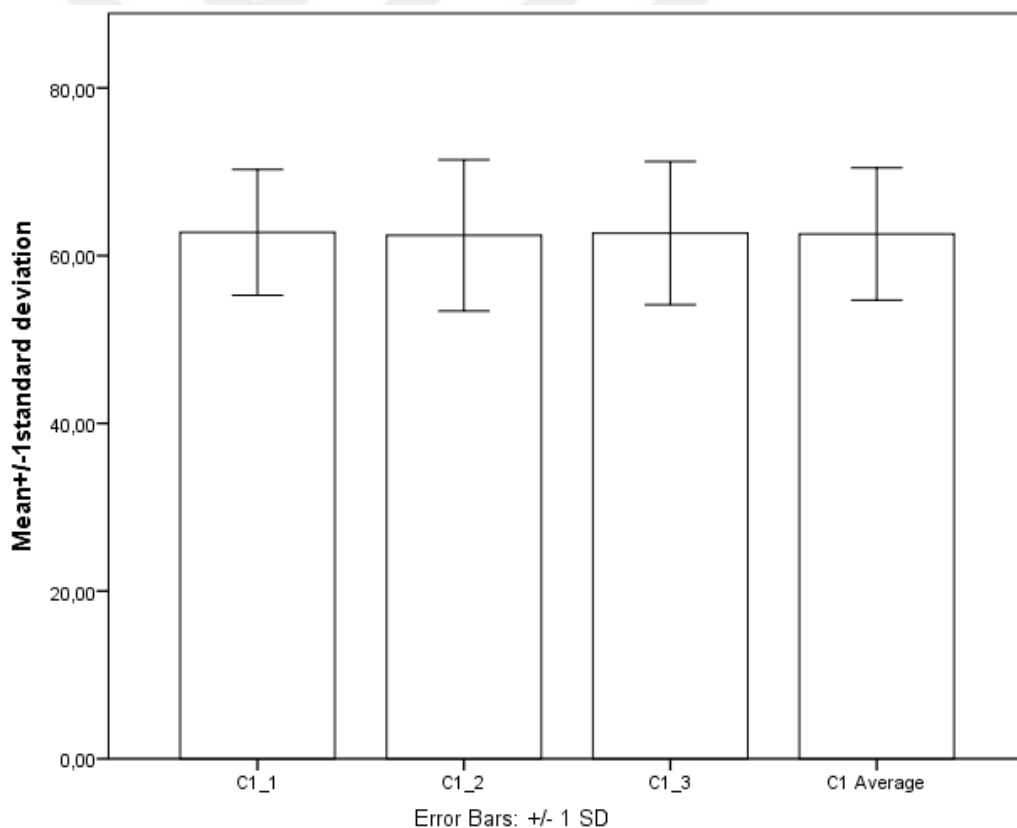


Figure 4.1. Bar graph with +/- 1 standard deviation of the all-repeated measurements

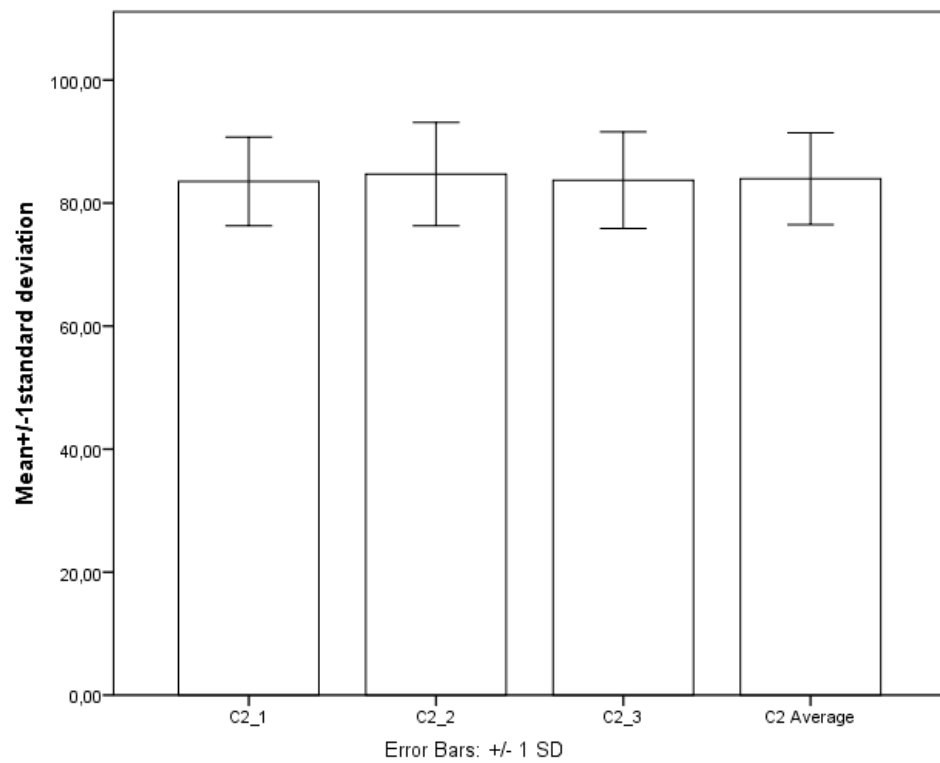


Figure 4.2. Bar graph with +/-1 standard deviation of the all-repeated measurements

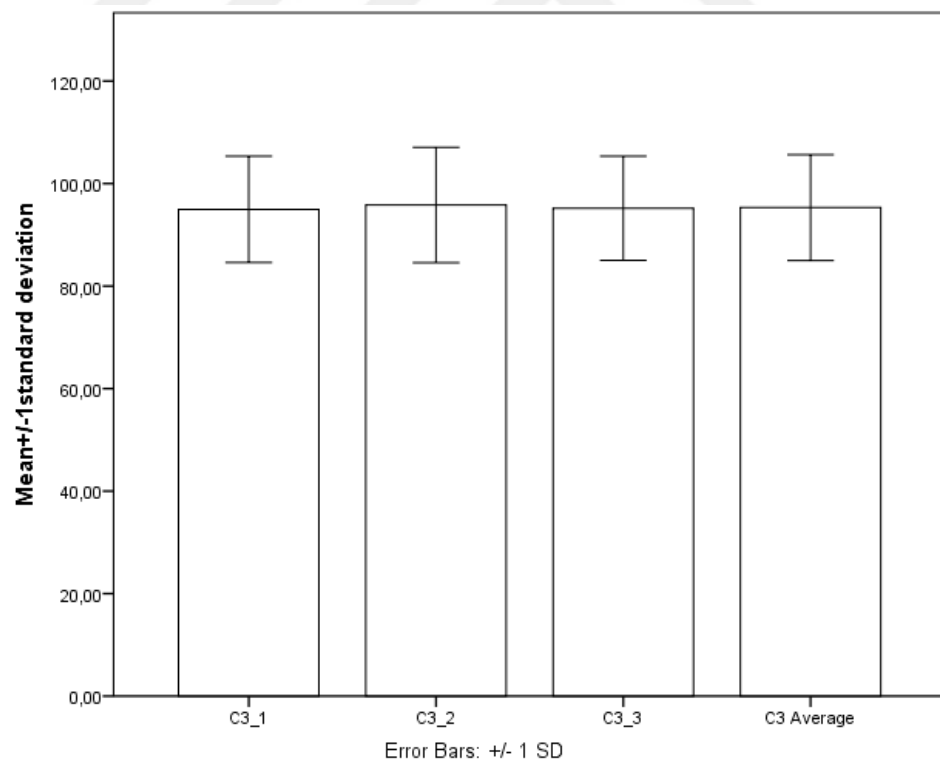


Figure 4.3. Bar graph with +/-1 standard deviation of the all-repeated measurements

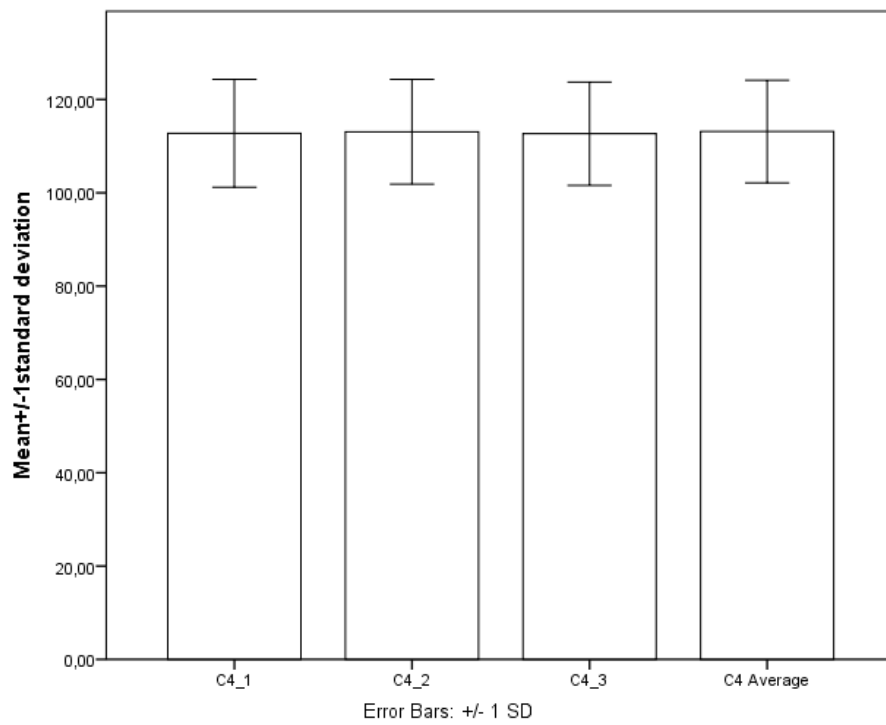


Figure 4.4. Bar graph with +/- 1 standard deviation of the all-repeated measurements

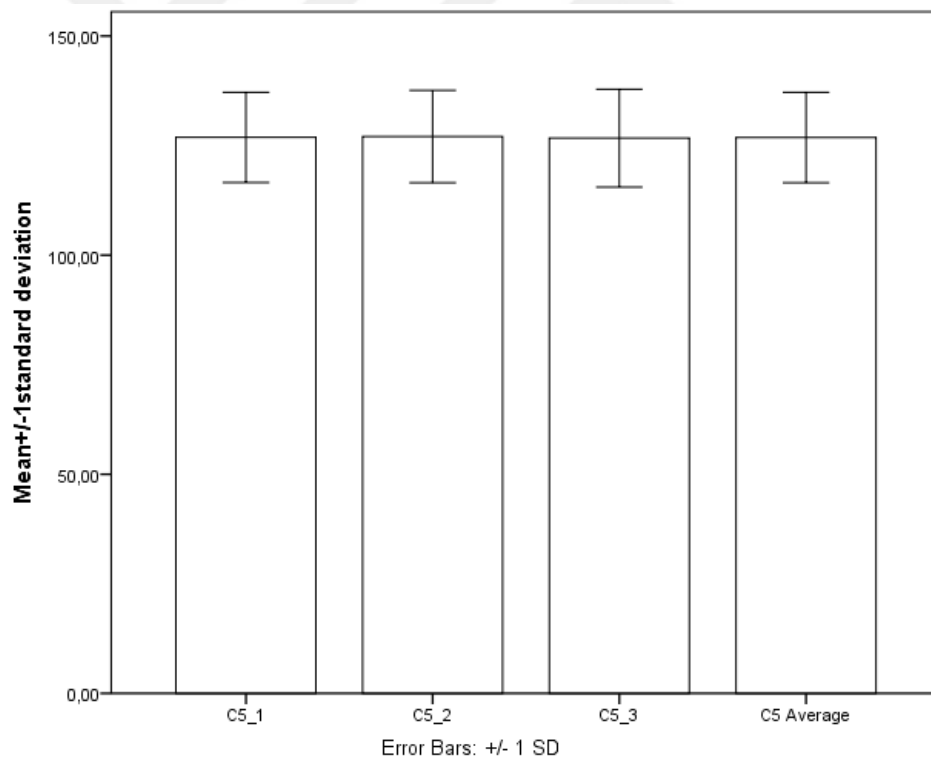


Figure 4.5. Bar graph with +/- 1 standard deviation of the all-repeated measurements

