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Osteoarthritis of the Thoracic Spine: An Analysis of the Relationship Between Sex Differences and Degeneration of the Thoracic Spine During the Life Course

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OSTEOARTHRITIS OF THE THORACIC SPINE: AN ANALYSIS OF THE RELATIONSHIP BETWEEN SEX DIFFERENCES AND DEGENERATION OF THE THORACIC SPINE DURING THE LIFE COURSE

by

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Under the Direction of Frank L'Engle Williams, Ph.D.

ABSTRACT

Osteoarthritis is one of the most common diseases associated with joint pain and will affect nearly all adults during their life course. There has been extensive research done involving the peripheral joints; however, the spine remains largely understudied, particularly the thoracic spine. Researchers suggest that this is due to the low prevalence of osteoarthritis seen in the thoracic vertebrae (Larsen 2015). However, there is evidence to suggest that osteoarthritis affects the thoracic skeleton extensively, primarily in the lower vertebral region. The aim of this research is to provide a better understanding of the processes that affect the thoracic spine, such as osteoarthritis, age and sex differences, and asymmetry of the thoracic superior and inferior articular facets.

INDEX WORDS: Thoracic skeleton, Osteoarthritis, Age differences, Sex differences, Frailty, Asymmetry, Handedness

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DEDICATION

This thesis is dedicated to my family who have never failed to offer their encouragement and support. They are my constant inspiration.

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1 INTRODUCTION

DEGENERATIVE JOINT DISEASE

Osteoarthritis also termed degenerative joint disease, is the most common form of arthritis and is a characteristic part of the aging process (White et al. 2012). According to Chen et al. (2017), by the year 2020, osteoarthritis will affect 25% of the adult population and it will be a significant cause of physical limitations for adults over the age of 40 years. It is characterized by a combination of progressive, degenerative loss of, and reactive bone formation in, the articular surfaces of the joints resulting in lipping, porosity, eburnation, and the formation of osteophytes (Larsen 2015). There are two types of osteoarthritis: primary and secondary. Primary osteoarthritis is related to age and accumulates progressively over time due to several factors, including sex, genetics, weight, and occupational stress. Secondary osteoarthritis is the result of stress suffered earlier in life, such as disease or trauma to the joint (Ortner 2003). The exact etiology of osteoarthritis is multifactorial, but the primary causal agents of the disease are age and mechanical stress (Ortner 2003). However, factors such as obesity, injury, inflammation, and genetic predisposition have also been cited as agents for osteoarthritis (Chen et al. 2017). The prevalence of osteoarthritis in individuals can also vary depending on different societies and the roles played by the individuals within a society (Ortner 2003).

Osteoarthritis affects the joints of various parts of the skeleton, most commonly the hands, knees, spine, and hips (Ortner 2003). Individuals will commonly experience pain, inflammation, and loss of mobility in the affected areas as they age (Goldring 2006). While it is generally agreed upon that osteoarthritis is characterized through the manifestation of eburnation, porosity, lipping, and osteophyte formation, there is some variability in the pathology of the different areas affected. For instance, the knees and elbows may exhibit deep grooves alongside eburnation, whereas the vertebral column may present lipping but experience less eburnation in less mobile areas (Ortner 2003). The hip exhibits eburnation and porosity within the ball and socket joint along with bony outgrowths of the femur known as “mushroom deformations” (Ortner 2003).

1.1 Occupational Stress

Although the etiology for the manifestation of osteoarthritis is multifactorial, there is research to suggest that mechanical or occupational stress could cause a greater severity of the manifestation of osteoarthritis. According to Weiss (2007), the repetitive use of specific muscles and joints could contribute to more severe cases of arthritis seen on specific articular surfaces. For instance, a study by Lovell (1994) suggested that specific physical stressors could correlate to more severe manifestations of osteoarthritis. She examined several skeletal remains from a Bronze Age Harappan cemetery and found that many of the individuals suffered more severely from degeneration of the cervical spine than from the thoracic or lumbar elements. They suggested that this could be due to the Harappan practice of transporting loads on the head, which would put a significant amount of mechanical stress on the cervical spine (Lovell 1994).

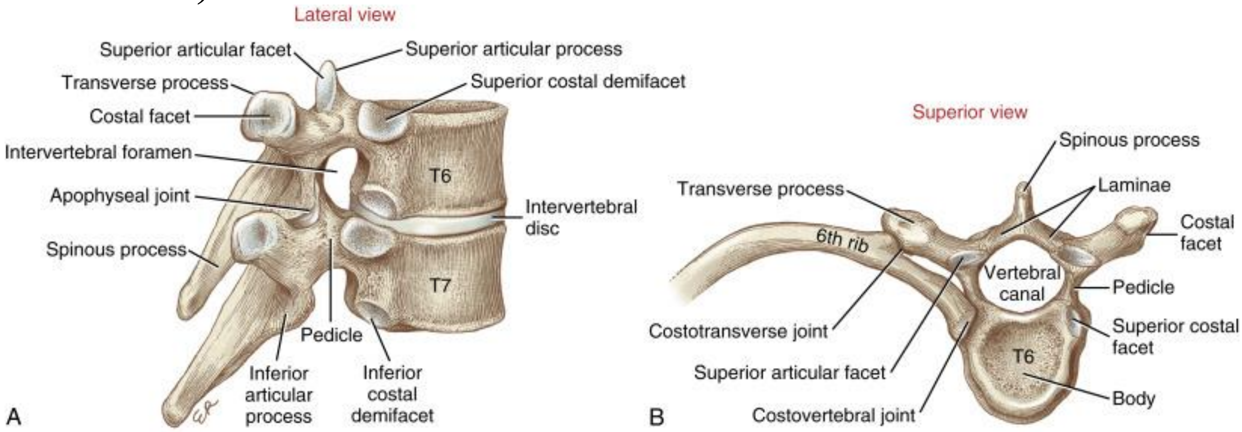
Since there is evidence to support this idea, some researchers believe that the study of occupational stress is an ideal method for reconstructing the past lifestyles of individuals (Weiss 2007). However, it has also been argued that because osteoarthritis is an age-related pathology caused by a variety of factors, it should not be considered as an absolute marker of repetitive actions. (Knusel 1997). Weiss et al. (2007) also suggest that while osteoarthritis may not be the best indicator of specific mechanical, repetitive activity overall, there could be a correlation in some situations concerning the age of onset and degree of occupational stress. For instance, research suggests that individuals who engage in agriculture as an occupation are often subject to mechanical stressors in the early stages of life (Weiss 2007).

Additionally, according to Lovell (1994), individual variance should also be taken into consideration when studying mechanical stress. She posits that stress markers will differ since the performance of a task will be contingent on individual variation such as “age, height, weight, handedness, preference, or pain threshold, or to other factors like training and experience” (Lovell 1994:150). In any case, when studying this disease, it is crucial to take into account the various factors that could be involved in the etiology of osteoarthritis.

1.2 Vertebral Osteoarthritis

In the spine, osteoarthritis primarily affects the subchondral bone of the intervertebral discs and the apophyseal joints (Ortner 2003). Degeneration is considered to begin with the intervertebral disc due to a decrease in cellular activity that is essential to the maintenance of the disc cartilage (Benoist 2003). According to Benoist (2003), the apophyseal joints will be affected by osteoarthritis secondary to the intervertebral discs, because the apophyseal joints act as a helper for load-bearing of the posterior (Fig. 1). The apophyseal joints are primarily associated with eburnation, porosity, and marginal lipping, and the subchondral bone (vertebral bodies) is characterized primarily by erosion and osteophyte development (Ortner 2003).

Figure 1: A lateral and superior view of the characteristics of thoracic vertebrae (Mansfield and Neumann 2018).



Osteoarthritic manifestations of the vertebral column are considered to be most prevalent on the lower cervical, lower thoracic, and lower lumbar regions that are subject to more pressure (Aufderheide and Rodriguez-Martin 1998). According to Andersson (1998), osteoarthritis affects the lower lumbar region sooner and more severely than the cervical and thoracic regions. Several studies of vertebral osteoarthritis have revealed four trends consistent with the manifestation of osteoarthritis on the spine. 1) the greatest prevalence can be seen between the fifth and sixth cervical vertebrae, 2) the lower thoracic shows a higher severity of osteoarthritis than the upper thoracic, 3) the greatest marginal lipping can be observed through the second and fourth lumbar vertebrae, and 4) the region least affected by osteoarthritis is the seventh thoracic to the upper thoracic (Larsen 2015).

Vertebral arthritis has been studied extensively since it is a common landmark of arthritis; however, arthritis of the thoracic region has been largely ignored. This is likely due to the larger number of vertebrae that must be analyzed to provide a comprehensive analysis of osteoarthritis compared to the fewer elements of the cervical or lumbar skeletons. Furthermore, according to Larsen (2015), this could also be due to the lower degree of movement in the thoracic vertebrae resulting in a lower degree of arthritis. It could be argued that there has not been enough research on degenerative joint disease of the thoracic vertebrae to suggest that there is less prevalence of the disease in the thoracic region. Through my previous research conducted at Western Carolina University, there was evidence of extreme osteoarthritis of the thoracic vertebra, including the middle region. However, this could be due to older age and, therefore, a greater progression of the disease. The research conducted at the University of Tennessee Knoxville aims to provide a more comprehensive understanding on the effect arthritis has on the thoracic vertebral region and to answer questions regarding how age, sex, and the severity of arthritis covary throughout the thoracic region.

2 THEORY

2.1 Asymmetry

Humans commonly exhibit bilateral asymmetry of the long bones, typically with the left femur being longer than the right and the right humerus being longer than the left (Auerbach 2005). Two types of asymmetry are recognized among osteologists: directional asymmetry and fluctuating asymmetry. Directional asymmetry occurs when traits on one side of a morphological structure are consistently larger than those on the opposite side. Fluctuating asymmetry occurs when the body is unable to develop bilaterally because it has encountered some form of stress (Van Valen 1962). For instance, researchers have suggested that more severe fluctuating asymmetry can occur when individuals undergo stress during growth and development (Larsen 2015).

There have been various studies on the relationship between the bilateral asymmetry of the humeri and mechanical loading. There is also evidence to suggest that bilateral asymmetry could result from more mechanical use of one side over the other. Studies have shown that this can result in the asymmetrical length and breadth of the distal humeri (Sladek 2007). Because of this, the humeral limbs can be assessed for bilateral asymmetry to determine handedness in individuals (Larsen 2015).

A study conducted by Ozener (2010) found that heavy working conditions can affect the directional asymmetry of individuals. They examined 309 males (ages 17-20) divided into three groups: “laborers of lower socioeconomic status,” “students who were of the same (lower) socioeconomic status as the laborers,” and “final year students . . . from the upper socioeconomic status” (Ozener 2010:113). The results suggested that mechanical stress did affect the directional asymmetry of individuals, primarily in those who spent critical developmental years engaging in difficult physical labor. Ozener also found that handedness plays an important role in the manifestation of directional asymmetry through the observation that right-handed individuals displayed larger traits in the upper limbs on the right side and left-handed individuals displayed larger traits in the upper limbs of the left side (2010).

An earlier study conducted by Ruff and Jones (1981) analyzed the breadths of cortical bone and the areas of the tibia and humerus of 79 adult individuals (30 males and 39 females) from the Stanford University Museum collection. They radiographed each right and left tibia and humerus and measured the breadths of the compact cortical bone. Their study aimed to determine whether age and sex had an effect on bilateral asymmetry. Their results suggested that bilateral asymmetry is more significant in the upper long bones than those of the lower limbs. It also suggested that bilateral asymmetry decreases with age. For instance, the younger females in this study exhibited greater bilateral asymmetry of the tibia and humerus than the older females. The authors posit that the loss of cortical bone individuals experience as they age will have a greater effect on the side with more cortical bone. Finally, Ruff and Jones (1981) consider the most notable discovery of the study to be the implication that bilateral asymmetry is variable among age cohorts, sex cohorts, and each bone.

My previous research conducted at Western Carolina University demonstrated that many individuals develop some asymmetry in the superior and inferior facets of the thoracic vertebrae. One of the aims of this project is to propose a suggestion for this phenomenon. The hypothesis is that individuals who favor a particular side or use one side of the body more than the other may develop asymmetry in the articular facets of the thoracic region. This can be seen in the asymmetry demonstrated on the muscle scarring of the long bones, which can be an indicator of handedness.

There has also been evidence of bilateral asymmetry in degenerative joint disease. A study by Ortner (1968) suggested that handedness could have an effect on the severity of osteoarthritis on one side over the other (Larsen 2015). The study demonstrated that there was a higher prevalence of osteoarthritis found in the right elbow than there was in the left elbow, suggesting that there had been greater mechanical use in the right arm. Larsen (2015) uses the example of spear or atlatl throwing by right-handed hunters explaining that predominant use of one arm over the other over time could contribute to the degeneration of the joints in that arm. Therefore, it is possible that there could be a correlation between handedness and thoracic osteoarthritis as well. Perhaps individuals utilize one side of the body more than the other resulting in an imbalance in the recruitment of muscles attached to the spine.

2.2 Sex Differences and Osteoarthritis

Sex differences have also been a common interest of study when examining osteoarthritis. There is a wide variety of the degree of osteoarthritis expressed in adult males and females across cultures. However, there are conflicting views on the correlation between sex differences and degeneration during the life course. According to Larsen (2015) when significant differences can be observed for osteoarthritis males tend to express a higher frequency of the disease than females. Rogers and Dieppe (2003) argue that while this is true for men before the age of 50 years, after the age of 50 years, women show greater prevalence of osteoarthritis. This could be due to the estrogen deficiency women experience while going through menopause. According to Rogers and Dieppe (2003), post-menopausal hormone deficiency can cause osteoarthritis in women to become rapidly progressive.

A study by Nevitt and Felson (1996) found two possible explanations for why estrogen could affect the degeneration of the joints. 1) Estrogen deficiency could enhance the production of cytokines and growth factors, which are essential in cartilage metabolism. The authors provide an example: "the cytokines interleukin (IL)-1 and tumor necrosis factor a (TNF-a). . . potentiate the production and activation of enzymes which degrade cartilage matrix" (p. 675).

2) A lack of estrogen could also have an effect on bone metabolism by reducing the rate of subchondral bone remodeling, therefore, allowing for the manifestation of osteoarthritis. It should be noted that the prevalence of osteoarthritis in males and females could differ depending on the location of degeneration. For instance, studies have shown that women exhibit more prevalence of osteoarthritis than men in the hand, knee, and hip (Nevitt and Felson 1996).

The relationship between sex differences and the degeneration of the vertebral column remains largely understudied. However, one study by Quispe and Williams (2019) provided an examination of the cervical vertebrae (C3-C7) of males and females of the same age cohorts (50-55 years and 70-76 years) to determine if a difference was expressed between these ages. They found that females exhibit a greater severity of degeneration than males in the 50-55 age cohort, and males exhibit a greater severity of degeneration than females in the 70-76 age cohort (Quispe and Williams 2019). This would further corroborate the theory that the severity of osteoarthritis could vary between the sexes depending on the location of osteoarthritis.

Srikanth et al. (2005) also provided a study on the relationship between sex differences and osteoarthritis. They analyzed 34 studies on sex differences and degeneration to determine whether studies have shown an increased severity in males or females. Out of the 34, only four studies were conducted on the spine and focused on the cervical and lumbar vertebrae. The results yielded no significant difference between males and females (Srikanth et al. 2005). This study shows that there is a lack of research on the degeneration of the spine and its correlation with sex differences.

2.3 Aging and Osteoarthritis

Osteoarthritis is considered to be closely correlated with the aging process. Throughout all cultures most individuals over the age of 50 years will experience osteoarthritis (Felson 2003). There are various theories for the correlation between aging and the accumulation of the degenerative processes of the skeleton. One of these theories is the idea that articular cartilage will be subject to "wear and tear" overtime due to extended periods of mechanical use (Van der Kraan and Berg 2008:107). Another theory suggests that a progressive change will occur in the extracellular matrix of the articular cartilage during the aging process (Van der Kraan and Berg 2008). This is supported in a study conducted by Cunha (2014) where they examined the peripheral and appendicular skeleton of thirty-six adults from a cemetery of an old church in Portugal. Their results suggested that osteoarthritis may rapidly progress in older individuals because of the decreased ability of articular cartilage to withstand the pressures of mechanical loading (Cunha 2014).

The idea of frailty could also contribute to the correlation of the accumulation of degenerative processes and aging. Frailty is most commonly defined as "a biological syndrome of decreased reserve and resistance to stressors, resulting from cumulative declines across multiple physiological systems, and causing vulnerability to adverse outcomes." (Fried et al. 2001:M146). Frailty is highly variable among individuals and will differ depending on factors such as, chronic illness and advanced age (Marklein 2016). Frailty includes the rigors of physical activity such as occupational stress and the presence of past trauma, which correlates with the manifestation of osteoarthritis. This could help explain why in some age cohorts there are outliers who seem to have suffered more severely from osteoarthritis than others.

