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Comparative anatomy of acromion process and its association with prevalence and prevention of impingement syndrome

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ABSTRACT

The objective of this study is to compare the morphometric features of, acromion process of humans with that of other vertebrates, and find its association with impingement syndrome. This study also aims to prevent the incidence of impingement syndrome by using various prevention techniques. For the comparative study, human scapulae were morphometrically measured and compared with the scapulae of other vertebrates. The influence of physical activities over modification of growth of acromion into various types was studied among the swimmers' population with radiographic evidence. The acromion process of 90 scapulae collected from the Anatomy Department of Saveetha Medical College and the scapula of other vertebrates like- canine, bovine, equine and apes collected from the Anatomy Department of Madras Veterinary College were studied and measured. The mean breadth of the right side and left side curved acromion is 24.26mm and 23.84mm, respectively. And for the right side and left side flat acromion it is 25.26mm and 25.36mm respectively. For canine, it is 14.87mm and 14.34mm, respectively. For bovine it is 20.33mm and 19.94mm respectively. It is concluded that apes do not have impingement syndrome due to the cranially oriented spinous and acromion process. This study also gives evidence that physical activities influence the growth of acromion into its various types, which is one of the important factors causing impingement syndrome.

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INTRODUCTION

The acromion is a bony process on the scapula. Together with the coracoid process, it extends laterally over the shoulder joint. It is a continuation of the scapular spine and hooks over anteriorly. It articulates with the clavicle to form the acromioclavicular joint (Gray and Standring, 2008). The scapular spine, originating from the medial border of the scapula, divides the dorsal surface into a superior and an inferior quadrant namely supraspinous fossa and infraspinous fossa which gives attachment to supraspinatus and infraspinatus muscle. The spine is prolonged laterally into a flattened or curved acromion process (Paraskevas, 2008). According to

Bigliani classification, three main types of acromion morphology have been described: type-I (flat); type-II (curved); type-III (hooked). This serves as a diagnostic tool for impingement syndrome and rotator cuff tears (Bigliani *et al.*, 1986). In these types of the acromion, the second type is found most common among the population, whereas the first type is comparatively less common, and the third type is very rare. The occurrence of rotator cuff tears is most closely associated with type III acromion (Morrison, 1987). The type - III (hooked) is also called a beaked type of acromion.

Impingement syndrome – also called subacromial impingement or swimmer's shoulder is a clinical syndrome which occurs when the rotator cuff tendons particularly supraspinatus tendon gets irritated and inflamed as it passes through the subacromial space. This can result in pain, weakness, and loss of normal movement in the shoulder.

When the arm is raised, the subacromial space narrows, through which the supraspinatus tendon passes. Anything that causes further narrowing has the tendency to impinge on the tendon and cause an inflammatory response, resulting in impingement syndrome.

One of the major causes of impingement syndrome is variations in the shape of the acromion. It can also occur due to other causes such as subacromial spurs, repeated over arm abduction, osteoporosis, sleeping in decubitus position and smoking.

This study also includes information regarding the acromion process and rotator cuff tears in several other vertebrates.

In the assessment of the canine model of the rotator cuff injury and repair, canine shoulder models were used to systematically investigate the factors influencing rotator cuff injury in humans (Derwin *et al.*, 2007). Given the similarities between human and canine musculoskeletal system, the incidence of rotator cuff injuries is similar in both canine athletes as well as humans. The cause of rotator cuff injury in agility dogs seems to be related to repeated strain, which may initiate actual degeneration of the tendon leading to shoulder joint instability. In humans and dogs, several degenerative disorders of the supraspinatus tendon have been identified, including rotator cuff tears, calcifying tendinitis, and tendinosis as a result of overuse. The degeneration of the supraspinatus tendon and bicipital tendon is thought to be a major factor in the development of medial shoulder instability in the canine population (Canapp, 2007a). Medial shoulder instability in canine is similar to rotator cuff injury in humans Canapp (2007a). Rotator cuff injury is often accompanied by impingement syndrome. The rotator cuff in bovines is also similar to that of humans, and the repetitive strain of their upper extremities causes impingement (Ailsby, 2011).