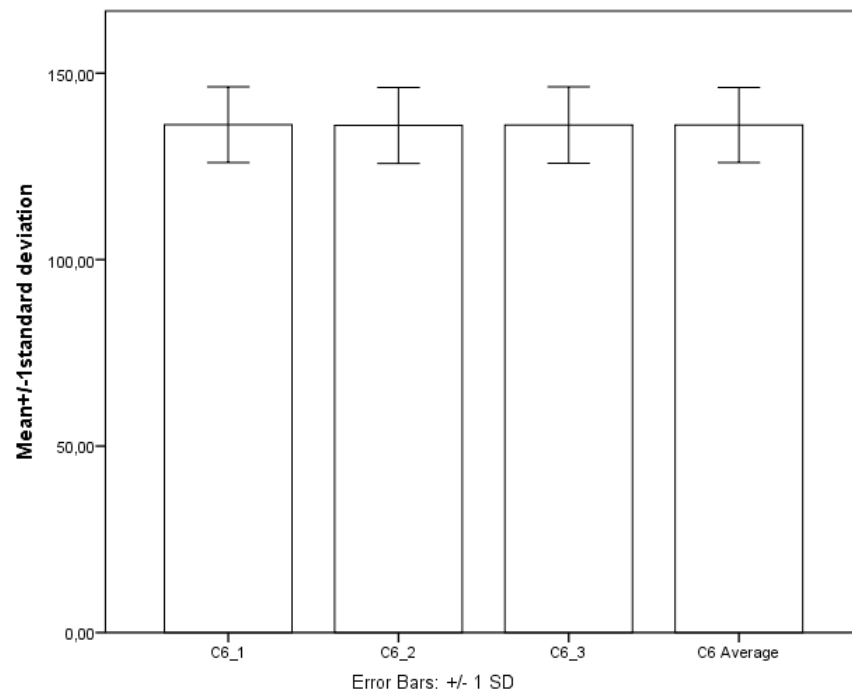


Figure 4.6. Bar graph with +/-1 standard deviation of the all-repeated measurements

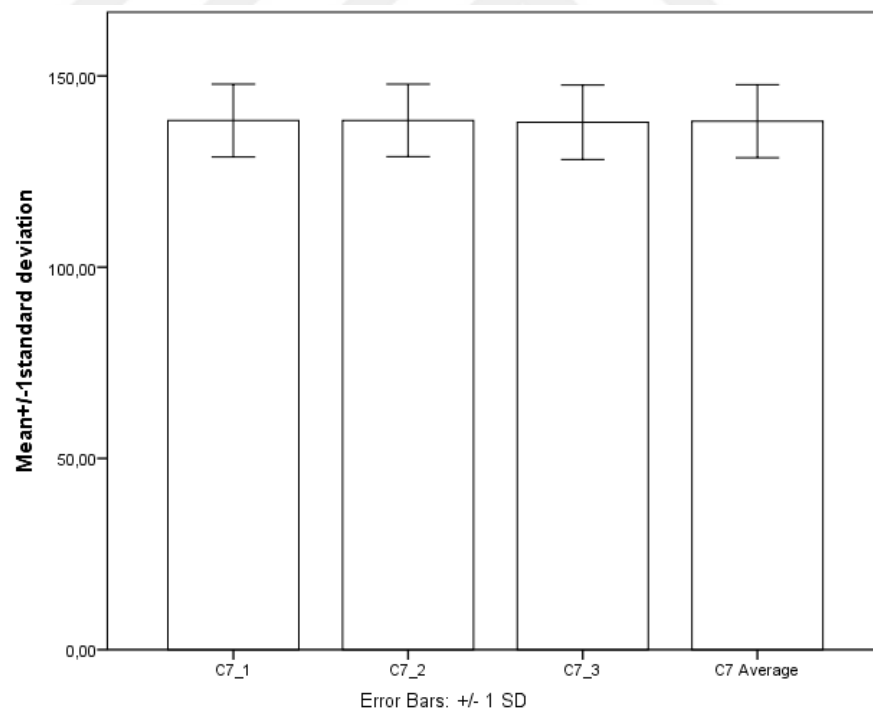


Figure 4.7. Bar graph with +/-1 standard deviation of the all-repeated measurements

4.2. Re-analysis costal angle measurement (RC 1, RC 2, RC 3, RC 4, RC 5, RC 6, and RC 7).

The re-analysis had made to the attachment angle of costal cartilages for the first seven costal cartilages (RC 1, RC 2, RC 3, RC 4, RC 5, RC 6, and RC 7). With the same methods as mentioned, by using ImageJ processing analyzed. These measurements were done for repeated measures three times for each costal cartilage. The table same as above in table 4.1, but for the validation of data re-analyzed again. Table 4.2. The Intra-class correlation (ICC) presented the RC 1 had reached excellent reliability when comparison the initial costal cartilage was good. While other data still had the same percentage of ICC when compare to the initial intra-class correlation. They had an intra-class correlation above 0.90, which indicates excellent reliability.

The average re-analysis of costal cartilage (RC 1) had less mean and standard deviation than initial costal cartilage (IC 1). And other seven costal cartilage angles have so similar. All data of costal cartilage angles were measured three times from RC 1 up to RC 7 are shown in the following Table 4.2.

Table 4.2. Distribution of quantitative variables RC 1 to RC 7 and their intraclass correlation coefficient

Variables	Intraclass correlation coefficient	Mean±SD (degree)	Minimum (degree)	Maximum (degree)
RC 1_1	0.933	59.68±6.73	48.00	78.00
RC 1_2		60.38±6.68	44.00	74.00
RC 1_3		59.89±6.64	45.00	78.00
RC 1 Average		59.98±6.28	47.67	74.33
RC 2_1	0.958	83.05±9.62	65.00	109.00
RC 2_2		83.09±9.09	66.00	105.00
RC 2_3		83.8±9.92	64.00	111.00
RC 2 Average		83.35±9.16	65.33	106.67
RC 3_1	0.986	95.02±11.4	72.00	124.00
RC 3_2		95.39±11.01	74.00	119.00
RC 3_3		95.55±11.05	74.00	125.00
RC 3 Average		95.32±11	74.33	122.67
RC 4_1	0.992	112.95±10.6	89.00	133.00
RC 4_2		114.3±10.67	90.00	136.00
RC 4_3		113.95±10.48	91.00	136.00
RC 4 Average		113.73±10.42	90.00	135.00
RC 5_1	0.979	127.57±9.47	105.00	145.00
RC 5_2		128.41±9.56	106.00	147.00
RC 5_3		127.57±9.13	105.00	144.00
RC 5 Average		127.86±9.19	105.33	144.33
RC 6_1	0.990	136.54±9.88	113.00	160.00
RC 6_2		135.82±9.5	114.00	157.00
RC 6_3		136.34±9.99	110.00	161.00
RC 6 Average		136.23±9.69	112.33	159.33
RC 7_1	0.991	138.66±9.16	120.00	161.00
RC 7_2		138.82±8.95	119.00	158.00
RC 7_3		138.63±8.81	118.00	158.00
RC 7 Average		138.7±8.89	119.00	159.00

Source: Primary data

Figures presented in the Re-analysis were as simplifying data; in Table 4.2, shown using a Bar chart. The arranged Bar chart indicates each, for example, Figure 4.8, figure 4.9, figure 4.10, figure 4.11, figure 4.12, figure 4.13, figure 4.14, presented below as a bar chart with a mean maximum or minimum level of data.

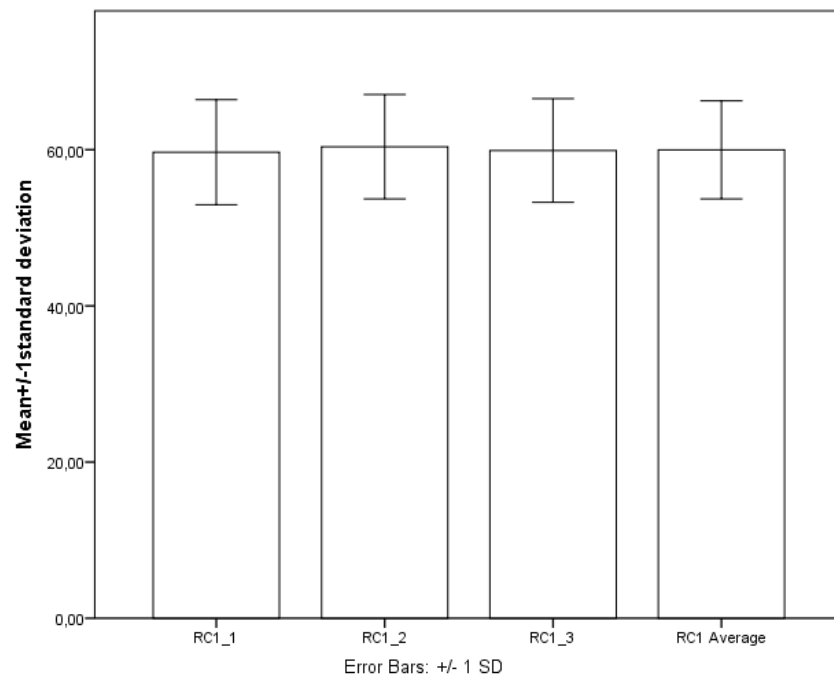


Figure 4.8. Bar graph with +/-1 standard deviation of the all-repeated measurements

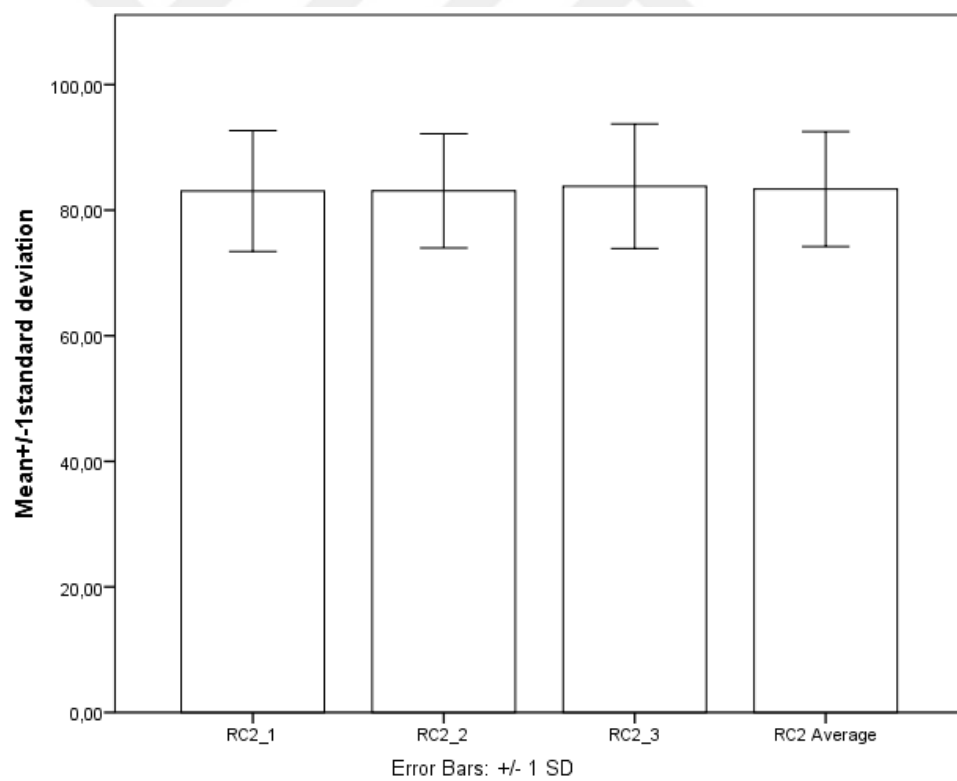


Figure 4.9. Bar graph with +/-1 standard deviation of the all-repeated measurements