2.4 Osteoarthritic Processes: Separate or One Condition?

Osteoarthritis is generally characterized by porosity, eburnation, osteophyte formation, lipping, and ankylosis. There is debate, however, that these may be separate processes and not the manifestations of one condition. For instance, Rothschild (1997) argues that porosity and eburnation may not be substantial markers of osteoarthritis. He posits that porosity is a phenomenon that affects the subchondral bone and does not have a direct relationship to degenerative processes and should therefore not be used to measure severity of osteoarthritis.

Rothschild (1997) also suggests that eburnation is the consequence of bone polishing due to bone rubbing over time and that the process demonstrates the location of articular joint degeneration and the severity of arthritis, but is not an indicator for the pathology specifically. Rogers and Dieppe (2003) however, argue that eburnation is undeniable evidence of the manifestation of osteoarthritis since it is proof of complete cartilage deterioration. Some paleopathologists have gone so far as to suggest that eburnation is the only true sign of osteoarthritis (Larsen 2015).

According to Nathan (1962), osteophytes are bony outgrowths that are a response to pressure on the vertebrae. This is supported by the evidence that osteophytes are generally found in the lower thoracic and lumbar and predominantly on the anterior of the vertebral body (Nathan 1962). Listi and Manhein (2012) conducted a study that examined all vertebrae, except the atlas and axis, of one hundred and four individuals aged to between 30 and 90 years to assess whether a correlation exists between age and osteophyte development. Their results suggested that not only did a relationship exist for age and osteophyte development, but it continued to exist when in combination with osteoarthritis (Listi and Manhein 2012). Other paleopathologists acknowledge the presence of osteoarthritis through multiple indicators, for instance when at least two or more indicators are expressed or when multiple indicators can be identified (Larsen 2015).

3 MATERIALS AND METHODS

3.1 Research Question

The aim of this research project is to answer the questions:

1. Do sex differences influence the degeneration of the thoracic vertebrae during the life course?
2. Do age differences influence the degeneration of the thoracic vertebrae?
3. Do age and sex differences influence the expression of asymmetry of the thoracic vertebral articular facets?
4. Is asymmetry of the thoracic articular facets related to handedness?

This research will attempt to provide a better understanding of the influence sex differences have on the degeneration and asymmetry of the thoracic vertebrae during the life course. Linking age and sex to the degree of osteoarthritis will lend insights into the chronology of the degeneration of the thoracic skeleton.

Thoracic vertebrae were examined from complete skeletons of the William M. Bass collection from the University of Tennessee Knoxville. The University of Tennessee Knoxville curates an extensive collection with known sexes, adult ages, and causes of death. The demographic trends explored by Shirley, Wilson, and Jantz (2011) found that the Bass collection consisted of 91% European Americans, 7% African Americans, and 2% Hispanic Americans with a larger number of males than females. Regarding socioeconomic status, 60% of donors could be categorized as low to middle income and 40% were laborers with a high school diploma (Wilson et. al 2007). Established parameters are crucial to the study since the aim is to determine the relationship between sex differences and the aging process. Ninety-eight individuals were scored for osteoarthritis using Buikstra and Ubelaker's (1994) non-metric (1- 4) system. The individuals were also scored for asymmetry using a non-metric (1-4) system developed by the author. The sample included four groups: females ages 50-55 years, females ages 70-75 years, males ages 50-55 years, and males ages 70-75 years. Each thoracic vertebrae from T1 to T12 were examined including the superior and inferior surfaces and the superior and inferior articular facets.

Fifty-five of the ninety eight individuals were examined to determine handedness due to time constraints. This was completed by observing the interosseus crests of the radius and ulna as well as the humeral, radial and ulnar tuberosities. Individuals examined for the study include white, working-class, and with a living stature between five-feet two inches and six-feet. Specific parameters were necessary to ensure there were fewer extrinsic forces that could potentially affect the expression of osteoarthritis. For instance, non-working class individuals may exhibit less osteoarthritis compared to working class individuals due to lack of activity. Although it is impossible to establish perfect parameters that do not involve some influence due to individual life histories, these parameters were set to decrease the possibility of extrinsic factors affecting the results.

3.2 Preliminary Research

A scoring error study was conducted on the osteological materials housed by Georgia State University through the Bioarchaeology Teaching Laboratory of the Department of Anthropology prior to the analysis of the remains at Western Carolina University. The error study utilized Buikstra and Ubelaker’s non-metric 1-4 scoring system (1994) and consisted of twenty-seven different thoracic vertebrae that were analyzed twice. A Mann-Whitney U test was then performed to assess whether there were any significant differences between the two scoring trials to which there were none.

Thoracic vertebrae were then examined from complete skeletons at the Western Carolina University’s Human Identification Laboratory. The collection includes of donated human remains for the University’s Forensic Osteology Research Station (FOREST), which aims to promote further research within the field of forensic anthropology. Twenty-one individuals were scored for osteoarthritis using Buikstra and Ubelaker’s non-metric (1-4) system (Buikstra and Ubelaker 1994). The sample included ten females who died between the ages of 50-69 years and ≥ 70 years. The sample also included eleven males from the ages of 37-89 years; a small number of these died under the age of 41 years while the rest died between the ages of 50-69 years, and from the ages ≥ 70 years. Four of the individuals (two females and two males) that were examined did not have associated ages. Each thoracic vertebrae from T1 to T12 were examined as were each superior and inferior surface.

The results obtained by a Mann Whitney U test suggested that for individuals within the age range of 50-69 years, males exhibited a higher degree of osteoarthritis than females. However, for individuals 70 years and older, females exhibited a higher degree of osteoarthritis than males. For the superior surface in individuals 50-69 years, the significant differences were found in degree of expression in lipping and osteophyte formation whereas in individuals 70 years and older the significant differences in degree was expressed in porosity, the extent of porosity, and the extent of eburnation. In contrast, for the inferior surface, individuals of 50-69 years exhibited a higher degree in lipping and extent of eburnation, and for individuals 70 years and older, the degree was expressed in porosity, the extent of lipping, and the extent of porosity. It should be noted that the sample was not evenly distributed concerning the age cohorts. For instance, for the age range 50-69, there were more males than females, and for the age range 70 years and older there were more females than males. This could account for the significant difference in the degree of osteoarthritis. The comparison of the degree of osteoarthritis within and between groups was also compromised since there were only two individuals in the sample to represent the age range of 49 and under. This study provided the rationale for a larger sample size with a more defined set of age ranges to more accurately answer the question: Do sex differences influence the degeneration of the thoracic vertebrae?

3.3 Method

A non-metric scoring analysis provided by Buikstra and Ubelaker (1994) was used to determine the degree of lipping, porosity, eburnation, and osteophyte formation (Table 1). The degree of lipping was scored from 1- 4, 1) barely discernible, 2) sharp ridge, sometimes curled with spicules, 3) extensive spicule formation, and 4) ankylosis (Fig. 2). Porosity was scored from 1-3, 1) pinpoint, 2) coalesced, and 3) pinpoint and coalesced (Fig. 3). Eburnation was analyzed 1-3 1), barely discernible, 2) polish only, and 3) polish with grooves (Fig. 4). Lastly, the degree of osteophyte formation was scored from 1-4, 1) barely discernible, 2) elevated ring, 3) curved spicules, and 4) fusion present (Fig. 5). The superior and inferior surfaces of the body were scored for lipping, porosity, and osteophyte formation and the superior and inferior articular facets were also scored for the degree of eburnation.

In order to evaluate asymmetry of the thoracic facets the author of this thesis developed a non-metric scoring method of (1-4), 1) not present, 2) slight asymmetry, 3) moderate asymmetry, and 4) significant asymmetry (Fig. 6; Table 2). The right and left of both the superior and inferior articular facets were scored separately. For both the superior and inferior surfaces of the thoracic vertebrae Mann-Whitney U tests were conducted between the sexes for both age categories and between all males and all females regardless of age to determine if significant differences exist. Asymmetry was also examined by comparing the osteoarthritic manifestations on the right and left within and across the sexes and age categories. A significant difference was determined by a *p-value* of <0.05.

To determine handedness the interosseus crests of the radius and ulna as well as the humeral, radial and ulnar tuberosities were examined for observable asymmetry. Individuals were scored from (1-3), 1) right-handed, 2) left-handed, and 3) indeterminate (Table 3). An indeterminate score was given to individuals who did not exhibit any observable asymmetry of the humerus, radius, or ulna. A Pearson correlation was performed to evaluate the relationship between handedness and raw asymmetry scores of each right and left, superior and inferior articular facet of each vertebrae. A Mann Whitney U test was also conducted on a pooled sample of the vertebrae with the indeterminates removed to attempt to answer the same question.

Table 1: Description of Buikstra and Ubelaker's scoring method for osteoarthritis.

Feature	Score	Extent	Description
Lipping	1	<1/3	Barely discernible
	2	1/3-2/3	Sharp ridge, sometimes curled with spicules
	3	>2/3	Extensive spicule formation
	4		Ankylosis
Porosity	1	<1/3	Pinpoint
	2	1/3-2/3	Coalesced
	3	>2/3	Pinpoint and coalesced
Eburnation	1	<1/3	Barely discernible
	2	1/3-2/3	Polish only
	3	>2/3	Polish with groove(s)
Osteophyte	1	None	Barely discernible
	2		Elevated ring
	3		Curved spicules
	4		Fusion present

Table 2: Description of the scoring method for asymmetry.

Feature	Score	Description
Asymmetry	1	Not present
	2	Slight asymmetry
	3	Moderate asymmetry
	4	Extreme asymmetry

Table 3: Description of the scoring method for handedness.

Feature	Score	Description
Handedness	1	Right
	2	Left
	3	Indeterminate

Figure 2: Buikstra and Ubelaker's (1994) scoring system for lipping. (A) barely discernible, (B) sharp ridge, sometimes curled with spicules, (C) extensive spicule formation, and (D) ankylosis Scale: 1 cm.

Figure 3: Buikstra and Ubelaker's (1994) scoring system for surface porosity. (A) pinpoint, (B) coalesced, and (C) both pinpoint and coalesced. Scale: 1 cm.

Figure 4: Buikstra and Ubelaker's (1994) scoring system for eburnation. (A) barely discernible, (B) polish only, and (C) polish with groove(s). Scale: 1 cm.

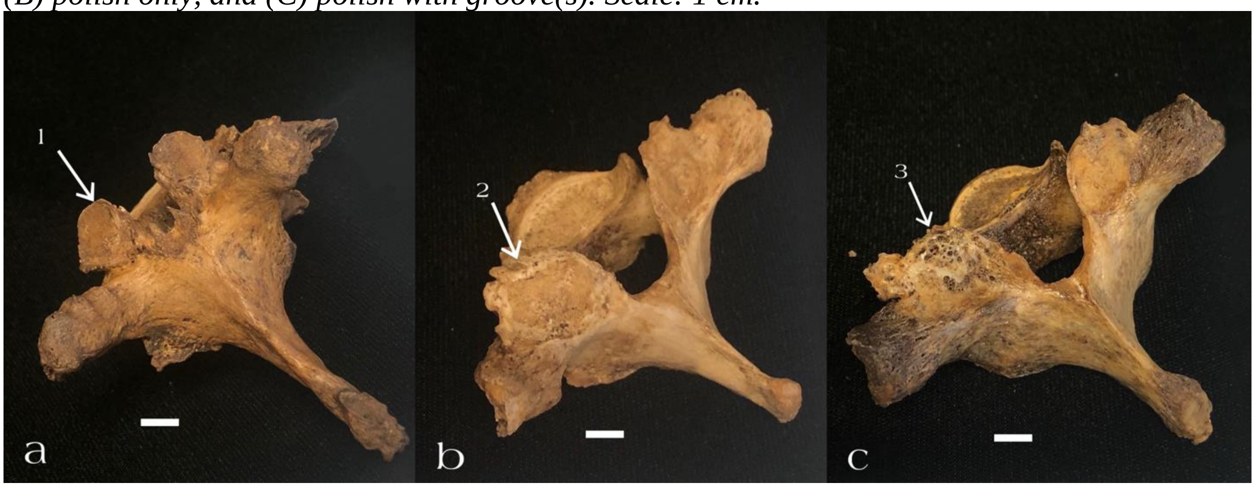


Figure 5: Buikstra and Ubelaker's (1994) scoring system for osteophytes. (A) barely discernible, (B) elevated ring, (C) curved spicules, and (D) fusion present. Scale: 1 cm.

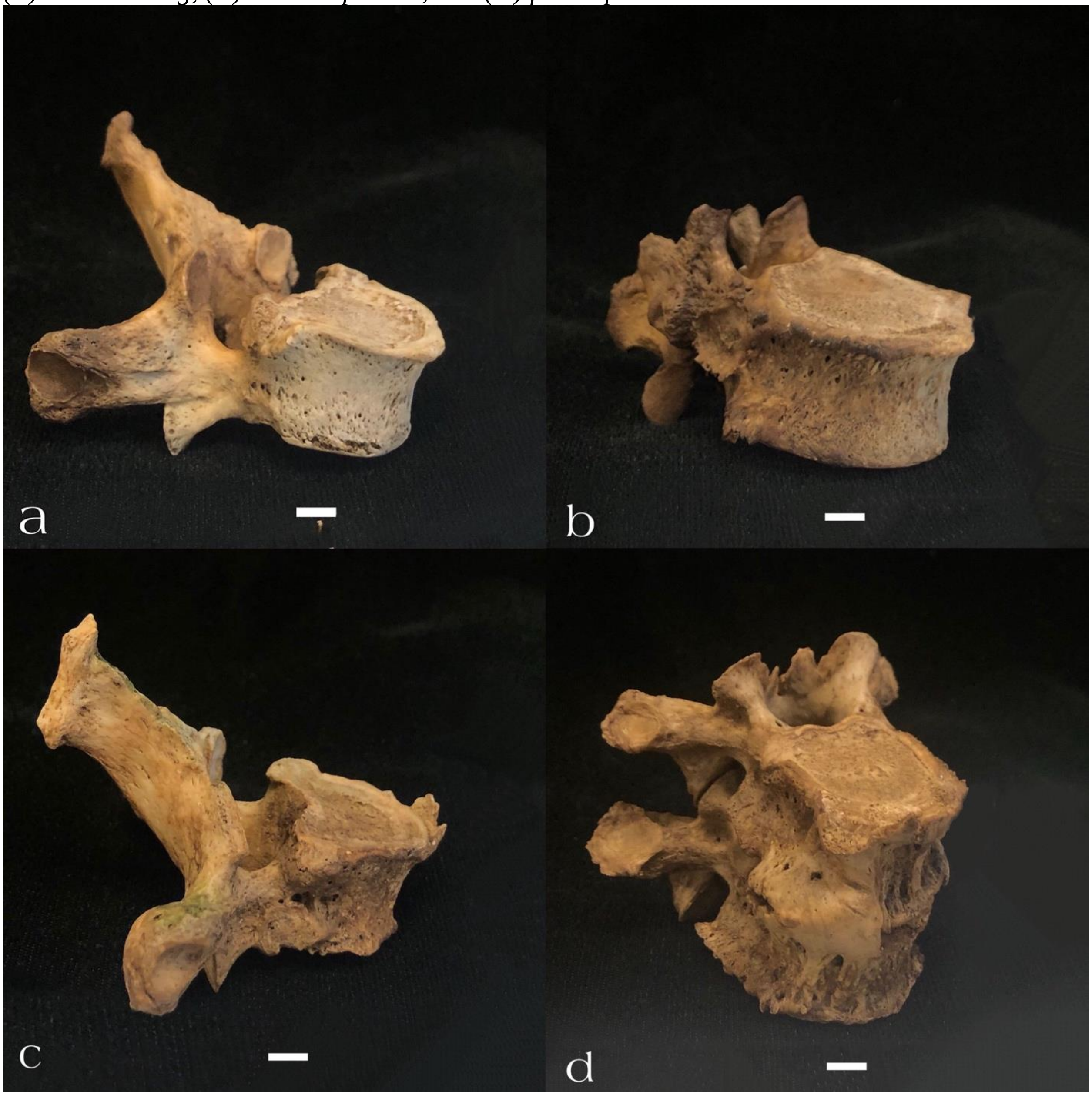
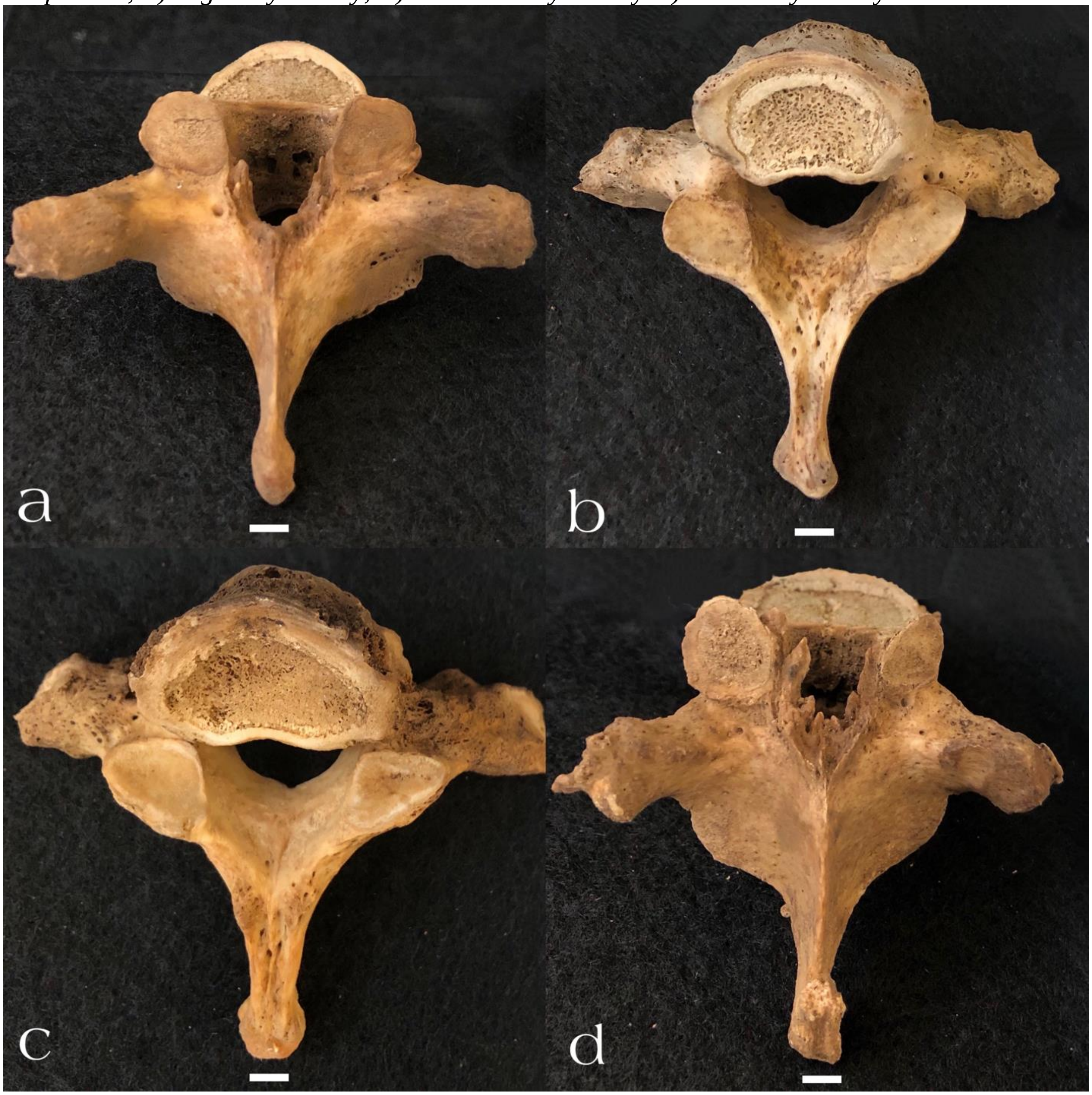