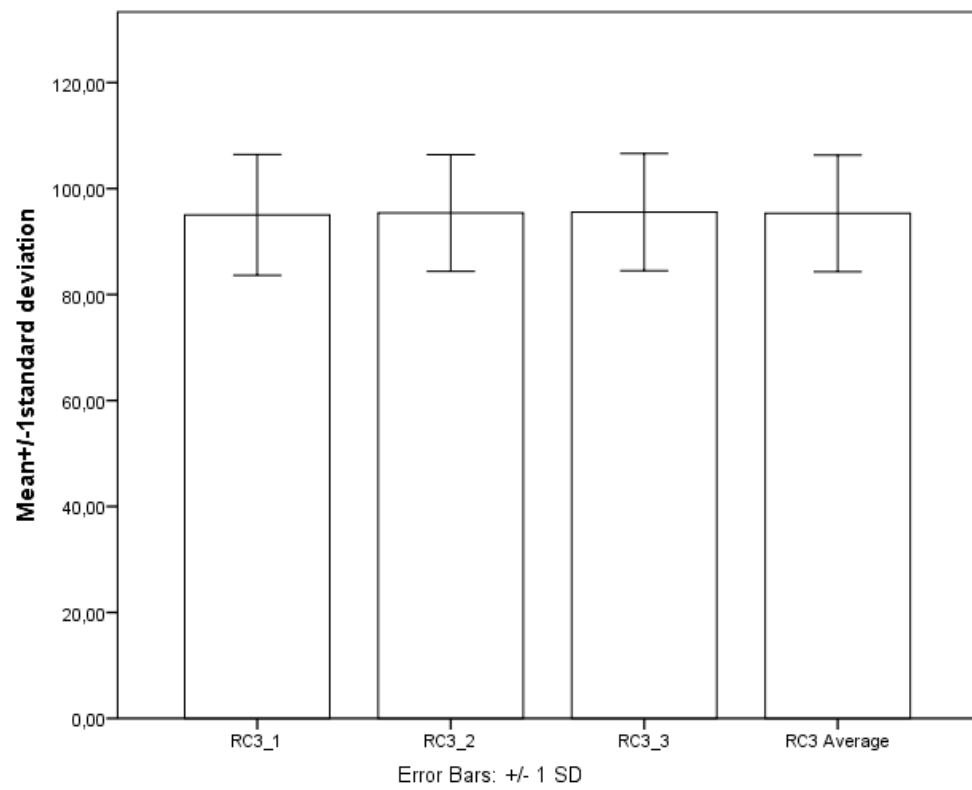


Figure 4.10. Bar graph with +/-1 standard deviation of the all-repeated measurements

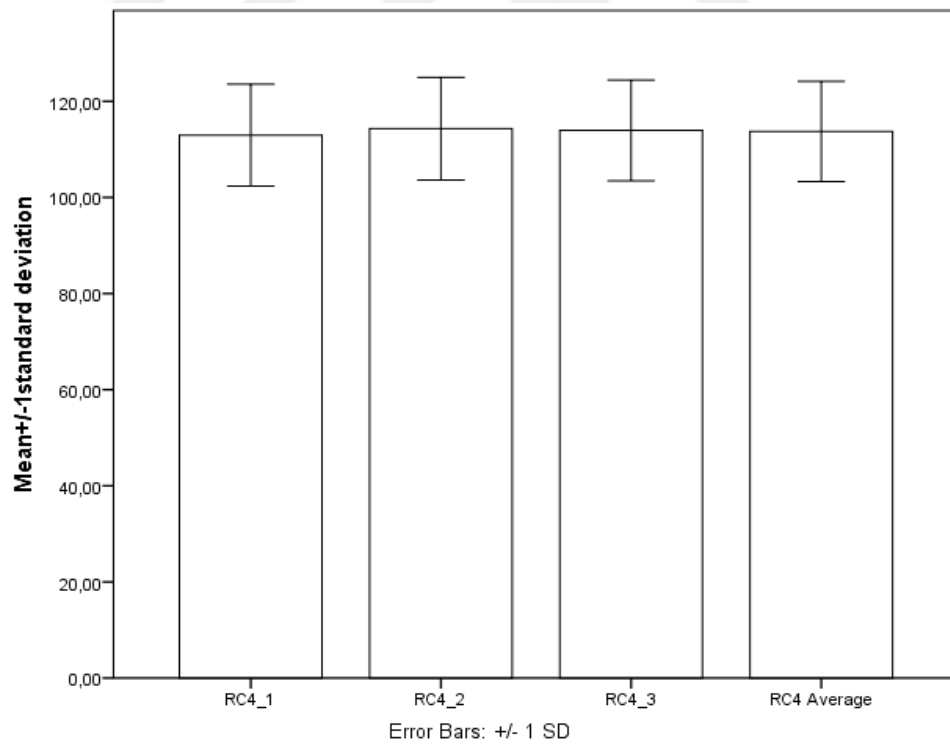


Figure 4.11. Bar graph with +/-1 standard deviation of the all-repeated measurements

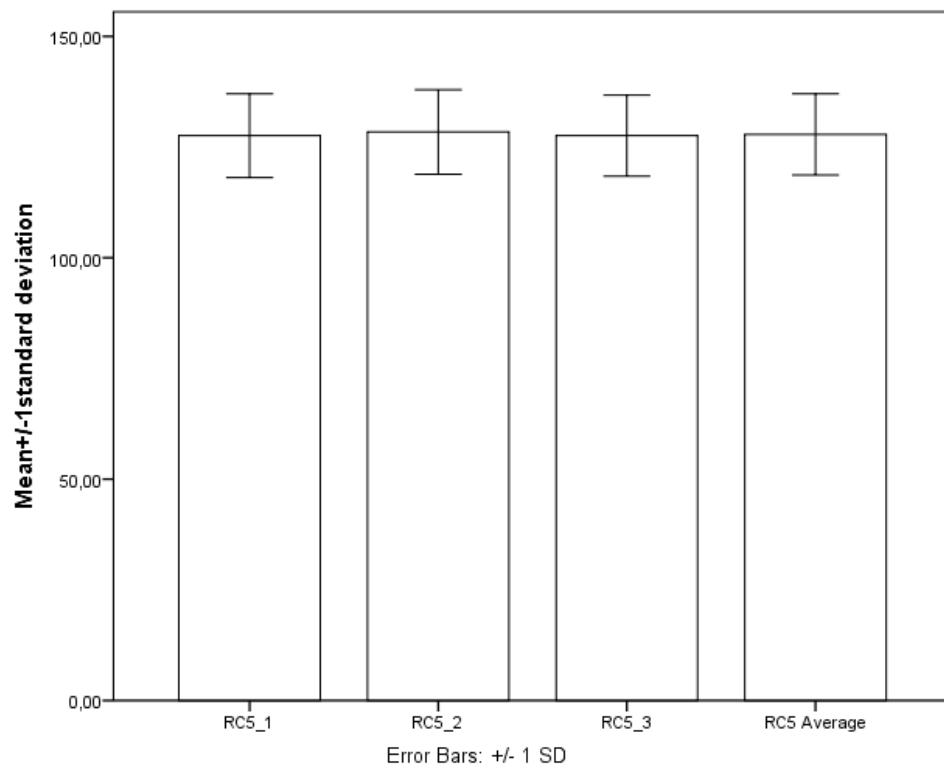


Figure 4.12. Bar graph with $\pm$ 1 standard deviation of the all-repeated measurements

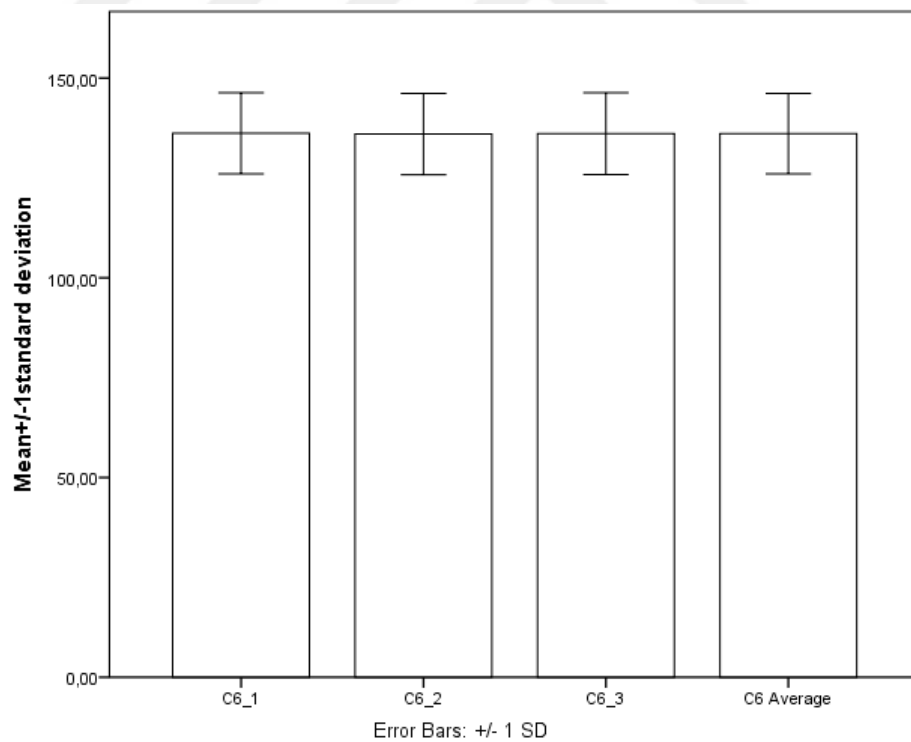


Figure 4.13. Bar graph with $\pm$ 1 standard deviation of the all-repeated measurements

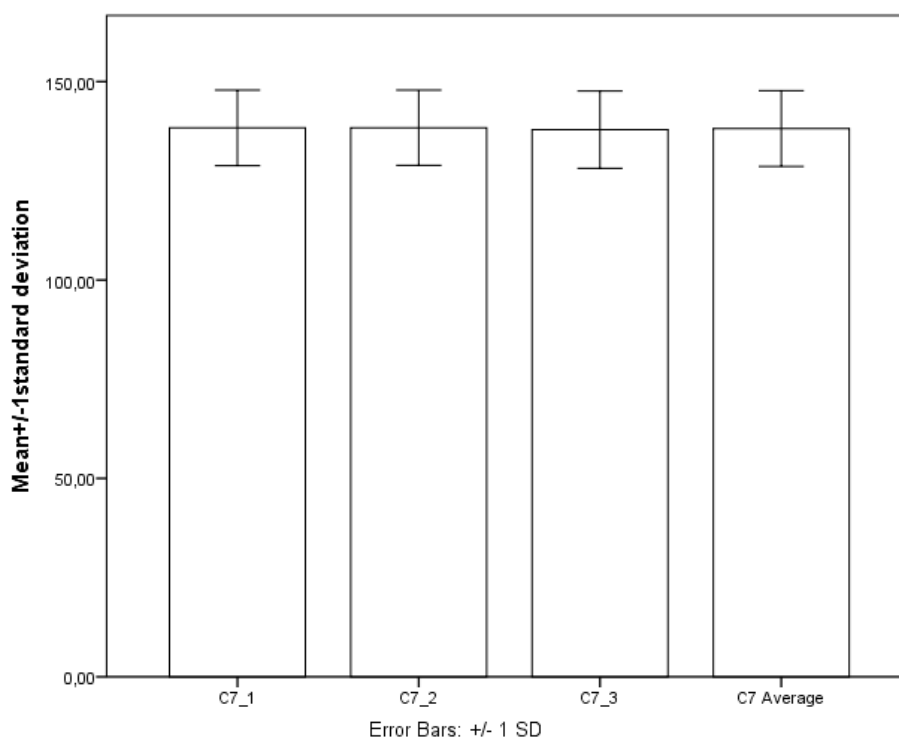


Figure 4.14. Bar graph with +/-1 standard deviation of the all-repeated measurements

4.3. Correlation of costal angle measurements to gender.

Initial and re-analysis tables and figures of costal cartilage angles, now, this section was shown the correlation of costal cartilage angle to gender (male & female) to determine gender differences. The total population was 73, and selected sample 63, a male was 31, while female 32 out of 63, which means each had percentage of 49.3% to 50.7%, respectively. The measuring mean and standard deviation is differences indicator. As data had more mean and standard deviation, the costal cartilage angles have more sizes.

Table 4.3 presented only costal cartilage angle measures based on gender, female had an average mean of repeated test of CI, had mean 62.16, $SD \pm 7.45$, while male average means 63.02, $SD \pm 8.43$. This data explains the female costal cartilage angle had less mean, which means less in angle size when compared to the male, which had a larger mean, which means broader angle size as we indicated. Again, Standard deviation indicated how data could spread. Another part of the costal cartilage angle (C 2, C 3, C 4, C 5, C 6 & C 7) shows that females have a high mean compared to males. The mean of C 2 was (female 85.65, $SD \pm 7.66$, and male 82.23, $SD \pm 6.97$), C 3 (female 97.59, $SD \pm 11.06$ and Male 92.97, $SD \pm 9.1$), C 4 (Female 116.65, $SD \pm 11.1$ and male 109.48, $SD \pm 9.77$), C 5 (female 129.59, $SD \pm 9.48$ and male 124.0 $SD \pm 10.5$), C 6

(female 137.38, SD±9.56 and male 134.75, SD±10.58), & C 7 (male 138.29, SD±9.44 and male 138.05, SD±9.8). All data from C 2 –C 7 indicated that males had less size costal cartilage angles when compared to females. But the first costal cartilage angle males were larger than females.

Table 4.3. Distribution of repeated measurements C 1-C 7 by gender

Variables	Gender		T	p ¹
	Female Mean±SD (degree)	Male Mean±SD (degree)		
C 1_1	62.72±7.45	62.84±7.68	0.063	0.95
C 1_2	61.44±7.58	63.42±10.32	0.871	0.387
C 1_3	62.56±8.62	62.81±8.62	0.112	0.911
C 1 Average	62.16±7.45	63.02±8.43	0.432	0.667
C 2_1	84.91±7.66	82.1±6.52	1.565	0.123
C 2_2	86.63±8.55	82.71±7.9	1.886	0.064
C 2_3	85.5±7.73	81.87±7.67	1.871	0.066
C 2 Average	85.65±7.66	82.23±6.97	1.852	0.069
C 3_1	97.16±11.49	92.71±8.69	1.728	0.089
C 3_2	98.22±11.94	93.32±10.08	1.756	0.084
C 3_3	97.41±10.51	92.87±9.4	1.804	0.076
C 3 Average	97.59±11.06	92.97±9.1	1.810	0.075
C 4_1	116.53±11.95	108.84±9.87	2.782	0.007
C 4_2	116.84±11.39	109.19±9.82	2.851	0.006
C 4_3	116.56±10.48	108.61±10.35	3.029	0.004
C 4 Average	116.65±11.1	109.48±9.77	2.715	0.009
C 5_1	129.94±8.93	123.71±10.75	2.505	0.015
C 5_2	129.72±10	124.32±10.48	2.091	0.041
C 5_3	129.28±9.93	124.03±11.9	1.903	0.062
C 5 Average	129.59±9.48	124±10.5	2.221	0.030
C 6_1	137.81±9.65	134.55±10.57	1.281	0.205
C 6_2	137.19±9.71	134.74±10.66	0.952	0.345
C 6_3	137.19±9.73	134.97±10.85	0.855	0.396
C 6 Average	137.38±9.56	134.75±10.58	1.033	0.306
C 7_1	138.56±9.38	138.1±9.85	0.192	0.848
C 7_2	138.34±9.43	138.39±9.69	0.018	0.986
C 7_3	138.06±9.55	137.68±10.06	0.156	0.877
C 7 Average	138.29±9.44	138.05±9.8	0.098	0.922

As shown in table 4.3, displaced as graphs with bar chart for simplification of data, mean of costal cartilage angles and gender of male and female was combined as one graph. Therefore, the figures are below (figure 4.15- figure 4.21).

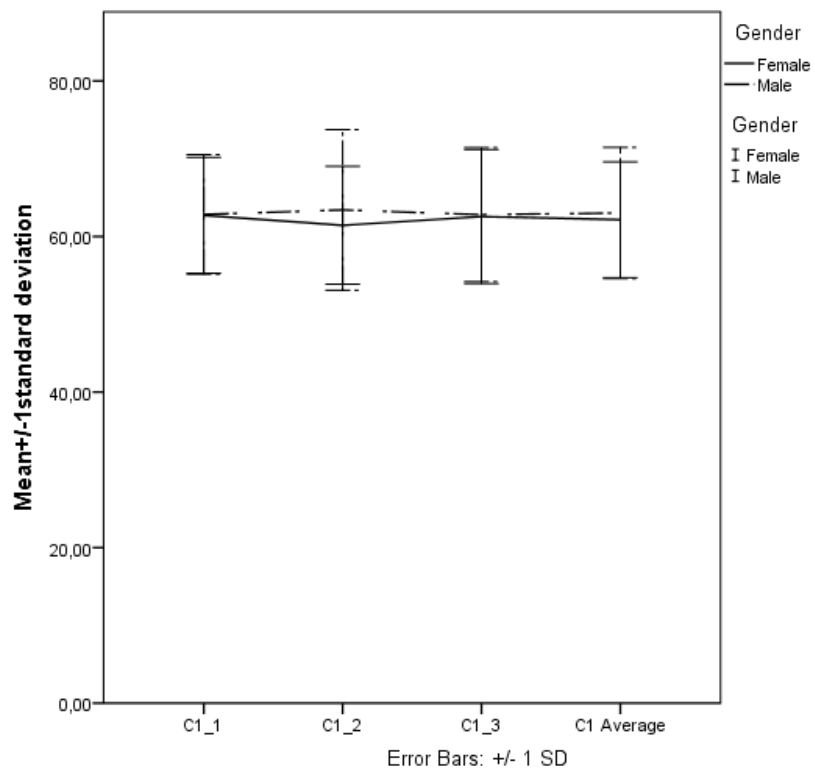


Figure 4.15. Line graph with +/-1 standard deviation of repeated measurements C 1 and av.

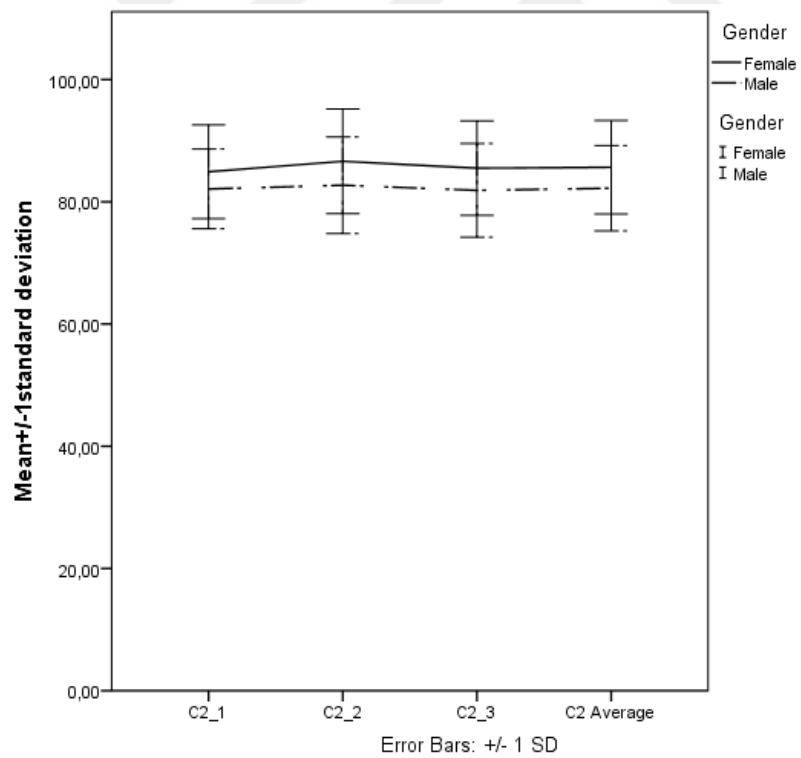


Figure 4.16. Line graph with +/-1 standard deviation of repeated measurements C 2 and av.

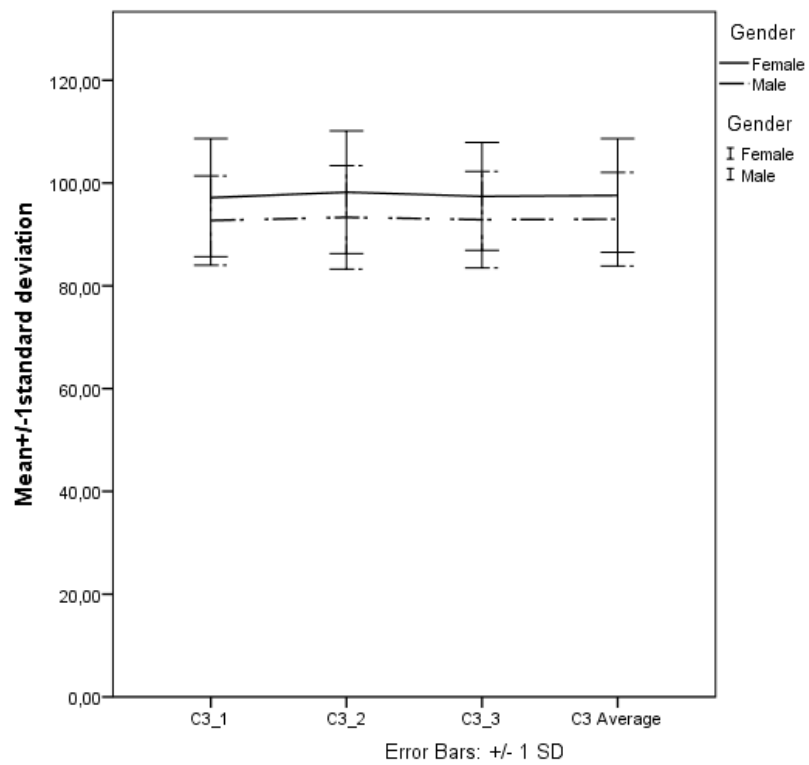


Figure 4.17. Line graph with +/- 1 standard deviation of repeated measurements gC 3 and av.

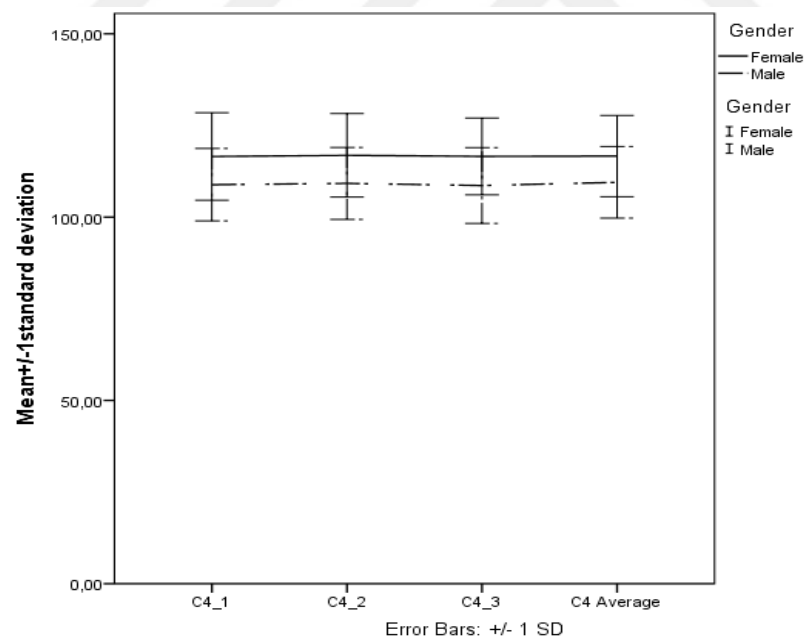


Figure 4.18. Line graph with +/- 1 standard deviation of repeated measurements C 4 and av.