Figure 6: Scoring system for asymmetry of the thoracic superior and inferior articular facets. A) not present, B) slight asymmetry, C) moderate asymmetry D) severe asymmetry. Scale: 1 cm.



3.4 Hypothesis

The aim of this study is to 1) assess the relationship between age differences and the expression of osteoarthritis of the thoracic region, 2) assess the relationship between sex differences and the expression of osteoarthritis of the thoracic region, 3) assess the relationship between age and sex differences and the asymmetry of the inferior and superior articular facets of the thoracic, and 4) assess the relationship between asymmetry and handedness. With regard to the first question it is expected that osteoarthritis of the thoracic vertebrae will increase with age. Considering the second objective for the relationship between sex differences it is expected that males will exhibit a greater severity of osteoarthritis than females. For the third goal, it is anticipated that a greater expression of asymmetry will be observed in females over males and the elderly over older adults. Finally, it is expected that handedness or some other biomechanical factor will have a relationship with directional asymmetry of the superior and inferior articular facets of the thoracic spine.

This study contributes to the understanding of osteoarthritis of the thoracic vertebral region. Osteoarthritis affects the majority of adults at some point during their lives, therefore it is an important issue to study. In order to better understand osteoarthritis and the ways in which it affects adults it is necessary to study the thoracic region as extensively as other regions of the body have been studied. This study also contributes to the study of trends of osteoarthritis and will lend insight on the effect age and sex differences have on the way it manifests. Asymmetry of the thoracic articular facets appears to affect most adults and there is a lack of information on asymmetry of the spinal region and the possible reasons it could occur. This study brings the scientific community closer to understanding why asymmetry arises and whether age and sex differences or handedness have an effect on its expression.

4 RESULTS

Tables 4 and 5 represent the descriptive statistics for each age and sex grouping. Older males have higher means than older females in all categories except for eburnation, extent of eburnation, and extent of osteophyte formation, where females show greater average values for extent of eburnation and the same average values as males for eburnation and extent of osteophyte formation. The means for elderly males and females are higher than those of older adults with the exception of extent of porosity, where older males exhibit higher scores overall. Elderly females also surpass all age and sex categories in degree of eburnation. The standard deviations are highest for extent of lipping and lowest for extent of osteophyte formation.

Table 4: Descriptive statistics for older adults (50-55 years).

Older adults (50-55 years)	Female					Male				
	N	Min	Max	Mean	SD	N	Min	Max	Mean	SD
Lipping	336	1	4	1.57	.687	300	1	3	1.67	.691
Lipping ext.	336	1	3	1.93	.878	300	1	3	2.03	.884
Porosity	336	1	2	1.02	.133	300	1	3	1.06	.244
Porosity ext.	336	1	3	1.61	.787	300	1	3	1.81	.844
Eburnation	336	1	3	1.04	.221	300	1	3	1.04	.204
Eburnation ext.	336	1	3	1.07	.306	300	1	3	1.01	.100
Osteophyte	336	1	4	1.24	.660	300	1	3	1.31	.742
Osteophyte ext.	336	1	2	1.02	.153	300	1	3	1.02	.151

Table 5: Descriptive statistics for elderly adults (70-75 years).

Elderly adults (70-75 years)	Female					Male				
	N	Min	Max	Mean	SD	N	Min	Max	Mean	SD
Lipping	285	1	3	1.68	.632	254	1	4	1.98	736
Lipping ext.	285	1	4	1.93	.893	254	1	3	2.17	.880
Porosity	285	1	3	1.16	.457	254	1	3	1.14	.392
Porosity ext.	285	1	3	1.73	.853	254	1	4	1.79	.885
Eburnation	285	1	3	1.15	.402	254	1	3	1.11	.350
Eburnation ext.	285	1	3	1.12	.428	254	1	3	1.10	.394
Osteophyte	285	1	4	1.26	.632	254	1	4	1.54	.996
Osteophyte ext.	284	1	3	1.05	.239	254	1	3	1.10	.336

4.1 Sex and Age

4.1.1 Differences in thoracic osteoarthritis with respect to age among females (50-75 years)

For the superior surface, when only females are considered significant differences exist for lipping, porosity, extent of porosity, and eburnation (Table 6). Elderly females exhibit a higher degree of thoracic osteoarthritis overall when compared to older adults. Although not significant it should also be mentioned that T10 and T12 also express a value of .051 in eburnation. For the inferior surface significant differences are the same for the superior surface with the exception of degree of eburnation and the addition of the extent of eburnation (Table 7). The inferior surface also exhibits a greater degree of osteoarthritis than the superior surface and elderly females continue to exhibit a higher degree than older adults overall. However, older females demonstrate a greater extent of eburnation in T1 and extent of lipping in T11 than elderly females.

Table 6: Differences in thoracic osteoarthritis of the superior surface between older females(50-55) and elderly females (70-75 years).

	Lipping	Lipping extent	Porosity	Porosity extent	Eburnation	Eburnation extent	Osteophyte	Osteophyte extent
T1	.496	.527	.123	.512	.080	.770	1.000	1.000
T2	.496	.118	.467	.526	.912	.890	.280	1.000
T3	.517	.948	.123	**.036 E>O**	.650	.355	.123	1.000
T4	.920	.650	.912	.410	.249	.507	.843	1.000
T5	.846	.753	.225	.570	.518	.481	.720	.355
T6	.925	.984	.280	.393	.289	.454	.567	.280
T7	.490	.899	.110	.281	.233	.123	.915	.280
T8	.782	.953	**.011 E>O**	.641	.467	.890	.404	.215
T9	**.030 E>O**	.740	**.005 E>O**	.604	**.012 E>O**	.123	.638	.225
T10	.462	.808	**.010 E>O**	.927	**.051 E>O**	.444	.737	.485
T12	.347	.393	.430	.853	**.051 E>O**	.233	.937	.444

Table 7: Differences in thoracic osteoarthritis of the inferior surface between older females (50-55) and elderly females (70-75 years).

	Lipping	Lipping extent	Porosity	Porosity extent	Eburnation	Eburnation extent	Osteophyte	Osteophyte extent
T1	**.026 E>O**	.112	.123	.640	.843	**.031 E<O**	.280	.280
T2	.150	**.004 E>O**	.123	.738	.454	.905	.683	1.000
T3	.683	**.040 E>O**	.233	**.021 E>O**	.874	.912	.506	1.000
T4	.157	.135	.153	.966	.233	.481	.548	.355
T5	.528	.200	.225	.248	.747	.280	.580	.890
T6	.216	.402	**.024 E>O**	.602	.382	.186	1.000	.233
T7	.834	.885	.088	.231	.233	.912	.309	.912
T8	**.036 E>O**	.422	**.001 E>O**	.784	.123	.481	.744	.110
T9	.152	.629	.056	.570	.056	.874	.796	.650
T10	.118	.504	.121	.828	1.000	.195	.711	.888
T11	.915	**.022 E<O**	.201	.722	1.000	.195	.811	.888
T12	.058	.647	.051	.470	1.000	1.000	.755	.710

4.1.2 Differences in thoracic osteoarthritis with respect to age among males (50-75 years)

When only males are considered for the superior surface significant values exist for lipping, porosity, eburnation, extent of eburnation, and extent of osteophyte formation, with elderly males exhibiting a higher degree than older males(Table 8). These differences are expressed in the mid thoracic, T4 through T6. The inferior surface shows significant differences for all characteristics except for osteophyte formation. The inferior surface affects a greater number of vertebra for the thoracic region than the superior surface (Table 9). As expected elderly adults exhibit a greater degree of osteoarthritis than older adults overall except for the extent of porosity.

Table 8: Differences in thoracic osteoarthritis of the superior surface between older males (50-55 years) and elderly males (70-75 years).

	Lipping	Lipping extent	Porosity	Porosity extent	Eburnation	Eburnation extent	Osteophyte	Osteophyte extent
T1	.520	.100	.074	.054	.150	.876	.119	1.000
T2	.435	.341	.873	.456	1.000	1.000	.673	1.000
T3	.835	.638	.455	.564	.119	.275	.424	1.000
T4	**.001 E>O**	.860	.475	.373	**.053 E>O**	.275	.514	.359
T5	**.009 E>O**	.288	.106	.252	.298	**.024 E>O**	.059	1.000
T6	**.004 E>O**	.229	**.049 E>O**	.586	.257	.275	.480	.455
T7	.095	.614	.119	.301	.661	.275	.400	**.053 E>O**
T8	.069	.631	.223	.567	1.000	.424	.118	**.053 E>O**
T9	.137	.369	.214	.594	.359	.119	.481	**.053 E>O**
T10	.344	.272	.111	.963	.128	.059	.424	.285
T11	.155	.894	.536	.625	1.000	.348	.609	.285
T12	.454	.183	.632	.694	.895	.127	.865	.243

Table 9: Differences in thoracic osteoarthritis of the inferior surface between older males (50-55 years) and elderly males (70-75 years).

	Lipping	Lipping extent	Porosity	Porosity extent	Eburnation	Eburnation extent	Osteophyte	Osteophyte extent
T1	.096	**.003 E>O**	.857	.270	.275	.359	.257	1.000
T2	**.053 E>O**	.344	.500	.990	1.000	.119	.440	1.000
T3	**.015 E>O**	.301	.214	.720	.119	.119	.172	.359
T4	**.009 E>O**	.207	.475	.878	**.053 E>O**	**.053 E>O**	.177	.119
T5	**.019 E>O**	.055	**.011 E>O**	.422	.455	**.053 E>O**	.270	.455
T6	**.003 E>O**	.496	.124	**.040 E<O**	.901	.699	.259	**.053 E>O**
T7	.068	.504	.206	.981	.275	.359	.174	**.024 E>O**
T8	.656	.743	**.020 E>O**	.654	.359	.275	.456	**.053 E>O**
T9	.364	.255	**.029 E>O**	.459	.275	.275	.308	.257
T10	.731	.118	.115	.952	.180	.466	.240	.115
T11	.483	.162	.523	.915	.927	.903	.224	.302
T12	**.046 E>O**	.441	.927	.293	.127	.927	.076	.271

4.1.3 Sex differences in thoracic osteoarthritis for older adults (50-50 years)

For the superior surface when older adult males and females are compared significant differences exist for porosity, extent of porosity, and extent of eburnation for T1,T3, and T12 (Table 10). Males exhibit a greater degree of porosity and extent of porosity, whereas females exhibit a greater extent of eburnation. A greater number of vertebrae are affected for the inferior surface and significant differences exist for lipping, extent of lipping, and extent of porosity (Table 11). For all three significant differences males express a greater degree of severity than their female counterparts.

Table 10: Sex differences in thoracic osteoarthritis of the superior surface for older adults (50-55 years).

	Lipping	Lipping extent	Porosity	Porosity extent	Eburnation	Eburnation extent	Osteophyte	Osteophyte extent
T1	.145	.250	**.006 M>F**	.186	.808	.199	1.000	1.000
T2	.276	.569	.935	.315	.345	.345	.131	1.000
T3	.117	.067	.290	**.003 M>F**	.177	.345	.957	1.000
T4	.246	.774	.490	.084	.345	.177	.876	.290
T5	.797	.669	.935	.231	.550	.345	.392	.345
T6	.324	.622	.290	.639	.907	.345	.884	.290
T7	.694	.574	.345	.447	.490	1.000	.845	1.000
T8	.264	.400	.935	.455	.345	.935	.650	.345
T9	.227	.886	.290	.360	.290	.345	.557	.345
T10	.695	.148	.290	.688	1.000	.345	.718	.907
T11	.301	.198	.131	.540	1.000	.935	.077	.907
T12	.079	.253	.490	.221	.131	**.052 M<F**	.117	.935

Table 11: Sex differences in thoracic osteoarthritis of the inferior surface for older adults (50-55 years).

	Lipping	Lipping extent	Porosity	Porosity extent	Eburnation	Eburnation extent	Osteophyte	Osteophyte extent
T1	**.029 M>F**	.936	.131	.576	.177	.105	.131	1.000
T2	.107	**.022 M>F**	.131	.169	.345	.177	.609	1.000
T3	.244	**.050 M>F**	.935	**.003 M>F**	.177	.345	.316	.290
T4	1.000	.526	.907	.217	.345	.345	.548	.345
T5	.500	.436	.345	.058	.350	1.000	.538	.935
T6	.791	.520	.490	.447	.360	.907	.443	.345
T7	.831	.093	.360	.416	.345	.957	.969	.345
T8	.055	.553	.935	.899	.290	.345	.820	.345
T9	**.040 M>F**	.945	.131	1.000	1.000	.177	.942	.907
T10	**.040 M>F**	.497	.624	.732	.131	.593	.489	.935
T11	.098	.070	.251	.521	.290	.624	.203	.490
T12	.661	.652	.290	.839	1.000	.290	.545	.656

4.1.4 Sex differences in thoracic osteoarthritis for elderly adults (70-75 years)

When elderly males and females are compared for the superior surface elderly males exhibit a greater degree of osteoarthritis through lipping, extent of lipping, and extent of porosity in T1, T4, and T5 (Table 12). However, in T9 the degree of eburnation is significantly greater in elderly females. There is no significant difference in porosity or osteophyte formation for elderly males or females. For the inferior surface significant differences exist only for lipping and osteophyte formation, however a larger number of vertebrae is affected than observed for the superior surface (Table 13). Elderly males exhibit a greater degree of lipping and osteophyte formation than elderly females.

Table 12: Sex differences in thoracic osteoarthritis of the superior surface for elderly adults (70-75 years).

	Lipping	Lipping extent	Porosity	Porosity extent	Eburnation	Eburnation extent	Osteophyte	Osteophyte extent
T1	.080	**.041 M>F**	.636	**.011 M>F**	.634	.226	.126	1.000
T2	.251	.935	.666	.356	.361	.361	.896	1.000
T3	.347	.073	.890	.849	.477	.285	.538	1.000
T4	**.008 M>F**	.734	.231	.960	.908	.345	.545	1.000
T5	**.019 M>F**	.730	.600	.537	.328	.316	.112	1.000
T6	.056	.403	.070	.397	.784	.655	.758	.477
T7	.322	.961	.464	.187	.368	.617	.365	.239
T8	.296	.263	.203	.691	.181	.477	.203	.906
T9	.412	.178	.378	.891	**.028 M<F**	.537	.574	.862
T10	.390	.980	.794	.706	.692	.574	.364	.601
T11	.081	.102	.602	.990	.328	.328	.233	.139
T12	.140	.272	.564	.194	.677	.528	.123	.602

Table 13: Sex differences in thoracic osteoarthritis of the inferior surface for elderly adults (70-75 years).

	Lipping	Lipping extent	Porosity	Porosity extent	Eburnation	Eburnation extent	Osteophyte	Osteophyte extent
T1	.112	.164	.890	.875	.617	1.000	.113	.361
T2	**.043 M>F**	.681	.531	.403	.181	.890	.511	1.000
T3	.232	.192	.817	.654	.890	.477	.101	1.000
T4	.264	.845	.631	.149	.862	.518	.153	.126
T5	.223	.221	.347	.891	.890	.213	.976	.511
T6	**.022 M>F**	.390	.952	.077	.924	.285	.070	.862
T7	**.026 M>F**	.547	.315	.690	.368	.350	.523	.117
T8	.591	.866	.572	.950	.181	.655	.484	.842
T9	**.028 M>F**	.057	.128	.815	.368	.617	.215	.113
T10	.466	.120	.732	.860	1.000	.144	.164	.139
T11	**.029 M>F**	.060	.705	.938	.307	.307	**.013 M>F**	.144
T12	.220	.448	.322	.641	.144	.307	**.008 M>F**	.311

4.1.5 Sex differences in thoracic osteoarthritis regardless of age

For the superior surface when males and females are compared regardless of age significant differences exist for all categories except eburnation, extent of eburnation, and extent of osteophyte formation (Table 14). Males exhibit a greater severity of osteoarthritis than females overall. The same trend is exhibited for the inferior surface (Table 15).

Table 14: Sex differences in thoracic osteoarthritis of the superior surface regardless of age.

	Lipping	Lipping extent	Porosity	Porosity extent	Eburnation	Eburnation extent	Osteophyte	Osteophyte extent
T1	**.022 M>F**	**.024 M>F**	.53	**.006 M>F**	.622	.076	.131	1.000
T2	.124	.701	.770	.178	.186	.186	.240	1.000
T3	.085	**.010 M>F**	.550	**.028 M>F**	.751	.931	.589	1.000
T4	.469	.991	.175	.212	.786	.121	.574	.288
T5	.226	.976	.614	.709	.260	.604	.499	.347
T6	.619	.856	**.038 M>F**	.792	.792	.383	.752	.253
T7	.817	.647	.307	.732	.823	.625	.436	.253
T8	.780	.165	.293	.401	.100	.544	.250	.803
T9	.129	.323	.635	.552	.127	.331	.959	.830
T10	.396	.324	.892	.575	.723	.898	.380	.621
T11	.056	**.040 M>F**	.199	.653	.337	.608	**.036 M>F**	.233
T12	.024	.926	.939	.070	.616	.282	.027	.616

Table 15: Sex differences in thoracic osteoarthritis of the inferior surface regardless of age.

	Lipping	Lipping extent	Porosity	Porosity extent	Eburnation	Eburnation extent	Osteophyte	Osteophyte extent
T1	**.015 M>F**	.334	.320	.816	.214	.121	**.033 M>F**	.352
T2	**.017 M>F**	.094	.180	.115	.100	.482	.905	1.000
T3	.938	**.025 M>F**	.834	**.013 M>F**	.493	.901	.058	.288
T4	.528	.561	.730	.058	.823	.877	.151	.489
T5	.642	.175	.594	.190	.564	.241	.683	.569
T6	.145	.913	.806	.547	.493	.538	.071	.823
T7	.271	.103	.167	.773	.218	.616	.734	.320
T8	.059	.588	.540	.944	.633	.377	.516	.589
T9	**.004 M>F**	.206	**.047 M>F**	.874	.372	.211	.442	.208
T10	.052	.632	.630	.709	.139	.608	.142	.194
T11	**.006 M>F**	.981	.302	.611	.139	.917	**.007 M>F**	.112
T12	.258	.419	.716	.615	.139	.139	**.017 M>F**	.621

4.1.6 Age differences in thoracic osteoarthritis regardless of sex

When age differences are compared for the superior surface regardless of sex, significant differences exist for every characteristic except for extent of lipping, extent of porosity, and osteophyte formation (Table 16). Almost all vertebra are affected and elderly adults exhibit a higher severity of osteoarthritis than older adults. For the inferior surface significant differences exist for every characteristic except for extent of porosity and osteophyte formation (Table 17). The only vertebra that does not show a significant difference is T11. As expected for all significant differences, elderly adults exhibit a greater severity of osteoarthritis than their older adult counterparts.

Table 16: Age differences in thoracic osteoarthritis of the superior surface regardless of sex.

	Lipping	Lipping extent	Porosity	Porosity extent	Eburnation	Eburnation extent	Osteophyte	Osteophyte extent
T1	.336	.105	.429	.059	**.023 E>O**	.734	.123	1.000
T2	.339	.075	.502	.347	.895	.883	.866	1.000
T3	.694	.875	.118	.373	.519	.907	.086	1.000
T4	**.026 E>O**	.831	.523	.950	**.032 E>O**	.295	.531	.357
T5	.060	.338	**.044 E>O**	.720	.227	**.032 E>O**	.221	.357
T6	**.040 E>O**	.382	**.029 E>O**	.829	.120	.228	.367	.236
T7	.093	.641	**.029 E>O**	.988	.538	.058	.508	**.027 E>O**
T8	.302	.725	**.005 E>O**	.443	.466	.483	.089	**.027 E>O**
T9	**.008 E>O**	.774	**.003 E>O**	.966	.059	**.030 E>O**	.871	**.028 E>O**
T10	.230	.608	**.003 E>O**	.948	**.013 E>O**	.058	.414	.204
T11	.111	.546	.162	.805	.278	.658	.403	.526
T12	.262	.717	.817	.624	.162	.848	.922	.162

Table 17: Age differences in thoracic osteoarthritis of the inferior surface regardless of sex.

	Lipping	Lipping extent	Porosity	Porosity extent	Eburnation	Eburnation extent	Osteophyte	Osteophyte extent
T1	**.011 E>O**	**.002 E>O**	.295	.276	.507	**.021 E<O**	.157	.272
T2	**.029 E>O**	**.010 E>O**	.162	.847	.459	.311	.810	1.000
T3	**.043 E>O**	**.035 E>O**	.084	.196	.295	.236	.139	.357
T4	**.005 E>O**	**.050 E>O**	.120	.881	**.029 E>O**	.061	.159	.466
T5	**.033 E>O**	**.027 E>O**	**.007 E>O**	.730	.833	**.027 E>O**	.244	.507
T6	**.004 E>O**	.897	**.007 E>O**	.330	.525	.250	.464	**.029 E>O**
T7	.274	.710	**.034 E>O**	.395	.118	.667	.085	.059
T8	.059	.423	**.000 E>O**	.610	.466	.240	.466	**.014 E>O**
T9	.125	.656	**.005 E>O**	.354	**.027 E>O**	.525	.577	.526
T10	.201	.594	**.028 E>O**	.844	.190	.779	.290	.157
T11	.504	.469	.186	.856	.907	.411	.365	.329
T12	**.006 E>O**	.406	.118	.205	.123	.907	.179	.544

4.2 Asymmetry

When comparing the thoracic articular facets overall, the superior right facet exhibits the greatest amount of asymmetry through T1 to T12 with some of the vertebrae expressing variation within the sum of raw scores for severity. For the superior articular facets females exhibit a greater amount of asymmetry than males overall with the exception of T2 and T6. Older adults and elderly adults do not differ significantly in terms of the degree of asymmetry, however, older male and female adults exhibit greater asymmetry than elderly adults from the mid to lower thoracic region. Elderly male and female adults appear to be impacted by asymmetry more in the upper thoracic region. For the inferior articular facets females exhibit greater asymmetry than males overall. Asymmetry appears to affect females more in the upper thoracic region and males in the lower thoracic region. Elderly females exhibit greater asymmetry than older adult females, however, older adult males exhibit greater asymmetry than elderly males.

4.3 Handedness

In order to determine a correlation between handedness and asymmetry of the thoracic articular facets, a Pearson correlation was utilized and examined each vertebra of the right and left superior and inferior facets as individual elements of right-handed, left-handed, and indeterminate individuals. The results found that there was not a significant correlation between handedness and asymmetry, however, when indeterminates were removed, handedness did correlate with some of the left superior and inferior asymmetry values. Spearman rank correlations confirmed these results. A Mann Whitney U test was also performed using a pooled sample of the vertebra looking at only the right-handed and left-handed individuals and resulted in the same conclusion, that the asymmetry values of some of the left superior and inferior facets correlated with handedness (Tables 18 and 19). Right-handed individuals do exhibit greater severity of asymmetry on the right, but because of the large amount of variation a significant difference does not exist like it does for left-handed individuals.

Table 18: Mean ranks for handedness and asymmetry of the thoracic superior and inferior articular facets.

	Handedness	Number	Mean rank
Superior R	1.00 (R) 2.00 (L)	240 36	139.54 131.54
Inferior R	1.00 (R) 2.00 (L)	240 36	139.63 130.96
Superior L	1.00 (R) 2.00 (L)	240 36	136.45 152.18
Inferior L	1.00 (R) 2.00 (L)	240 36	135.70 153.26

Table 19: Differences for handedness and asymmetry of the thoracic superior and inferior articular facets.

	Handedness, T1-T12			
P Value	.387	.383	.053	.039
Mean rank side difference	R>L	R>L	R<L	R<L

5 DISCUSSION

5.1 Thoracic osteoarthritis

The aims of this study were to 1) assess the relationship between age differences and osteoarthritis of the thoracic region, 2) assess the relationship between sex differences and osteoarthritis of the thoracic region, and 3) assess the relationship between the asymmetry of the inferior and superior articular facets of the thoracic and handedness. The results obtained by Mann Whitney U test suggest that age and sex differences exist for osteoarthritis of the thoracic region.

When only females were compared, elderly females exhibited a greater severity of osteoarthritis than older adults overall with the exception of the extent of eburnation in T1 and the extent of lipping in T11 on the inferior surface. For males, a greater expression of osteoarthritis was observed for elderly individuals across the board. Lipping in particular affected elderly males more than older males throughout the thoracic skeleton.

Differences between the sexes within specific age cohorts were also examined. When older adults were compared, males presented a greater severity of lipping, porosity, extent of lipping, and extent of porosity and females presented a greater extent of eburnation. This was restricted to the upper and lower thoracic region. There were no significant differences observed for the mid thoracic region or for osteophyte formation. When elderly adults were compared, elderly males exhibited a greater degree of lipping, extent of lipping, extent of porosity, and formation of osteophytes whereas females exhibited a greater degree of eburnation. Elderly males expressed a significantly greater severity of lipping throughout the thoracic region than elderly females contrary to Rogers and Dieppe’s (2003) predictions.

Sex differences were also examined regardless of age. Significant differences existed for all categories except eburnation, extent of eburnation, and extent of osteophyte formation. Males exhibited a greater severity of osteoarthritis than females overall, particularly observable in lipping and osteophyte formation, which affected much of the thoracic region. The mid thoracic region did not appear to be affected as greatly as the upper and lower regions. When age differences were examined regardless of sex, elderly adults exhibited greater severity for arthritis than older adults.

The study showed that significant differences can be observed through age and sex when studying osteoarthritis of the thoracic vertebral region. As predicted by Larsen (2015), there also appears to be a trend in arthritis affecting the upper (T1-T3) and lower thoracic (T9-T12) more than the mid thoracic (T4-T8) region. The lower thoracic region may express a greater severity of osteoarthritis due to the amount of weight it has to withstand whereas the mid thoracic may be subject to less mobility. A greater number of vertebrae are also affected more on the inferior surfaces than on the superior surfaces. This may be related to the differential shape in the superior and inferior thoracic vertebral bodies and the shape and placement of the articular facets.

5.2 Asymmetry of the thoracic articular facets

The results from the raw data compared in the sum of scores for severity indicated that the superior right articular facet exhibited the most severe asymmetry throughout the thoracic vertebral region. The frequency of the absolute differences between the right and left for the superior and inferior articular facets per sex and age of each vertebra suggested that females expressed a greater degree of asymmetry than males overall.

In some of the vertebrae older adults appear to be affected more severely than the elderly adults. This could suggest that fluctuating asymmetry of the thoracic articular facets could have a correlation with frailty in older adults and could represent systematic complications. Perhaps individuals with chronic illnesses express a greater severity of asymmetry due to an already compromised system resulting in a decrease in the resistance to stressors.

5.3 Handedness

When left-handed, right-handed, and indeterminate individuals were compared for correlations of handedness and raw asymmetrical scores a significant correlation was not observed. However, when only right-handed individuals and left-handed individuals were compared there was a correlation between handedness and asymmetry values for the left superior and inferior facets. A clear significant difference was observed in the left-handed individuals for the left facets exhibiting more severe asymmetry values. The observation that left-handed people have more severity of the trend is not apparent with right-handed individuals due to a greater amount of variation. The signal is there, but there is more variation so the results are not significant. Right-handed individuals generally have a more severe asymmetry on the right and left have more severe expression of asymmetry on the left although only the left-handed individuals show significant differences between right and left sides.

This could mean that left-handed individuals overcompensate for the left side of their bodies more than right-handed individuals. However, since the sample provided such a large number of indeterminates, it is possible that there were more left-handed individuals in the sample who expressed bilaterally in their handedness and asymmetry, and could therefore not be sided effectively in the humerus, radius, or ulna. The low number of definitive lefts may reflect the tendency for left-handed individuals to use both hands. This study reveals at the very least that there are left-handed individuals who exhibit a far greater degree of asymmetry of the thoracic superior and inferior articular facets. However, further research with a larger sample size is required to determine if there is a truly significant correlation between handedness and asymmetry of the thoracic articular facets.

6 CONCLUSIONS

Osteoarthritis is one of the most common diseases in individuals over the age of 40 years (Larsen 2015). The study of the disease provides insights on the aging process of individuals. It can also be helpful when reconstructing life histories since there is a link to osteoarthritis and stress. Thoracic vertebral arthritis is rarely studied, therefore, there is a need for more analysis of thoracic arthritis in the literature. This study examines 1) the influence of sex and age differences on the degeneration of the thoracic vertebrae during the life course, 2) the influence of sex and age differences on the asymmetry of the thoracic articular facets, and 3) the relationships between asymmetry of the thoracic articular facets and handedness.

The study suggests that elderly adults of both sexes express a greater severity of osteoarthritis than their older adult counterparts. It also found that males expressed a greater degree of arthritis than females overall. However, when elderly males and females were compared females appeared to express a greater degree of eburnation. The differences found in males and females are likely to be produced from differences in hormones associated with reproductive cessation and occupational stress.

This study also corroborates that elderly adults express a greater severity of asymmetry than older adults and females express a greater severity of asymmetry than males. Although there appears to be a great deal of variation throughout the thoracic vertebral region. Older adults could exhibit such an extensive severity of asymmetry due to an association with frailty.

Finally, the study proposes that a trend exists for asymmetry of the thoracic facets and handedness. The mean ranks show that right-handed individuals exhibit asymmetry on the right side and left-handed individuals exhibit asymmetry on the left side. However a significant correlation only existed for left-handed individuals while right-handed individuals expressed more variation. A larger sample size and further research will provide better insights on the correlation between asymmetry of the thoracic facets and handedness.