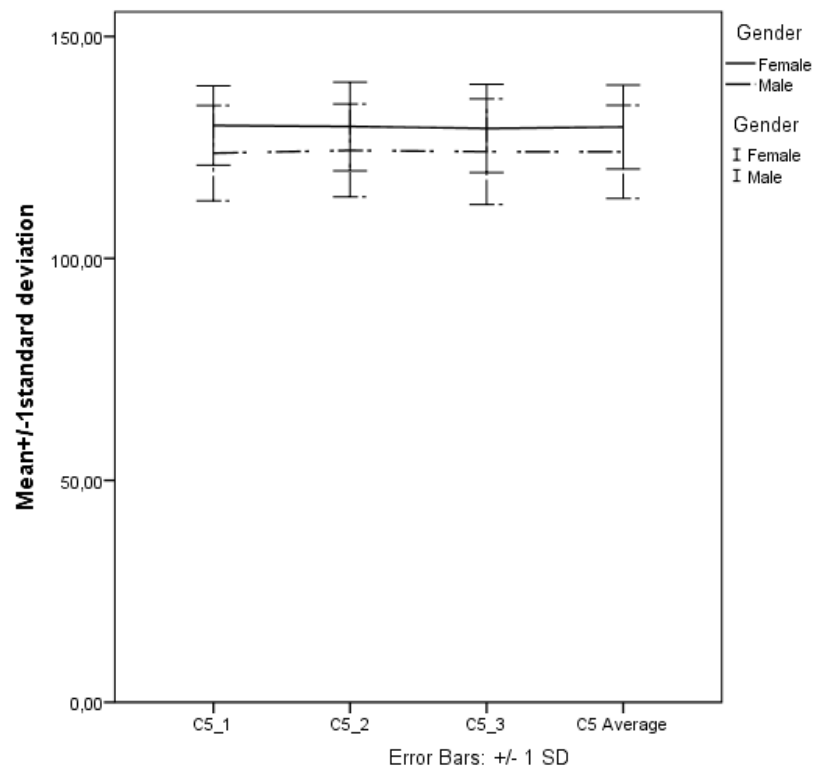


Figure 4.19. Line graph with +/-1 standard deviation of repeated measurements C 5 and av.

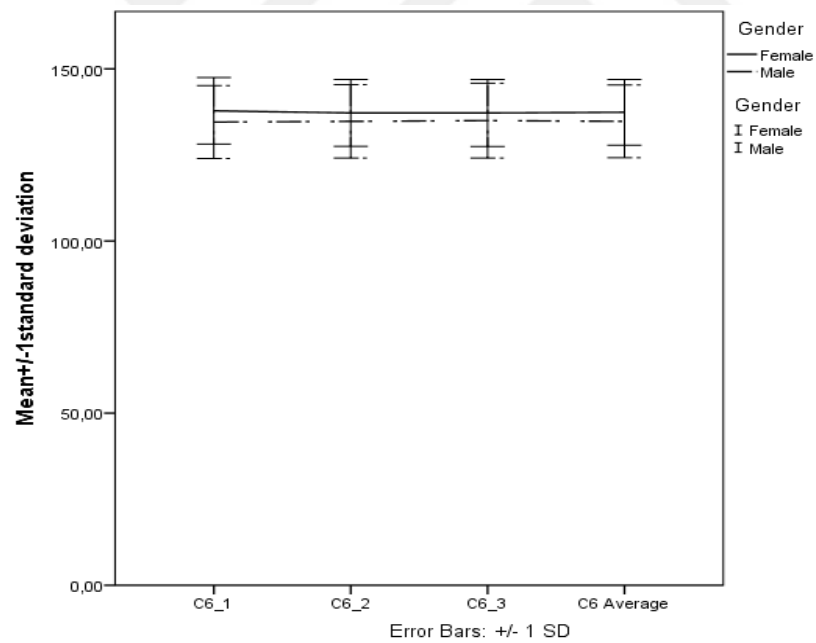


Figure 4.20. Line graph with +/-1 standard deviation of repeated measurements C 6 and av.

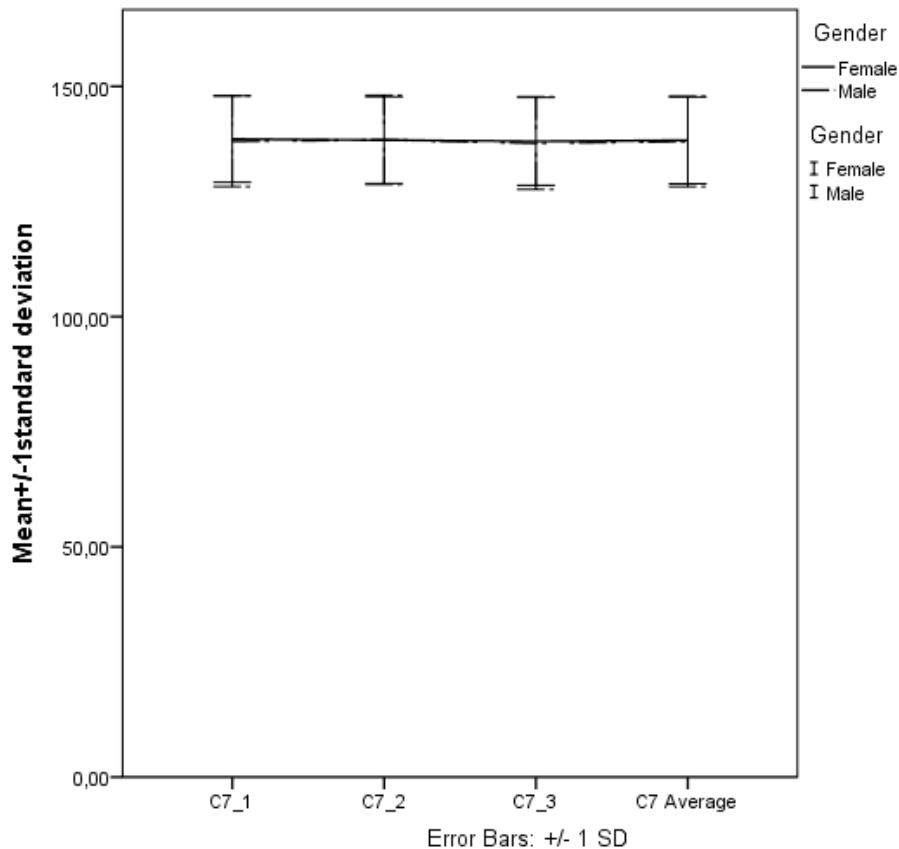


Figure 4.21. Line graph with +/- 1 standard deviation of repeated measurements C 7 and av.

4.4. Re-analysis correlation costal angle measurement with Gender (RC 1, RC 2, RC 3, RC 4, RC 5, RC 6, and RC 7).

The re-analysis of correlation of costal angle and gender with test validity of data, but this data followed with the initial correlation of costal angles with gender, the difference only numbers, but the same result, the first RC 1 gender-based was get female mean of 59.9, $SD \pm 5.55$ and male mean 60.08, $SD \pm 7.14$. That means males had a large size than females and same with first table 4.3. All other sections of costal angle measurement similar to the above.

Table 4.4. Distribution of repeated measurements from RC 1 to RC 7 by gender

Variables	Gender		T	p ¹
	Female	Male		
	Mean±SD (degree)	Mean±SD (degree)		
C 1_1	59.33±6.28	60.08±7.32	0.409	0.684
C 1_2	60.3±5.7	60.46±7.78	0.089	0.929
C 1_3	60.07±5.98	59.69±7.45	0.209	0.836
C 1 Average	59.9±5.55	60.08±7.14	0.104	0.917
C 2_1	83.67±10.02	82.35±9.28	0.509	0.613
C 2_2	84.47±9.88	81.5±7.97	1.224	0.226
C 2_3	84.73±10.63	82.73±9.12	0.75	0.456
C 2 Average	84.36±9.73	82.19±8.48	0.88	0.383
C 3_1	97.47±12.31	92.19±9.72	1.76	0.084
C 3_2	97.07±12.77	93.46±8.39	1.227	0.225
C 3_3	97.23±12.23	93.62±9.37	1.228	0.225
C 3 Average	97.26±12.33	93.09±8.95	1.427	0.159
C 4_1	116.13±11.43	109.27±8.34	2.532	0.014
C 4_2	118.2±11.12	109.81±8.23	3.167	0.003
C 4_3	117.5±10.59	109.85±8.88	2.905	0.005
C 4 Average	117.28±10.89	109.64±8.31	2.915	0.005
C 5_1	129.63±9.28	125.19±9.29	1.785	0.08
C 5_2	130.5±9.32	126±9.44	1.792	0.079
C 5_3	129.8±9.07	125±8.67	2.016	0.049
C 5 Average	129.98±9.03	125.42±8.92	1.893	0.064
C 6_1	137.77±9.77	135.12±10	1.002	0.321
C 6_2	137.03±9.51	134.42±9.49	1.025	0.31
C 6_3	137.13±9.72	135.42±10.42	0.635	0.528
C 6 Average	137.31±9.57	134.99±9.87	0.893	0.376
C 7_1	138.23±9.19	139.15±9.29	0.372	0.711
C 7_2	138.43±9.11	139.27±8.92	0.346	0.731
C 7_3	137.93±9.02	139.42±8.66	0.628	0.533
C 7 Average	138.2±9.05	139.28±8.84	0.451	0.654

Above the table of re-analysis of costal cartilages by gender presented as figures for more detail. Figures list as costal-based numbers with seven graphs of bar charts (figure 4.22 – figure 4.28).

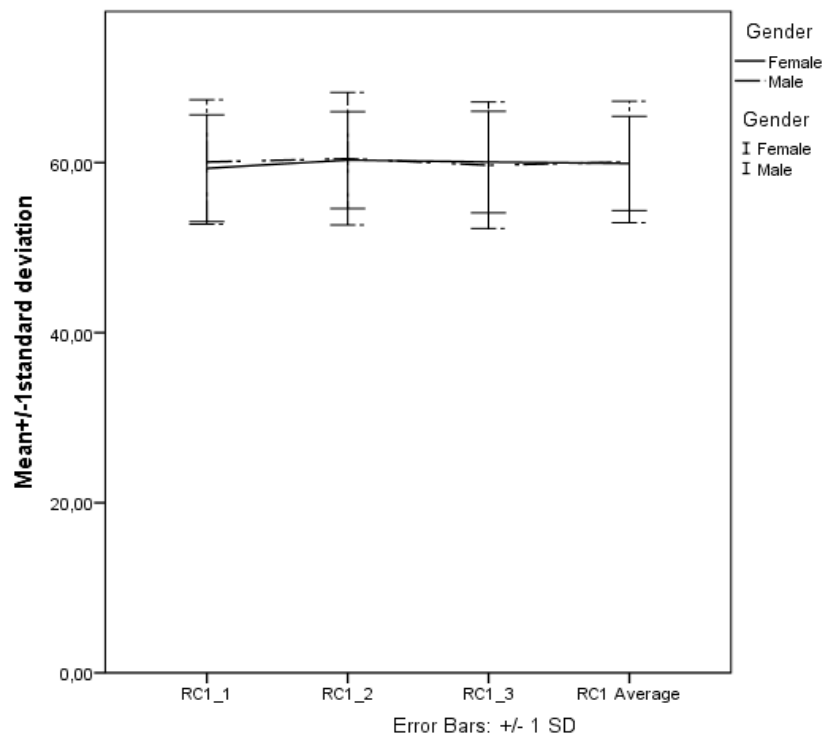


Figure 4.22. Line graph with +/- 1 standard deviation of repeated measurements RC 1 and av.