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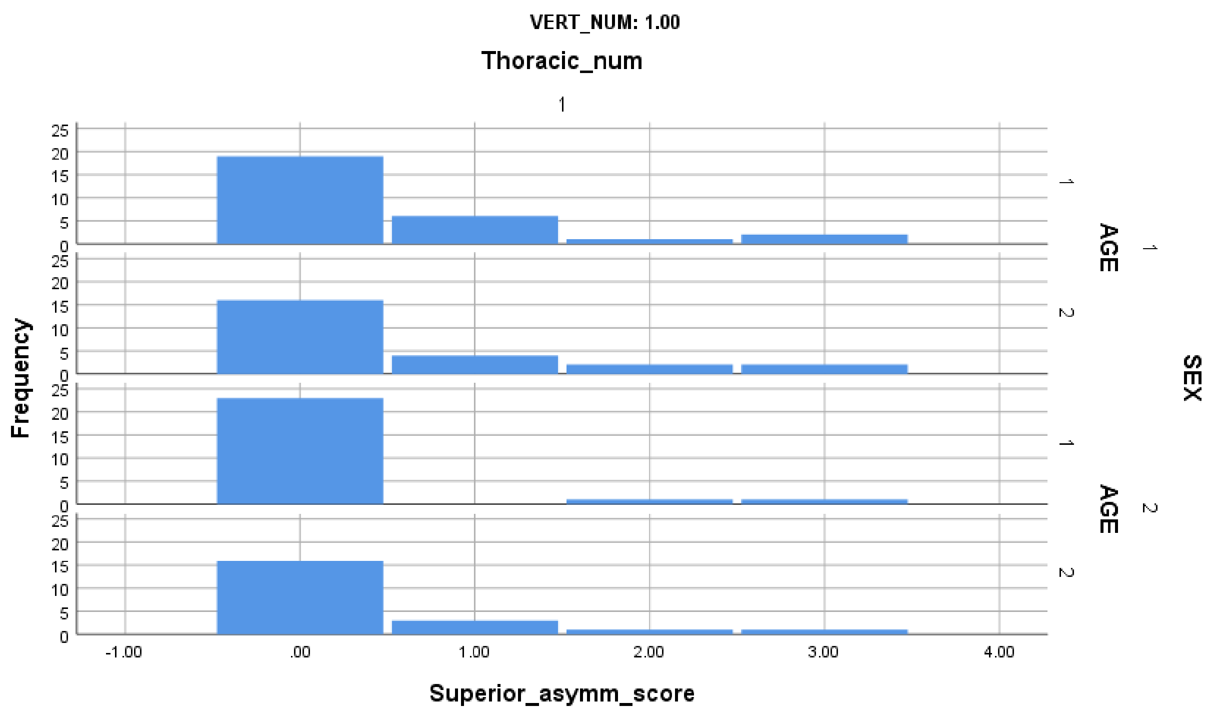
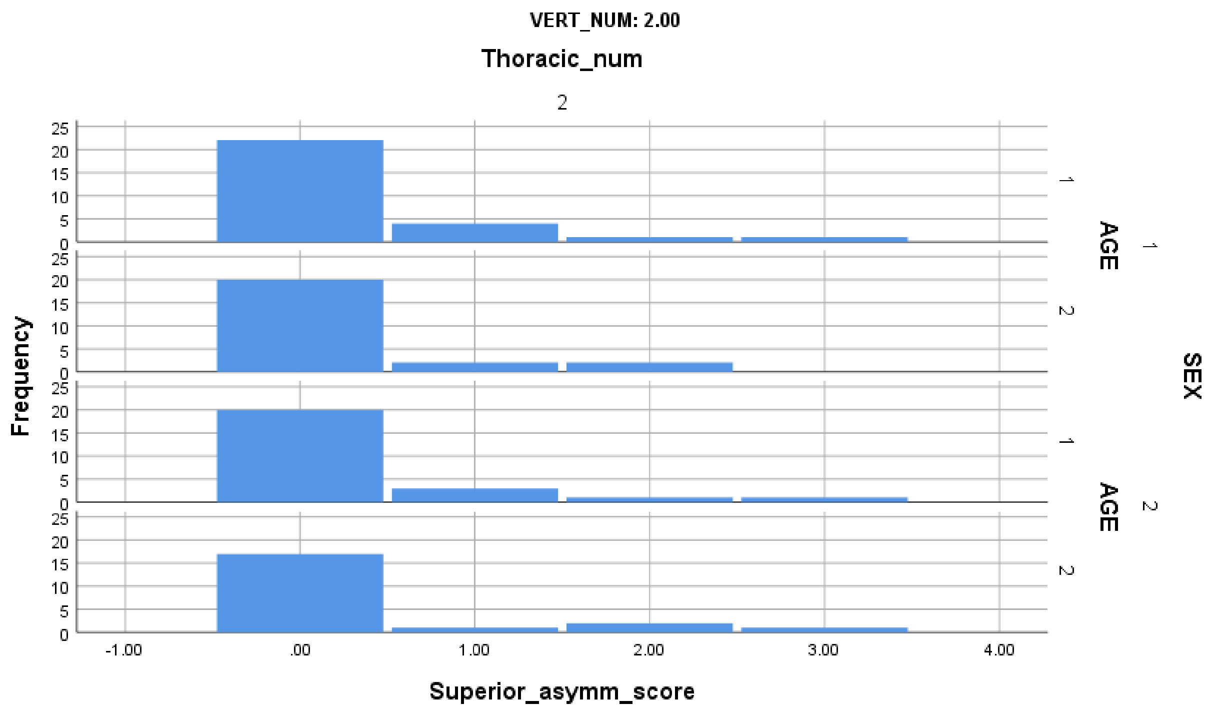
APPENDICES

Appendix A Asymmetry

Appendix A.1 Histograms showing the absolute differences in right and left asymmetry with respect to sex and age for the superior articular facets.





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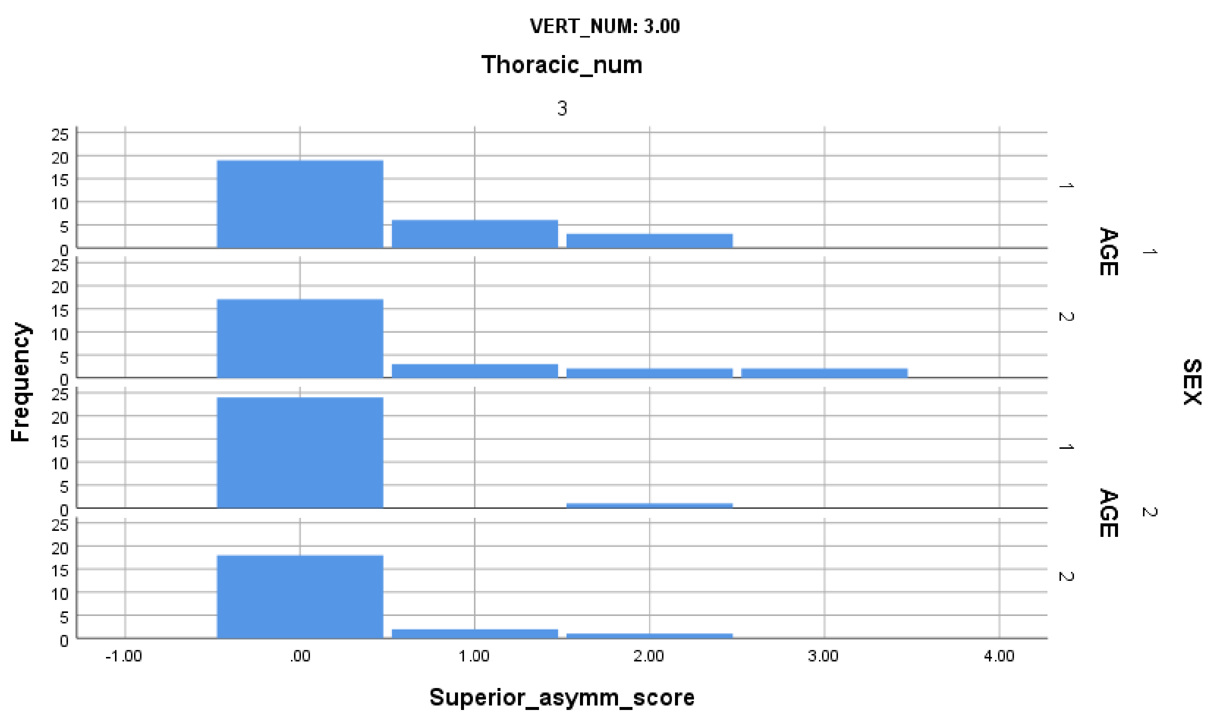