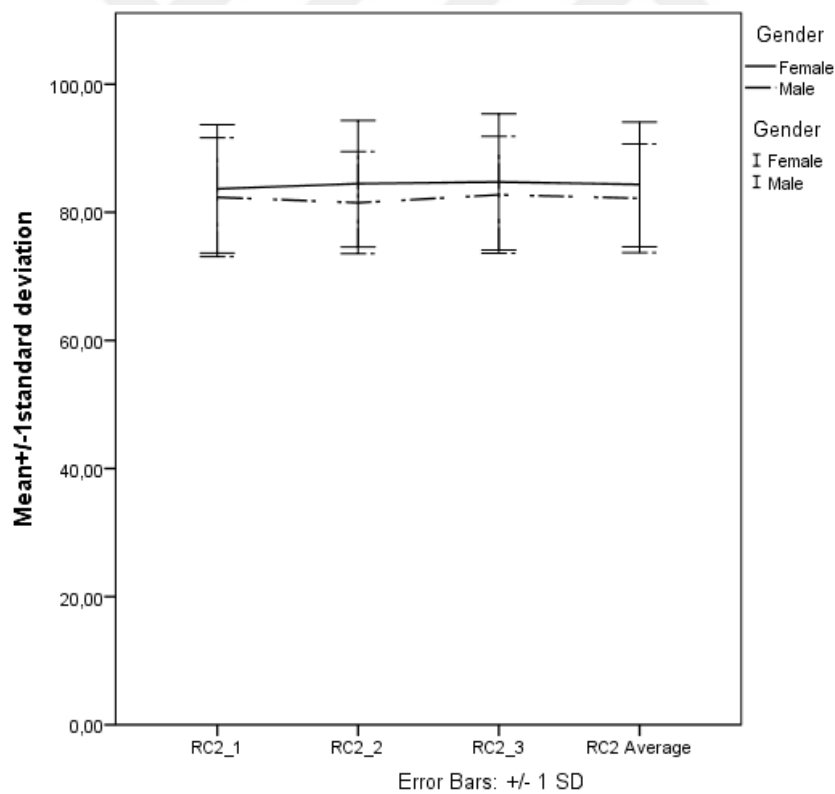


Figure 4.23. Line graph with +/- 1 standard deviation of repeated measurements RC 2 and av.

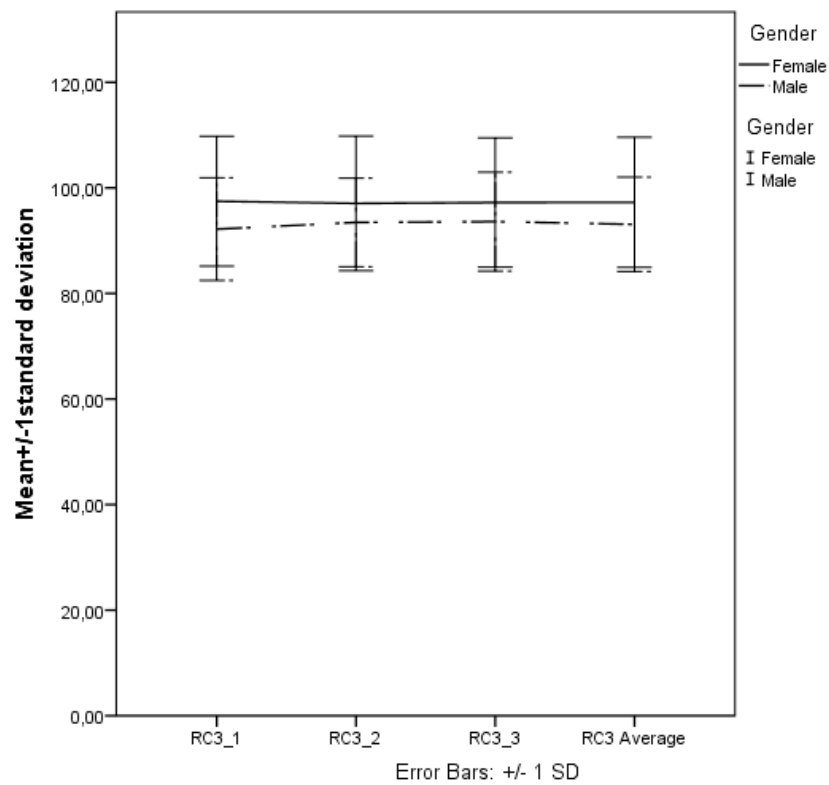


Figure 4.24. Line graph with +/- 1 standard deviation of repeated measurements RC 3 and av.

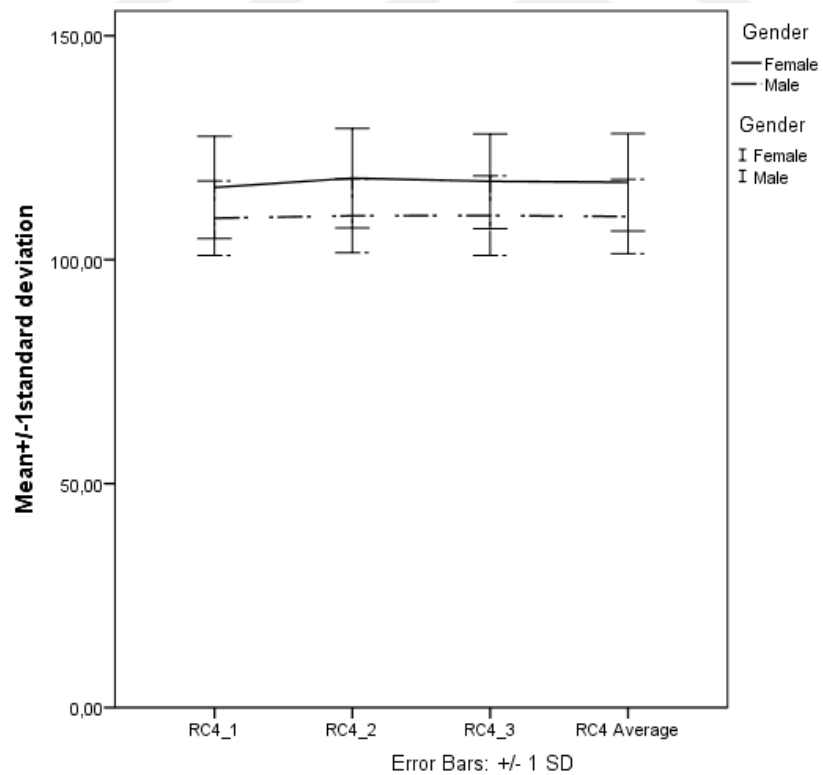


Figure 4.25. Line graph with +/- 1 standard deviation of repeated measurements RC 4 and av.

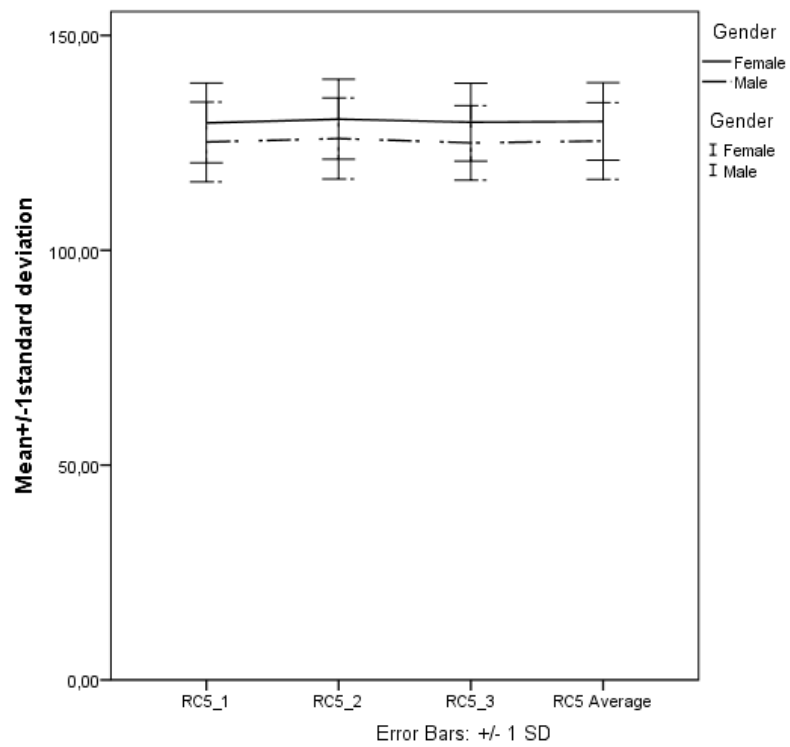


Figure 4.26. Line graph with +/-1 standard deviation of repeated measurements RC 5 and av.

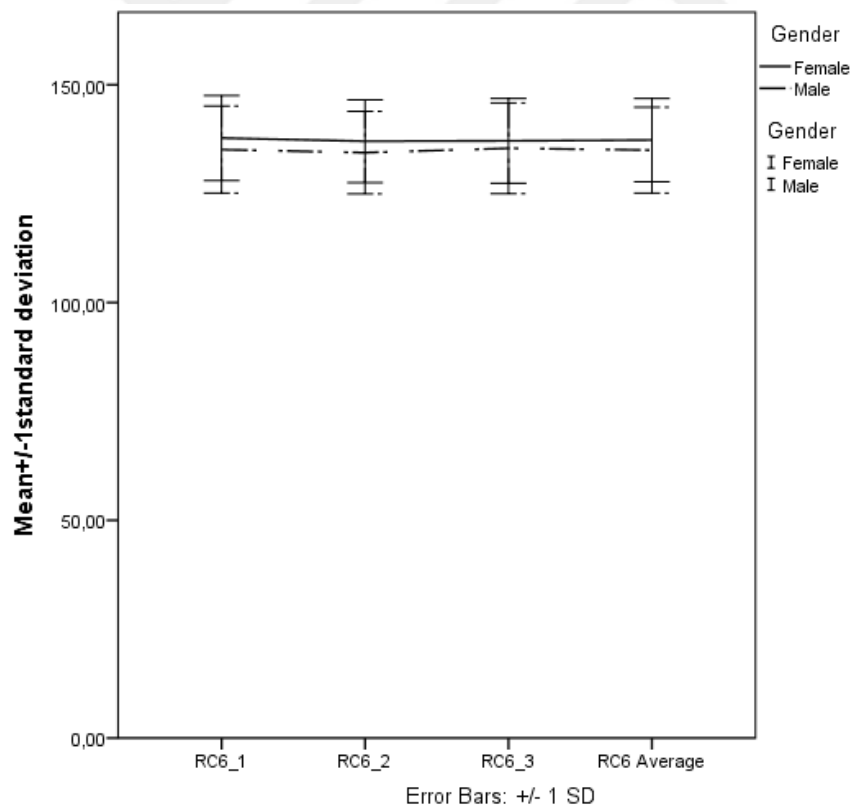


Figure 4.27. Line graph with +/-1 standard deviation of repeated measurements RC 6 and av.

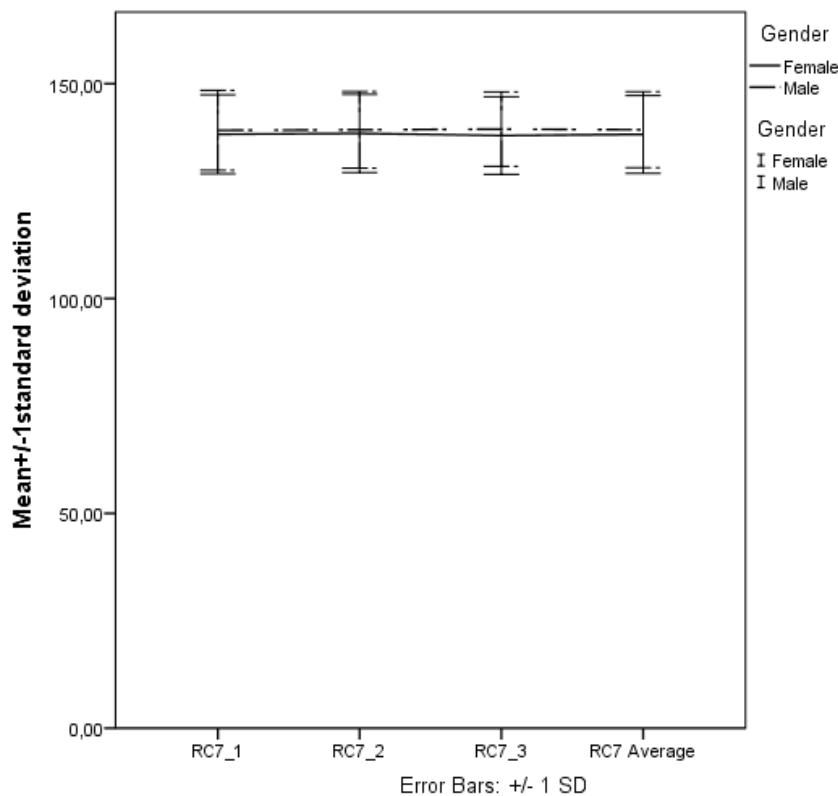


Figure 4.28. Line graph with +/- 1 standard deviation of repeated measurements RC 7 and av.