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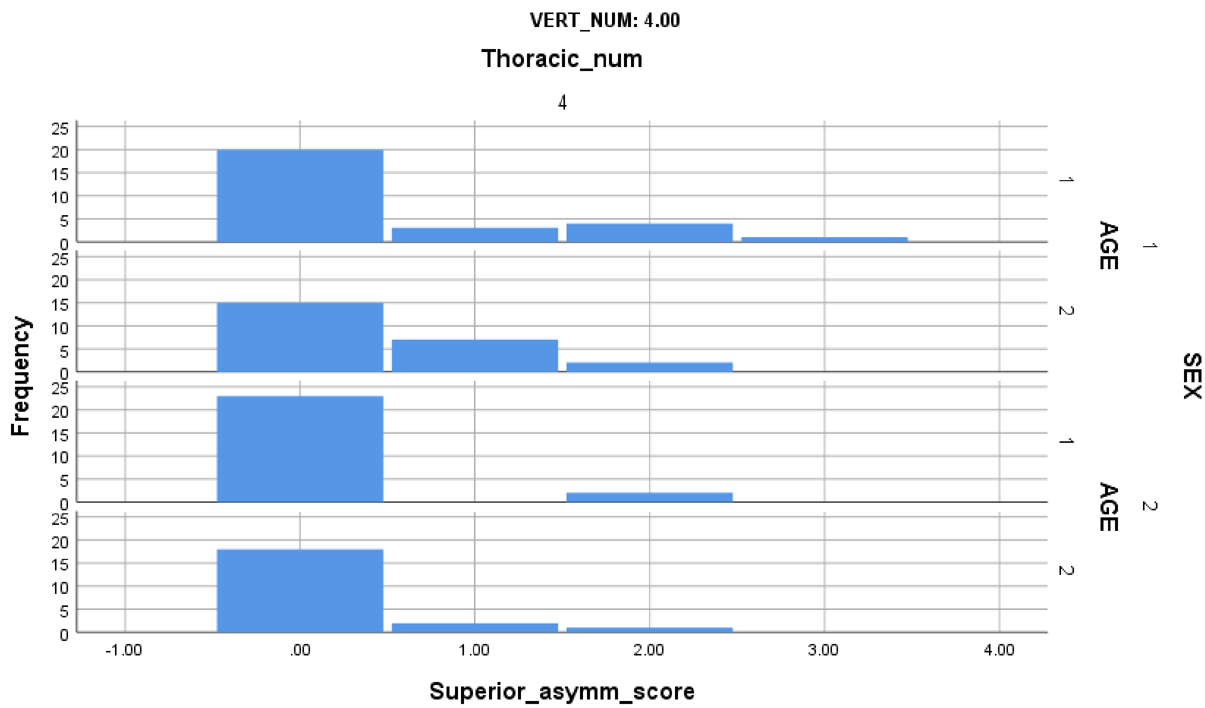
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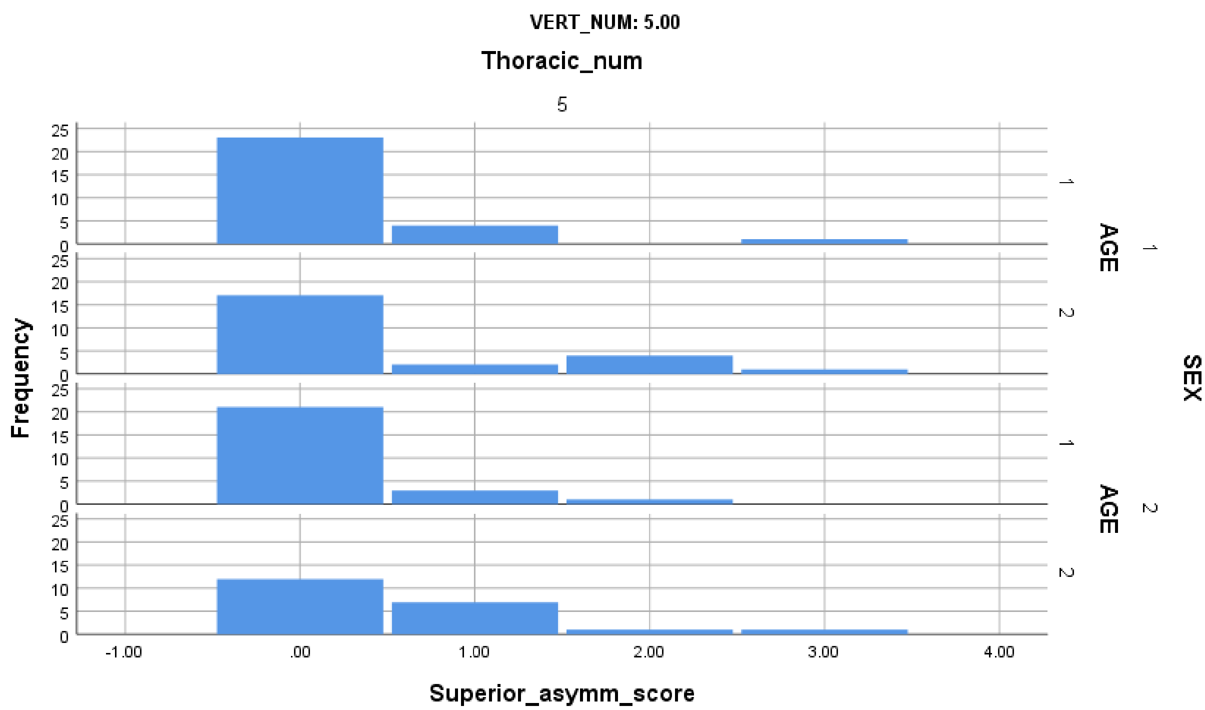
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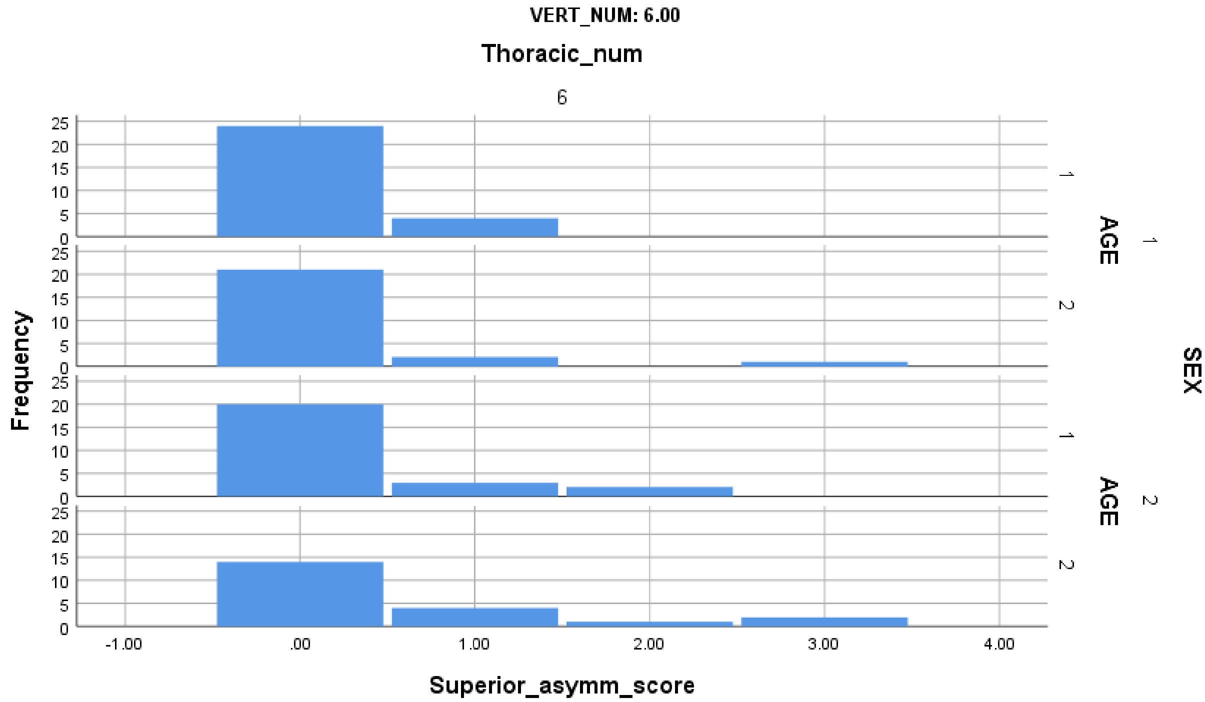
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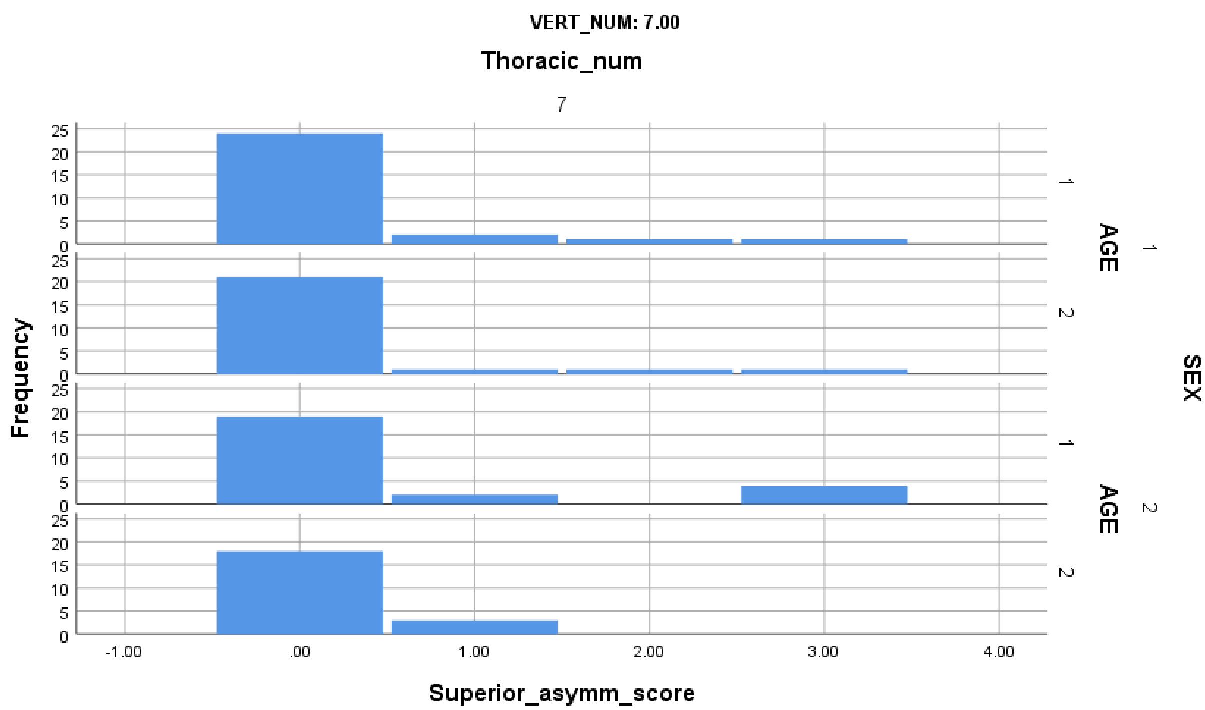
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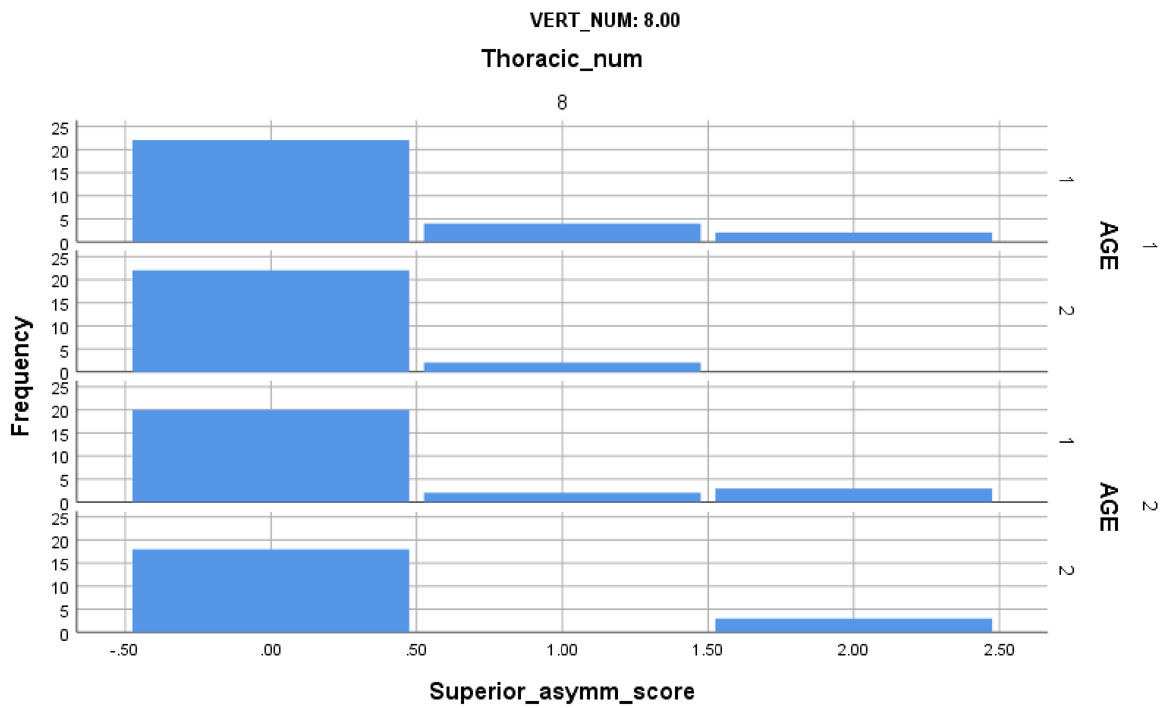
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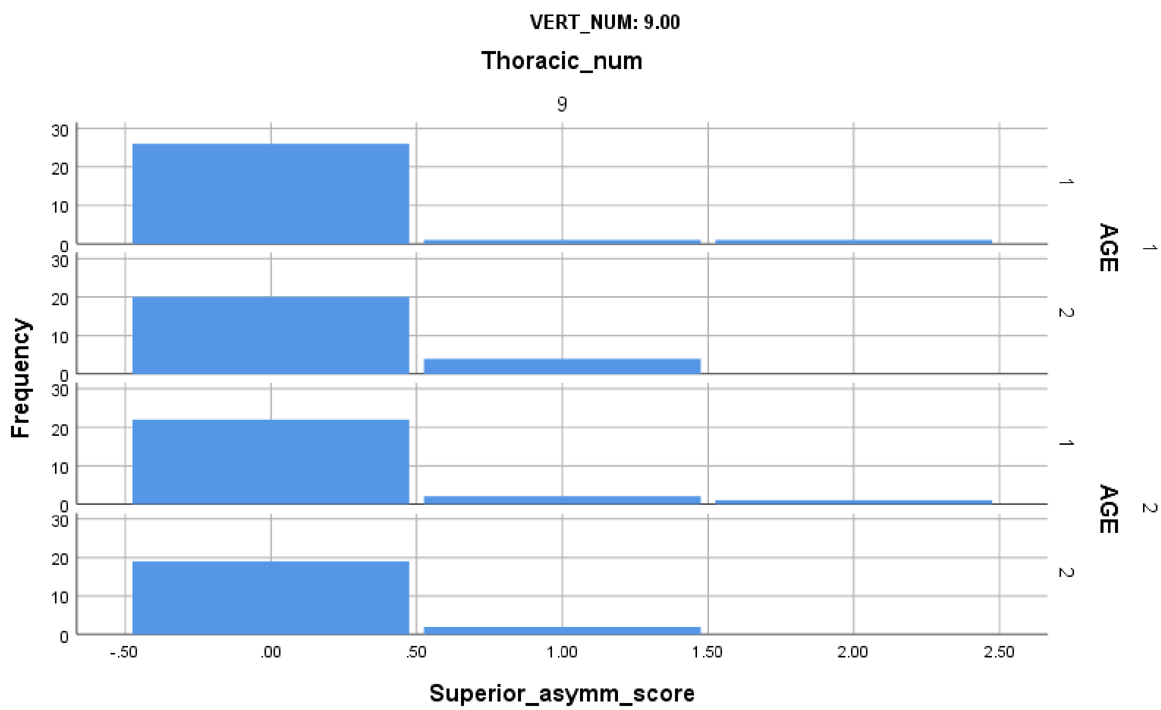
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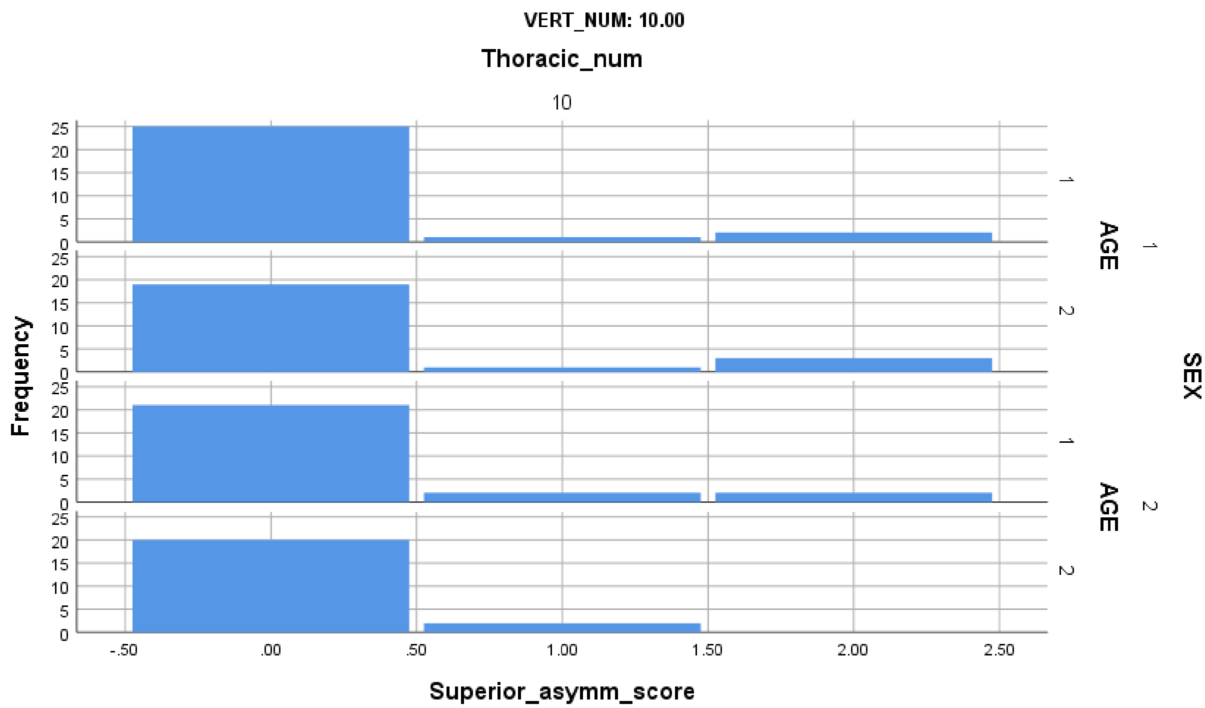
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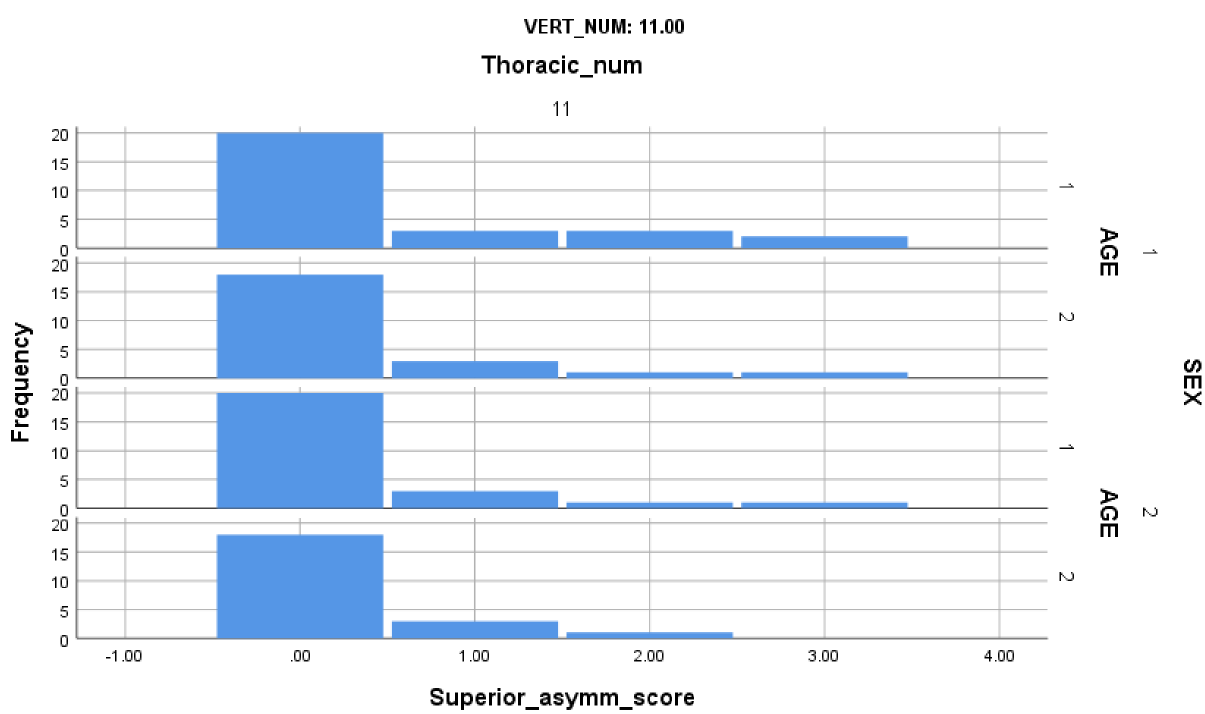
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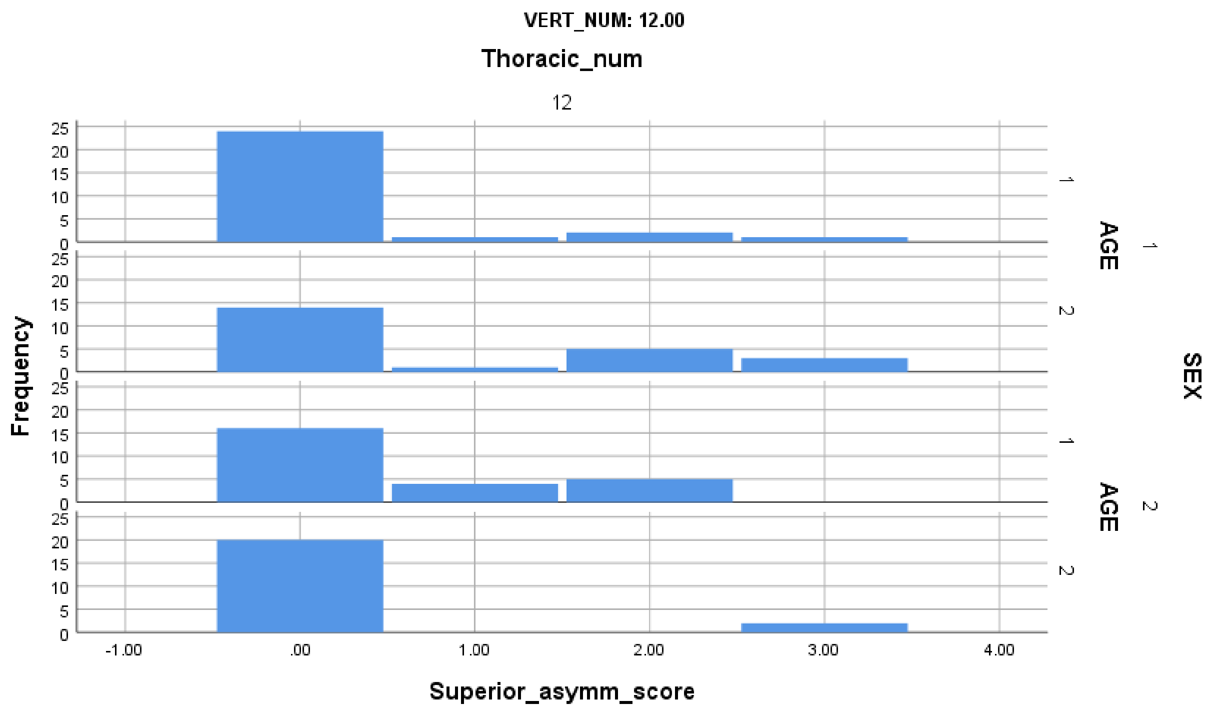