4.5. bivariate correlation of initial and repeated measures of costal cartilage angles to the sternum.

After computed mean and standard deviation of data of costal measures for both initial and re-analysis of data, then presented the correlation with the particularly Bi-variate correlation. As we know correlation have rules, for instance; if data is near $r = (-1, -0)$ negative correlation, $r = 0$, means no correlation, $r = (0, +1)$ means positive correlation (Schober et al., 2018).

Table 4.5. bivariate correlation of repeated measurements of both initial data and repeated or re-analyzed data. C 1 and RC 1 average have ($r=0.688$), that positive correlation, while other like C 2 and RC 2, C 3 and RC 3, C 4 and RC 4, C 5 and RC 5, C 6 and RC 6 average & C 7 and RC 7, all have bivariate correlation of $r=0.872$, $r=0.917$, $r=0.946$, $r=0.943$, $r=0.963$, & $r=0.947$ respectively. That means all have strong positive correlation.

Table 4.5. Bivariate correlation of repeated measurements

Variables	RC 1 Average	RC 2 Average	RC 3 Average	RC 4 Average	RC 5 Average	RC 6 Average	RC 7 Average
C 1 Average	0.688*	-	-	-	-	-	-
C 2 Average	-	0.872*	-	-	-	-	-
C 3 Average	-	-	0.917*	-	-	-	-
C 4 Average	-	-	-	0.946*	-	-	-
C 5 Average	-	-	-	-	0.943*	-	-
C 6 Average	-	-	-	-	-	0.963*	-
C 7 Average	-	-	-	-	-	-	0.947*

*: Correlation is significant at 0.05 level

4.6. The variance analysis results of two-way repeated and initial costal angle measurements

In this study, the primary purpose was to compare the costal cartilage angle of the sternum in both males and females; this section computed the result of C 1 Average, RC 1 Average, and variance analysis results. The P-value added to the determination of the significance of data of different means. P-value had a significance level of (P 0.05). If the results were less than 0.05 value, this data accepted, and if it not (greater then), we reject it.

In table 6., total P value is (n=63, P =0.01), which means the relationships C 1 and RC 1 average was significant. But by separation of male and female, the female had (n=32, P=0.02), indicating the result is more important, while males (n=31, P=0.128) have not significance level. Therefore, the section of this table 4.6 was present a P-value, but the remaining data had a high p-value, indicating not significance level. That means there is not statistical gender effects between male and female.

Table 4.6. Distribution of the repeated variables C 1 Average and RC 1 Average and the variance analysis results of two-way repeated measurements

Variables	Total (degree)	Gender		p1
		Female (degree)	Male (degree)	
C 1_AV	62.58±7.89	62.16±7.45	63.02±8.43	0.826
RC 1_AV	59.98±6.28	59.9±5.55	60.08±7.14	0.917
p2	0.010	0.027	0.128	
C 2_AV	83.96±7.47	85.65±7.66	82.23±6.97	0.100
RC 2_AV	83.35±9.16	84.36±9.73	82.19±8.48	0.383
p2	0.183	0.086	0.828	
C 3_AV	95.32±10.33	97.59±11.06	92.97±9.1	0.115
RC 3_AV	95.32±11	97.26±12.33	93.09±8.95	0.159
p2	0.416	0.530	0.597	
C 4_AV	113.12±10.99	116.65±11.1	109.48±9.77	0.011
RC 4_AV	113.73±10.42	117.28±10.89	109.64±8.31	0.005
p2	0.253	0.315	0.528	
C 5_AV	126.84±10.31	129.59±9.48	124±10.5	0.062
RC 5_AV	127.86±9.19	129.98±9.03	125.42±8.92	0.064
p2	0.082	0.470	0.087	
C 6_AV	136.08±10.08	137.38±9.56	134.75±10.58	0.610
RC 6_AV	136.23±9.69	137.31±9.57	134.99±9.87	0.376
p2	0.193	0.930	0.092	
C 7_AV	138.17±9.54	138.29±9.44	138.05±9.8	0.747
RC 7_AV	138.7±8.89	138.2±9.05	139.28±8.84	0.654
p2	0.762	0.674	0.983	

Source: primary data

4.7. Standard deviation of the all-Initial and repeated measurements

We then calculated the Standard deviation for all repeated costal cartilage angles with the gender differences. The graphic figure of this data shows you with a minimum number of 50 and the maximum number of 150, starting with RC 1, and data increases as the number increases. This graph is line graphs constructed for different variables such as gender, seven costal cartilages, mean and standard deviation.

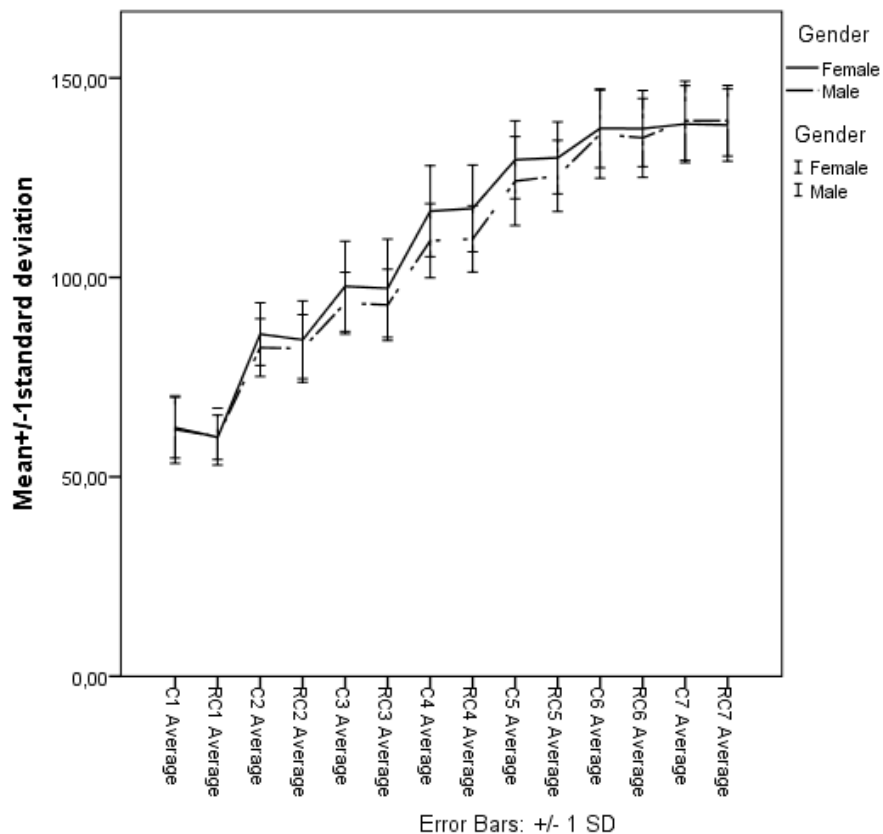


Figure 4.29. Line graph with +/- 1 standard deviation of the all-repeated measurements

5. DISCUSSION

This section discussed the findings, and based on the general objective of this study, then compared these data to other available literature. The discussion arranges in the order of the tables presented in the findings. It also points out the last section advising the need for further study in research in the future. The discussion clearly emphasizes the difference between males and females to the angle of costal cartilages to the sternum and differentiated similarities and differences between them. This study's valuable information is the first one of its nature because it measured and compared the attachment angle of costal cartilages of ribs and sternum on gender difference so that this study will contribute new knowledge to science, particularly medical science.

The main objective of this study was to identify and compared attachment angles of costal cartilages and sternum on gender among patients in Karabük university hospital in Karabük, Turkey. So that, the independent variable was attachment angles of costal cartilages. In comparison, the dependent variables were gender (male and female). The collected data was for the measurements of the first seven costal cartilages attachment with the sternum, both male and female, and with sample size 63 was obtained images in computed tomography (CT) in three dimensions and then measured the angles. As presented in the finding, the researcher estimated the Initial costal cartilages (C 1-C 7). Re-analysis of costal cartilage (RC 2-RC 7), correlation of costal cartilage with gender (C 1-C 7). Re-analysis correlation of costal cartilages to the gender (RC 1-RC 7) as shown in both tables and figures. The last section was bivariate correlation for both initial IC and Re-analyzed RC, then recalculate the two samples of IC and RC.

According to Carrier, G., Fréchette, É., Ugalde, P., & Deslauriers, J. (2007), measuring Correlating anatomy imaging is crucial if you want to identify surgical and probable operating difficulties (Carrier et al., 2007). Conventionally, biomedical researchers trust on established analyses of the definite bone for study purposes by using modern computerized or virtual methodologies. Therefore, the study was to analyze costal cartilage angles and sternum. The instrument was the computer scan of radiology images (Cattaneo, 2007; Darwish et al., 2017).

Data finding of the first section used tables and figures, the table 4.1. Summarize the initial costal cartilage angle of ribs and sternum, as the intra-class correlation of C 1 is 0.779, indicates “good” reliability. Still, other parts like (IC 2, IC 3, IC 4, IC 5, IC 6 & IC 7) their intra-class correlation was above 0.90. The excellent reliability indicates their correlation”. That means C 1 slight difference between others, as marked by the ICC (Dupras and Pfeiffer, 1996). Also found that the average of each three repeated measured costal angles of every initial costal cartilages from C 1 to C 7. The standards of each costal angle then calculated C 1 (62.58 ± 7.89), and from (C 2, C 3, C 4, C 5, C 6, & C 7), had averaged between (83.96, to 138.17). This select angle of the first C 1 was less than other costal cartilage angles. Their difference was space of Mean for costal angles was increased as a sequence of the costal number increase from C 1 to C 7. The variability exists in the angles of costal cartilage when the average means less, angle size also less, when average means was high, and the angle was also high (Wan et al., 2014). The sternal angle had variations in size, location, and fusion. Another study also mentioned variation of angles (Kirum et al., 2017). The figures explained the average means of each costal cartilage angles attachment with the sternum, which accessible as graphs for determining data distribution with a comparison of normal distribution.

Section two found as presented for re-analysis of Costal cartilage angles of seven costal cartilages (RC 1, RC 2, RC 3, RC 4, RC 5, RC 6, and RC 7). These quantities of repeated costal cartilage angles on three times for each costal cartilage (C). Because if data have three sources of variation in results for a first, second and third test are distinguished: if data had similar of different test that means data is more reliable. But data can be unreliable if it got variation over trials (Noble et al., 2019). For example, table 4.1 had an Intra-class correlation (ICC) similar to that of table 4.2. Therefore, the re-analyzed costal cartilage RC 1 had reached excellent reliability.

In comparison, other data still had the same ICC percentage compared to the initial intra-class correlation. However, they had an intra-class correlation above 0.90, which indicates excellent reliability. Sternum and costal cartilage rib angle size revealed significant differences in this clinical importance. The variation of the first costal cartilage angle between individuals was in the appearance. The variation was the size of the costal cartilage angle of ribs and sternum. We know the first seven true ribs attach front to the sternum and dorsal to the vertebral column, the front to the

sternum connected by cartilage known as costal cartilage (Kuo and Kim, 2019). The other evidence this study discovered was the angle of costal cartilage of ribs should increase from the First rib to rib seven.

Section three of the findings, in more detail, gender has a difference in biological. The study now turns to the correlation of costal cartilage angle to the sternum based on Gender (male & female), detection of gender differences, and similarity. A numerical male was 31 and female 32 out of 63, with 49.3% male to 50.7% female. The difference between males and females determines by the measuring mean and standard deviation. As data had more mean and standard deviation, they have more size of costal cartilage angles. Table 4.3, the Costal cartilage angle measured with the relation of gender, Female had an average mean of re-analysis test of CI, mean 62.16, $SD \pm 7.45$, while Male average means 63.02, $SD \pm 8.43$. Male costal cartilage was more in size than female. The sternum and costal cartilage angle of rib had extent revealed significant metric sex differences using computed scan images (Darwish et al., 2017). The Standard deviation presents the level of the data distribution to the normal and indicates how data can convert into percentages. The females had a large average mean compared to males in another part of Costal cartilage angle (C 2, C 3, C 4, C 5, C 6 & C 7). There was no similarity between the first costal cartilage (C 1) and other costal cartilage angles. Other literature also mentions different the Vertebral sections in older females had higher angles relative to other individuals (Holcombe et al., 2017b).

The usability of sternum parts and sternal angle (SA) measurement had values for sex identification because there are sex differences, not the first rib angles, but other ribs (Oner et al., 2019). The costal cartilage of ribs and vertebrates is primarily accountable for the rib cage's increased volume and depth, as mentioned by previously available data (Shi et al., 2014). The fourth section re-tested the correlation of costal cartilage angle of ribs and sternum with gender. The data had similar terms and counts with an initial correlation of costal angle with gender mentioned above. We got so important, no difference, have the same result, for instance; the first RC 1 gender-based was get female mean of 59.9, $SD \pm 5.55$ and male mean 60.08, $SD \pm 7.14$. This means males had a large size than females and same with first table 4.3. After we go forward, have other costal cartilage RC 2, RC 3, RC 4, RC 5, RC 6, & RC 7. The determination of sex for medical cases is statistically the most vital criteria as it

immediately eliminates almost half the population (Shkrum and Ramsay, 2007). There is some limitation of measurement of sternum parts like manubrium, which is manubrium, which cannot be considered a reliable parameter for both males and females (Ashley, 1956; Dahiphale et al., 2002).

After counting the mean and standard deviation of costal measures for both above mentioned initial and re-analysis of data, the Fifth section counted the mean and standard deviation of costal measures for both those mentioned above initial and re-analysis of data. The correlation coefficient of bivariate analysis computed. The coefficient correlation have rules, that must understand, for example; if data is near $r = (-1, -0)$ negative correlation, $r = 0$, means no correlation, $r = (0, +1)$ means positive correlation (Schober et al., 2018). So, measurement scale of this data can give us a positive correlation with a strong correlation. The finding of table 4.5. Was bivariate correlation of repeated dimensions of both initial data and repeated or re-analyzed data? C 1 and RC 1 average have ($r=0.688$), that positive correlation, while other like C 2 and RC 2, C 3 and RC 3, C 4 and RC 4, C 5 and RC 5, C 6 and RC 6 average & C 7 and RC 7, the result has bivariate correlation of $r=0.872$, $r=0.917$, $r=0.946$, $r=0.943$, $r=0.963$, & $r=0.947$ respectively. The bivariate correlation had a significant P-value of ($P 0.05$). These insights were a positive correlation; by differentiation of correlation would be a strong positive and moderate positive correlation. The last six costal cartilage had been strong positive correlation coefficient.

The sixth section of findings has presented the variance analysis results of two-way repeated and initial costal angle measurements; the P-value of data added to determine the significance of data of different means. P-value had a significance level of ($P 0.05$). If outcomes were less than 0.05 value, this data could accept and if it not, or can reject it. The total P value is ($n=63$, $P=0.01$), which average means the relationships C 1 and RC 1 average was significance level. But by separating males and females, the female had ($n=32$, $P=0.02$), the representative result is more significant, while males ($n=31$, $P=0.128$) have no significance level. The section of this table 4.6 was present a P-value, but the lasting data had a high p-value, indicating not significance level. The meaning all P values were higher than. This error in P-value is also a need to control these factors and alter the Statistical significance to confirm the present study results.

The average P-value of both males and females consists of significant and non-significant results. In female costal cartilage angles, significance level means accepted data, while males have a P-value more significant than $P = 0.05$ ($N=63$, $P=0.128$). So, the Male average P-value was not substantial. When we connect all data interpretation, intra-class correlation abbreviated (ICC), measured correlation of costal cartilage in seven true ribs. The test-retest each costal had got strongly positive correlated, except costal cartilage (C 1). In average mean, the difference between Means of costal angles increased as a sequence of the costal number increased from C 1 to C 7. The inconsistency existed in the costal cartilage angles when average means were less, angle size also less, when mean were large and increased angled. Other literature presented only the importance of the sternum, the distance of the manubrium (part of the sternum), was established to be the most reliable criteria you choose of determining sex from sternal bone (Darwish et al., 2017). Also, reveal the Sternum and rib width had significant metric sex differences using Multislice Computed Tomography 3D images (Oner et al., 2019). Finally, the findings presented one last figure, 4.29. It compared the standard deviation of all repeated and initial costal cartilage angles between genders. So, this data shows you with both upper and lower bound or minimum number of 50 and a maximum number of 150, starting with RC 1 and data increases as number increases. This graph is line graphs constructed for different variable such as gender, seven costal cartilages, mean and standard deviation.

After computed mean and standard deviation of data of costal measures for both initial and re-analysis of data, the correlation is a statistical method, particularly inferential statistics that evolve to assess the type of linear association between two study variables. The correlation of two groups such as initial and re-analysis costal cartilage. As known correlation have rules, for instance; if data is near $r = (-1, -0)$ negative correlation, $r = 0$, means no correlation, $r = (0,+1)$ means positive correlation (Schober et al., 2018). So, measurement scale of this data can give us a positive correlation with a strong correlation. Or can be written, the correlation between -1.0 and 1.0. A correlation level can, if $r = -1.0$, display a perfect negative correlation. In contrast, a correlation can equal to 1.0 expresses a perfect positive correlation, the correlation of 0.000 displays no linear relationship between the two study variables (Ganti, 2020).

The finding of table 4.5 presented the bivariate correlation of repeated measurements of both initial data and repeated or re-analyzed data; the data compare same costal cartilage with Initial and re-analysis for example, C 1 and RC 1 average have ($r=0.688$), that means positive correlation or perfect correlation. In contrast, other like C 2 and RC 2, C 3 and RC 3, C 4 and RC 4, C 5 and RC 5, C 6 and RC 6 average & C 7 and RC 7, all have a bivariate correlation of $r=0.872$, $r=0.917$, $r=0.946$, $r=0.943$, $r=0.963$, & $r=0.947$ respectively, the remaining data starting from C 2 & RC 2 to C 7 & RC 7. The interpretation all had a strong positive or perfect correlation. The bivariate correlation with the significance of ($P 0.05$). Table 4.7. The P-value was extra to a determination of the significance of data of different means. P-value had a significance level of ($P 0.05$). If findings were less than 0.05 value, this data would accept and if it not, it will reject it. The significance level between from (0.01, 0.05 & 0.10). In table 4.6. The P-value was ($n=63$, $P =0.01$), which means the C 1 and RC 1 average correlation was significant. But by separating males and females, the females had ($n=32$, $P=0.02$), indicating the result is more significant, while males ($n=31$, $P=0.128$) have no significance level.

6. CONCLUSION AND RECOMMENDATION

The current study showed the determination and comparison of attachment angle of costal cartilages and sternum and the difference between genders. This study focuses on the bones like sternal bone, costal cartilage of ribs. The CT scan images were collected from the archival system of the radiology department in Karabük University hospital in Karabük. The CT scan images of the study population were 73, ten images had low resolution hence could not be processed through ImageJ application, then selected sample size of 63 (n=63). That was analyzed using analyzing software of SPSS version 22. The data presented in tables and figures and used descriptive statistics like mean, standard deviation, and intra-class correlation. At later parts added inferential statistics by bivariate correlation.

The first goal of this research was to measure the angle size of each costal cartilage of seven ribs and sternum, first table 4.1 and figures 4.1 to 4.7. The initial angle measurement of costal and sternum, then as validation, repeated the data to measure it. Second table 4.2, and its figures (4.8-4.14), showed the re-analyzed angles of costal cartilage and sternum. The results of this objective were the appearance of the first costal cartilage angle between individuals. The variation was the size of costal cartilage angle and sternum. The other confirmation was the angle of costal cartilage of ribs should increase from the First rib to rib seven. The average mean of table 4.1 (from 83,96 to 138,17) increased from C 1 to C 7 as the order of the costal cartilage number.

The second objective was to compare the size of the costal cartilages and gender angle to determine the difference. So, the third table 4.3 & 4.4, and figures (4.15-4.21) presented the initial correlation between costal angles and gender using mean and standard deviation and P-value. The findings of this objective, the males, were 31 and females 32 out of 63, with 49.3% male to 50.7% female. male's first costal cartilage angle was more in size than female but remained costal angle (2nd, 3rd, 4th, 5th, 6th & 7th), females had a large average mean compared to males (Kirum et al., 2017). they presented there were sternal differences. These cases were prevalent. As detected, this study will be unique research, and it is the only study comparing attachment of costal cartilage angles on gender.

As a result, it is significant because it raised awareness of these discoveries as they may identify the accurateness of medical and other processes in the chest area. This research discovered that costal cartilage angles were different sizes. The objectives were to measure and compare the attachment angle of costal cartilages among the sexes on three-dimensional models obtained from the computed tomography images. The first costal cartilage males have a great angle compared to the females, but the other costal cartilage females have a significant number in angle size. In summary, males have a compact thorax. When compared to the females, the females have an open thorax.

The participants of this study were Turkish citizens in Karabük university hospital. The researcher advises other researchers to measure costal angles and compare the ethnic groups to measure the variation between them and verify the applicability of the obtained comparisons on larger samples of other countries. The study used CT scan views. It is an implication; the researcher recommended searching other alternative scans, which perform or make images more quality than CT scan.

We recommended making a further study about determine any abnormality like congenital deformity, for example, Kyphosis, also determination of physical activity of individuals, structure thorax cavity of typical persons, the position of patients during the radiological examination and post-surgical history related to the angle of costal ribs and sternum because this research was typical patient. Finally, the researcher recommends that further study must evaluate the age difference of costal cartilage angles. by utilizing other computed tomography (CT) images to discover the age difference. Addition point that CT image is more harmful to patients so it was important to recommended to use another less harmful investigation like MRI.

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ETHICAL COMMITTEE APPROVAL CERTIFICATE

İLGİLİ MAKAMA,

Yürütücüsü olduğum “Bilgisayarlı Tomografi görüntüleri rekonstrüksiyonu ile elde edilen görüntüler üzerinden angulus sterni ve sternum’un parçalarının uzunluk ve oransal değerlerinin cinsiyet tayininde kullanımına dair bir deneme” başlıklı araştırmamıza Karabük Üniversitesi Girişimsel Olmayan Etik Kurulu tarafından 5.7.2017 tarih ve 6/19 sayılı karar ile uygunluk kararı verilmiştir. Etik kurul başvurusunda Yardımcı Araştırmacı olarak yer alan Prof. Dr. Bünyamin Şahin çalışma için kullandığımız Bilgisayarlı Göğüs Tomografisi görüntü serilerini yapacakları tezlerde ya da araştırmalarında görüntü bankası olarak kullanabilmeleri için kendisine tarafımızda muvaffakiyet verilmiştir.

Gereğini saygılarımla arz ederim.

16.05.2018

Dr. Öğr. Üyesi Zülal Öner

Karabük Üniversitesi Tıp Fakültesi

Anatomi Anabilim Dalı

CURRICULUM VITAE

Ahmed Ibrahim ABDI, after finishing Al Fajr high school, joined University of science and Technology in Sana'a, Yemen and graduated with BSc in Medicine and General Surgery in 2010. In the year 2021, graduated with Ph.D. program in Anatomy from Ondokuz Mayıs University, College of Medicine, Samsun, Turkey. Along with the Ph.D. program, also is an assistant Professor of anatomy in Mogadishu University, Somali National University and Zamzam University, Mogadishu, Somalia. Have a good knowledge in English, Arabic and Turkish languages.

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