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AGE
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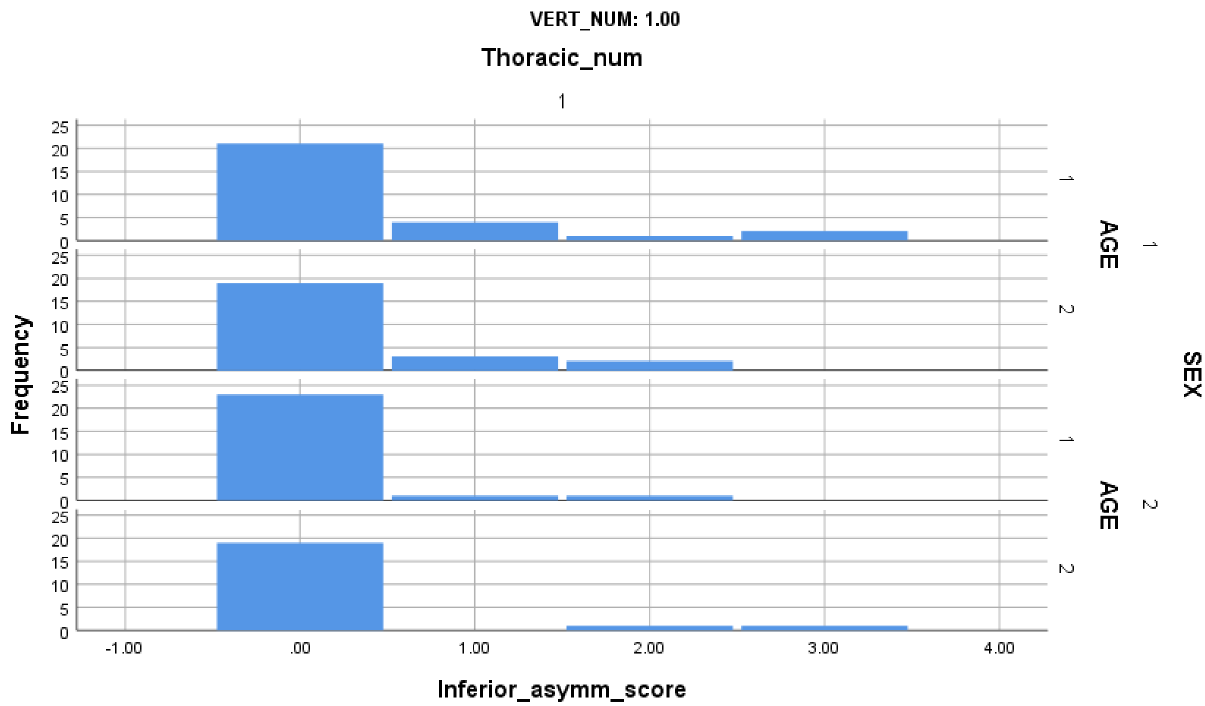
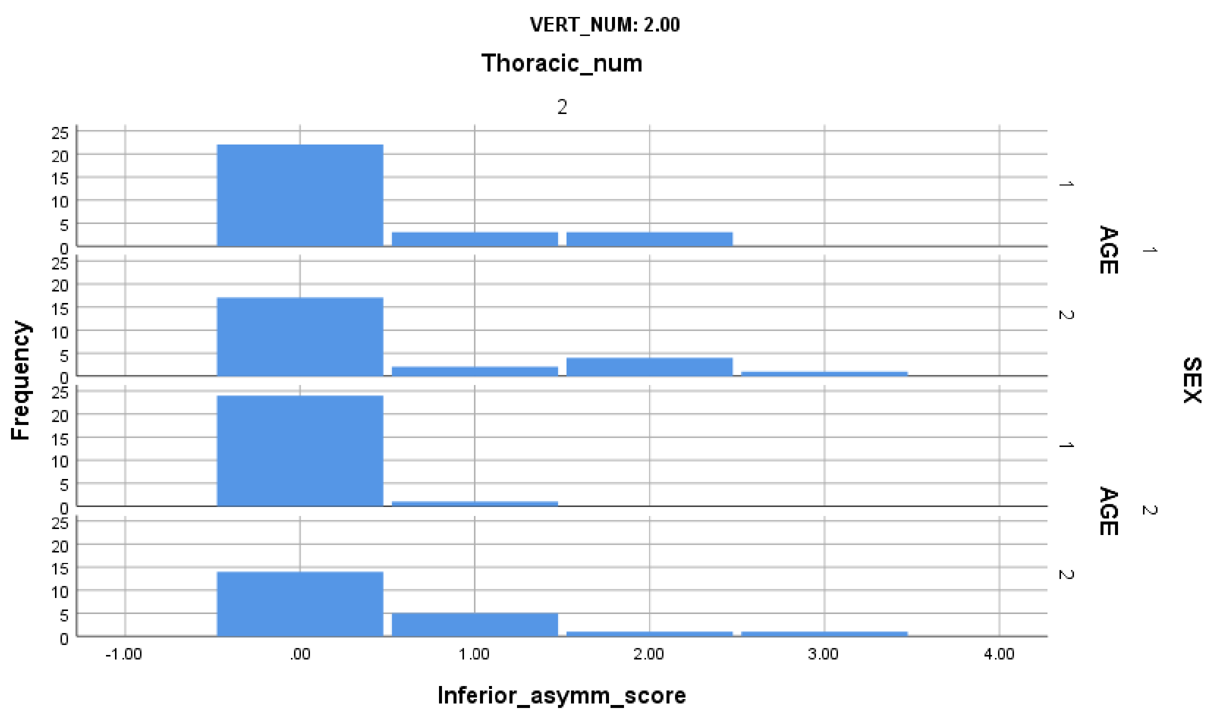
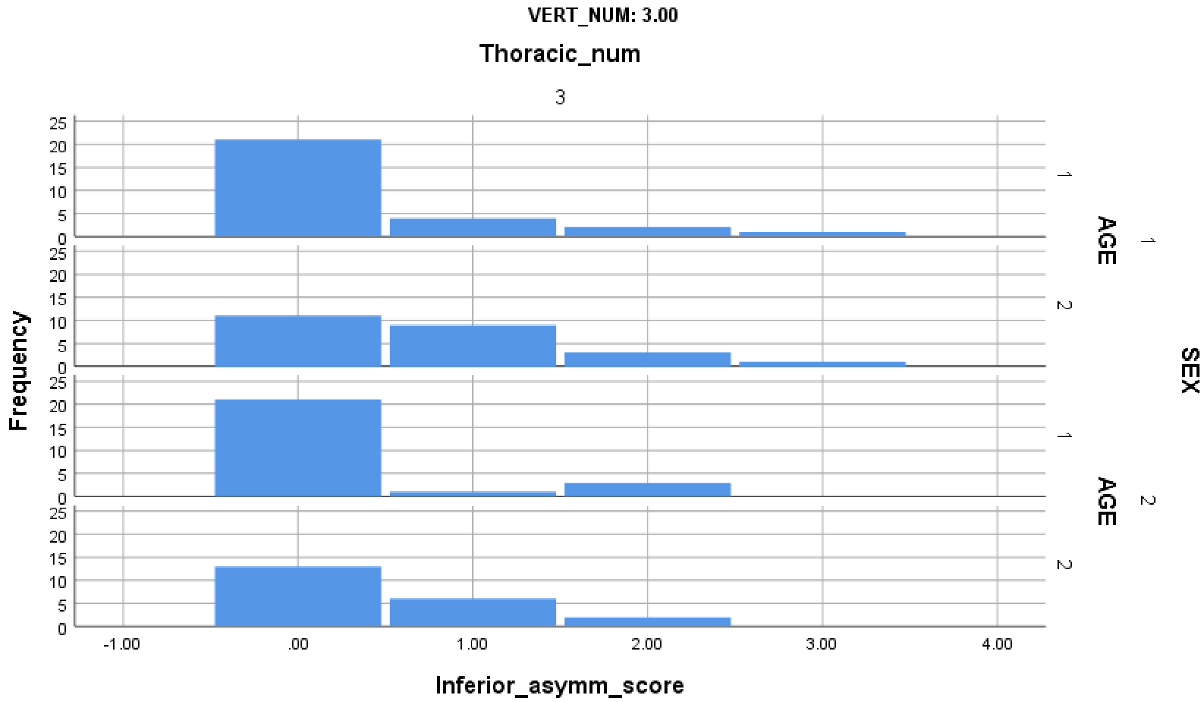
Appendix A.2 Histograms showing the absolute differences in right and left asymmetry with respect to sex and age for the inferior articular facets.



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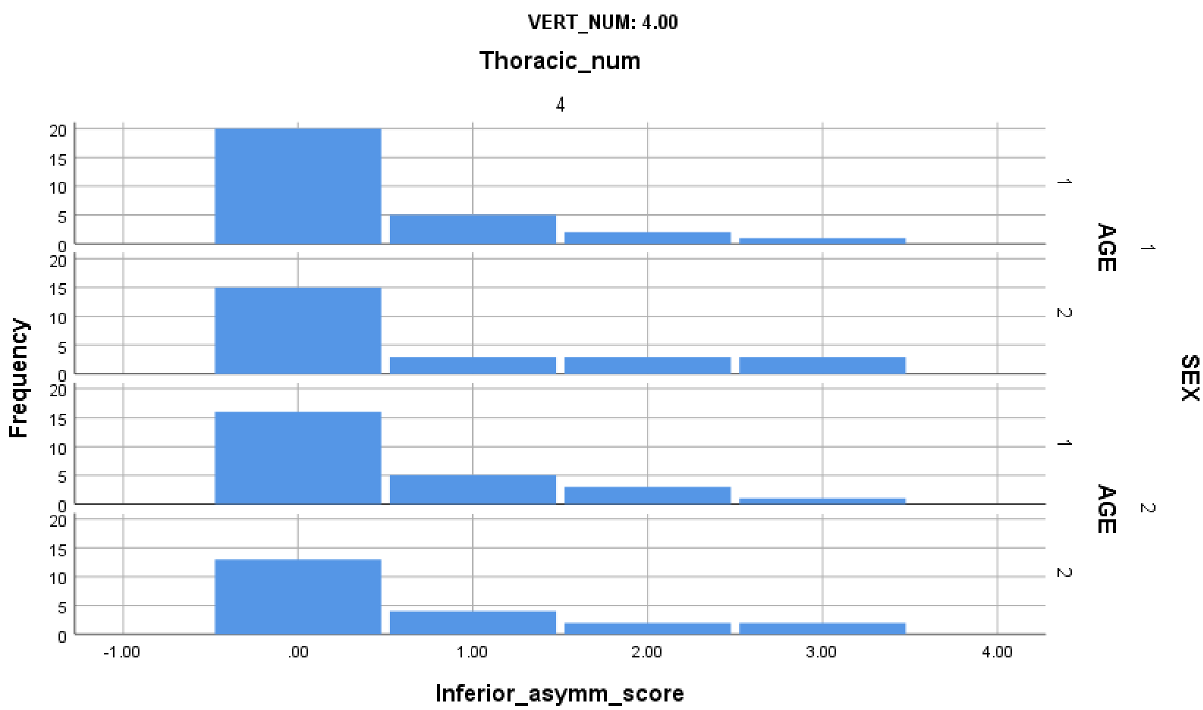
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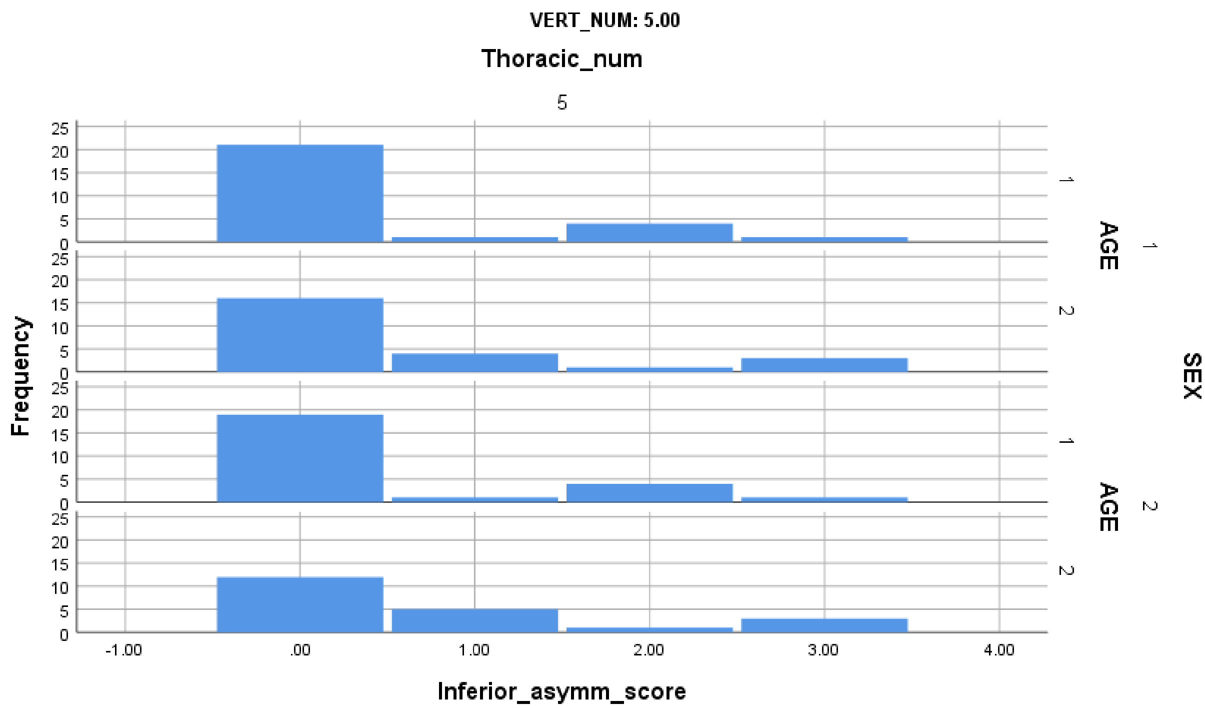
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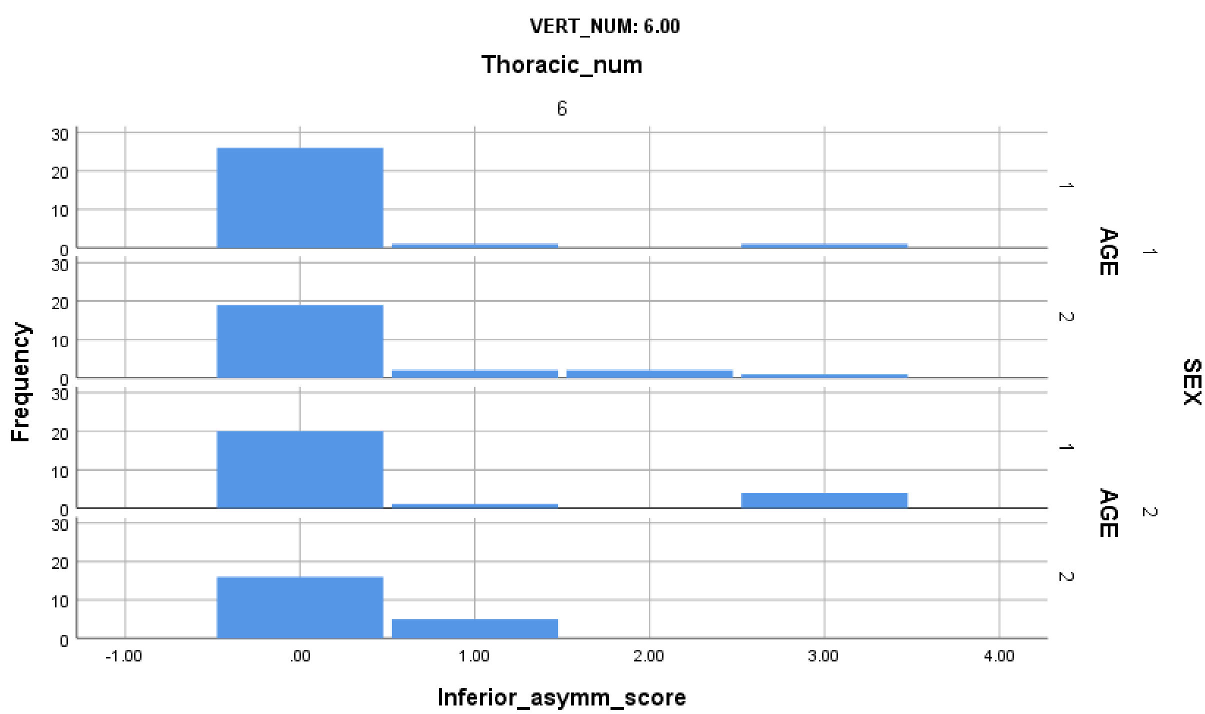
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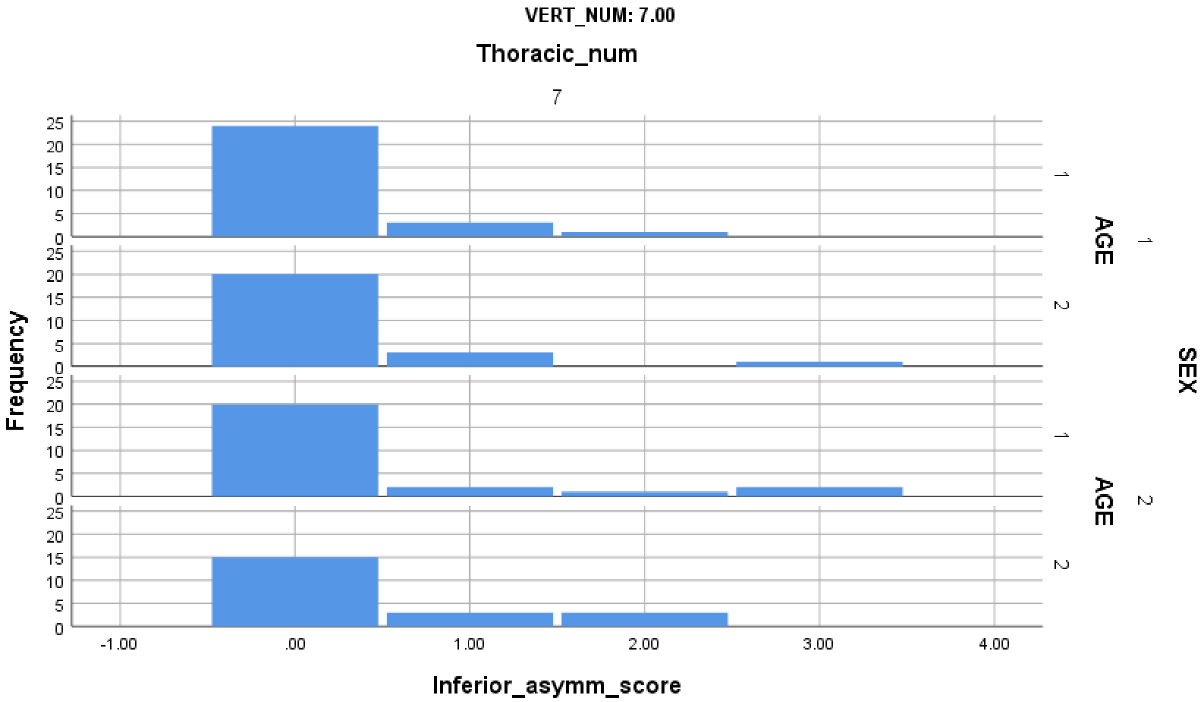
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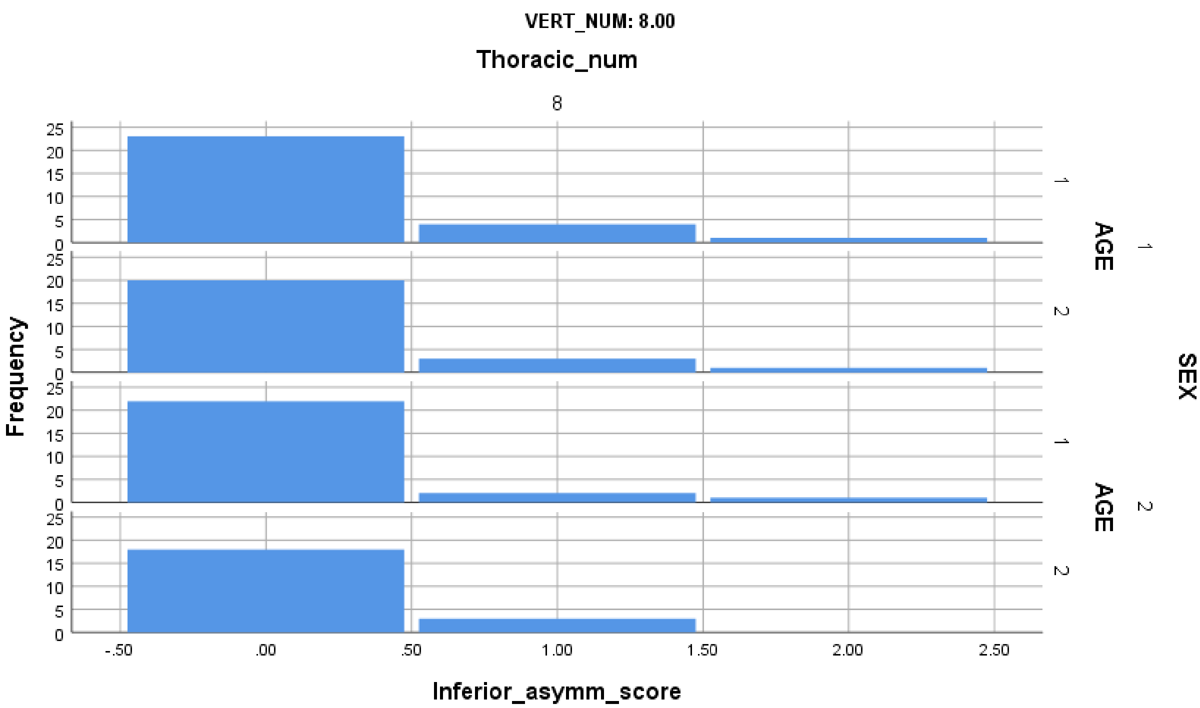
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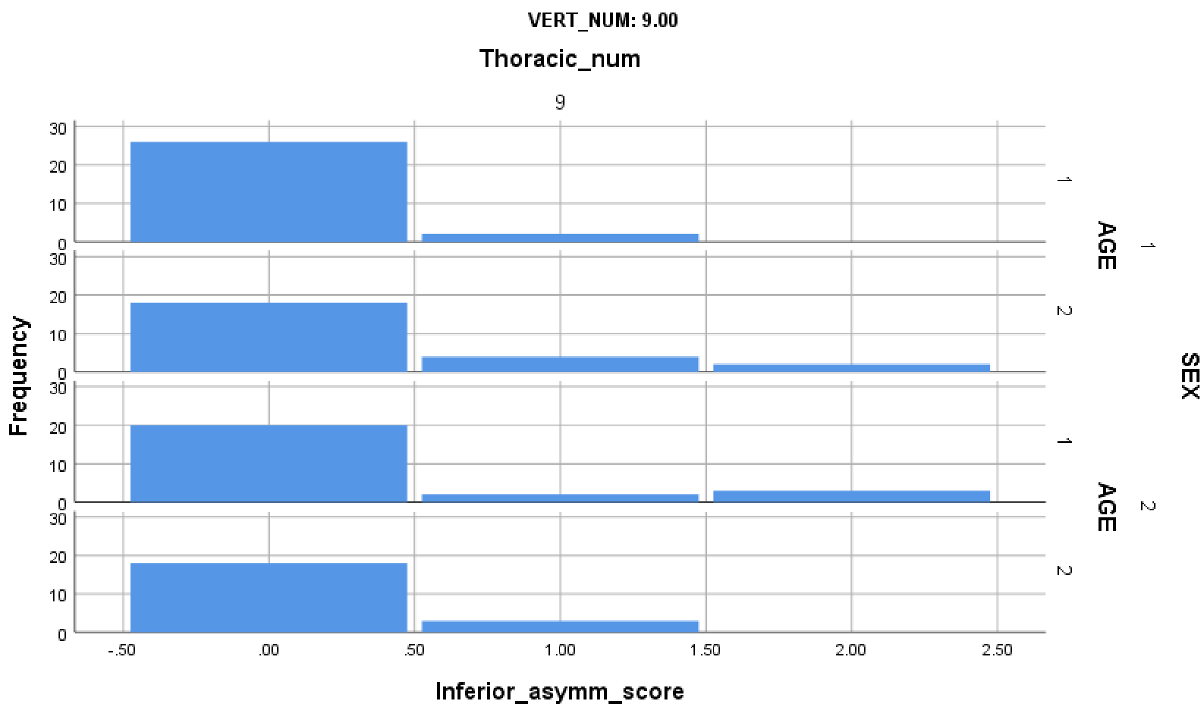
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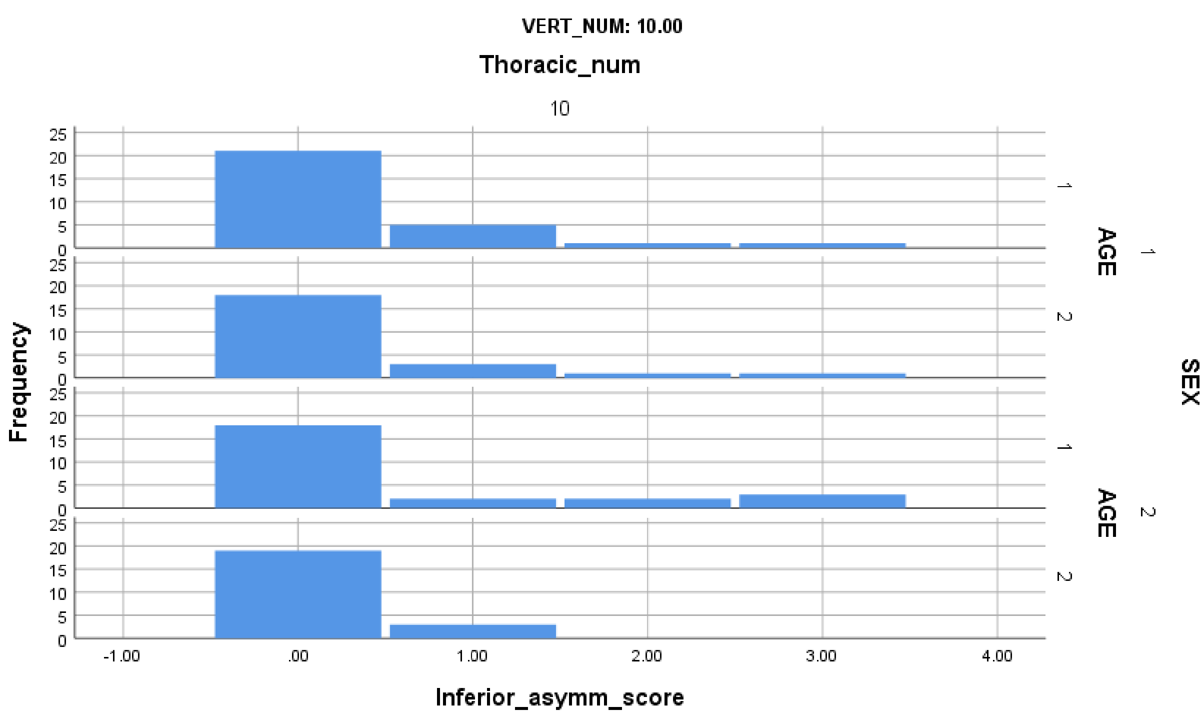
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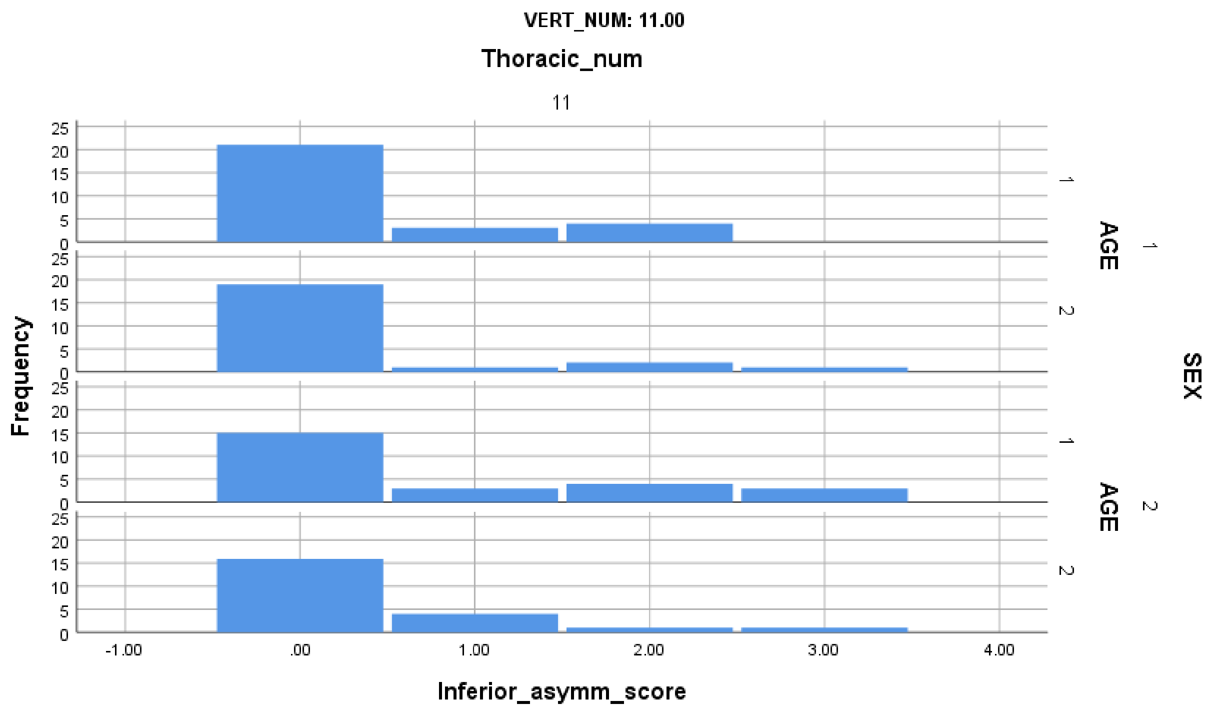
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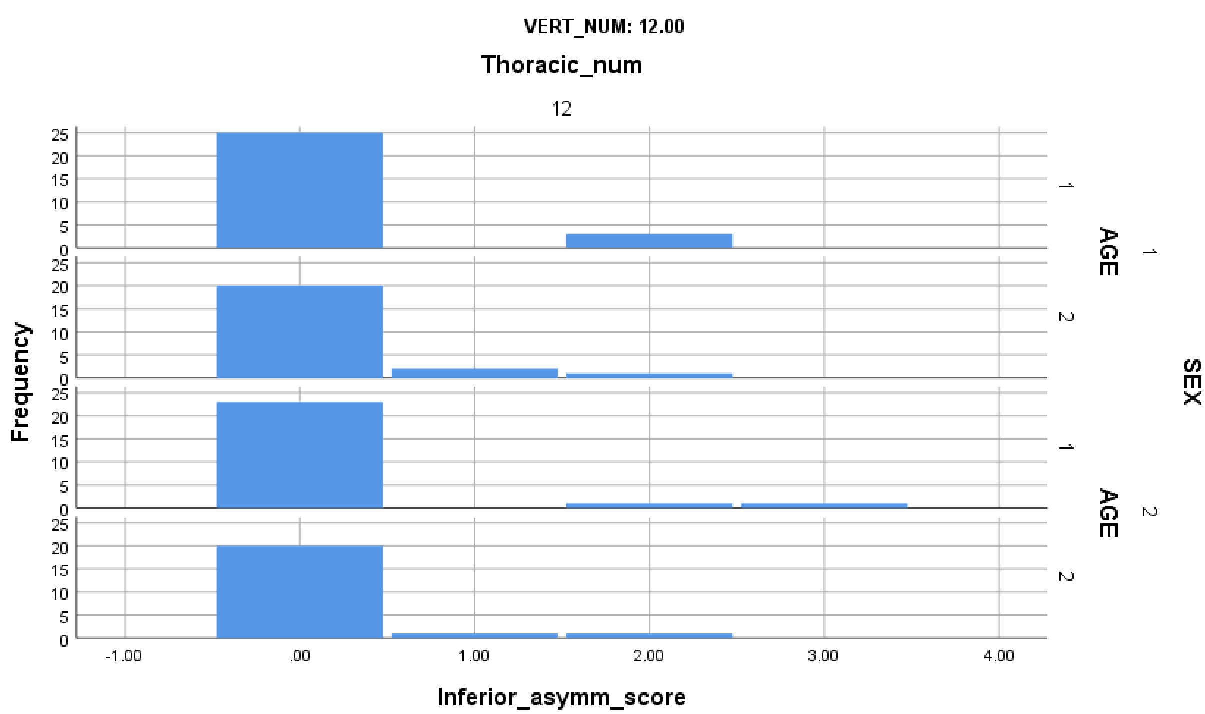
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