This study includes all the respective information about the acromion process, regarding its morphometric measurements, modification through evolutionary perspectives, the influence of physical activities and genes over its growth, clinical significance and prevention of impingement syndrome. The knowledge regarding the shape and various distances of the acromion process might benefit the orthopaedists during surgical repair around the shoulder joint, and the reason behind the difference in the type of acromion process that is prone to a particular disease might benefit to get a better treatment protocol. Each individual presents with variations in shoulder anatomy, overall conditioning and fitness, and degrees of shoulder laxity, which makes the precise evaluation of pathologic lesions difficult (Warner *et al.*, 1992). Patients with less slope to their acromion have a propensity towards impingement because of subacromial stenosis. The impingement is due to age-related issues also. Enthesophytes are an important factor for impingement syndrome. A study stated that acromion's shape influences the rotator cuff tears size. Scapula development is modestly affected by the genetic pathways that pattern the limb (Prahlad *et al.*, 1979; Ros *et al.*, 1996). And there is only rudimentary knowledge of the genes that act upstream of the blade and head development (Huang *et al.*, 2006). By contrast, much information has been gathered on genes that finely pattern these structures. For example, Pax 1/ Hoxa 5 and Hoxc 6 are involved in acromion and head development, respectively (Aubin *et al.*, 1998; Timmons *et al.*, 1994). Acromion has three ossification centers (pre-acromion, Meso-acromion, and meta-acromion). These three centers start ossifying during 12 years of age and fuse with each other by 16-18 years of age. The acromion normally has a secondary center of ossification which usually fuses to the rest of the acromion by the age of 25 (Butler *et al.*, 2012).

We hypothesized that the acromion's complete, unrestricted, ossification is as a hooked process (type-III), but the shoulder related physical activities done during the period of ossification of acromion, like overhead arm movements, influences the growth of the bone by serving as restriction to its growth and results in the halt of its growth as a flat (type-I) or curved(type-II) process depending upon the intensity of physical activities done.

MATERIALS AND METHODS

The acromion process of 90 scapulae, collected from the Anatomy Department of Saveetha Medical College, Thandalam, Chennai, were studied and measured with the help of digital vernier caliper, goniometer, divider, and scale.

The parameters of measurement were

1. Length of acromion
2. Width of acromion
3. Breadth of acromion
4. Acromiocoracoid distance
5. Acromioglenoid distance
6. Angular measurements

The acromiocoracoid distance is measured between the tip of the acromion process and the tip of the coracoid process, while the acromioglenoid distance is measured between the supraglenoid tubercle and tip of the acromion.

The inclination of the acromion is recorded as the angle that is formed between the tangential line of the inferior surface of the acromion and the horizontal plane. The inclination of the articular surface of the acromion is recorded as medial, lateral, and vertical to the sagittal plane.

For the comparative study, acromion process of other vertebrates was collected from the Anatomy Department of Madras Veterinary College, Chennai was studied and measured on the following parameters:

- 1. Length of acromion
- 2. Width of acromion
- 3. Breadth of acromion

1. Acromio-glenoid distance (AG-1) - from supraglenoid tubercle to the tip of the acromion.
2. Acromio-glenoid distance (AG-2) - from the center of the glenoid cavity to the tip of the acromion.
3. The thickness of spine 1- at the center
4. Thickness of spine 2- near the acromion

To study the correlation of physical activities and it's an association with impingement syndrome, various swimming academies were been visited, and the swimmers of various age groups and their coaches were interviewed with various questions such as:

1. Their present age
2. Their age when they started swimming practice
3. Their regularity in swimming
4. Any shoulder related complaints throughout their swimming carrier.

For further investigations, radiographic imaging was done for various people who were exposed to various forms of physical activities involving the shoulder.

Shoulder joint radiography was taken in the A-P view.

The radiograph was taken for:

1. Professional Swimmers
2. Nonswimmers
3. Irregular swimmers
4. People exposed to very minimal activities involving shoulder
5. People exposed to the average amount of physical activities involving shoulder

Observation

The scapulae and acromion of canine, bovine, equine and apes were observed. The observations were compared to that of human scapulae and acromion.

In the scapula of canine (dog) the spine is placed in the middle of the dorsum, and it increases in height from above downwards to the level of the acromion process. (Singh *et al.*, 2013)[Figures 1 and 2]

Figure 1: Canine Scapula - Lateral View

The scapula of bovine (cattle) consists of two surfaces, three borders, and three angles. The lateral

Figure 2: Canine Scapula - Inferior view

surface is wide above and narrow below, it is traversed by the scapular spine which divides the lateral surface into a cranial supraspinous fossa and caudal infraspinous fossa. (Singh *et al.*, 2013) The free edge of the spine is rough and tuberous in the middle and is prolonged downward to form the acromion process. The clavicle is absent, and the scapula is connected to the axial skeleton by the muscles. [Figure 3]

Figure 3: Bovine Scapula - Lateral View

For equine (horse), the acromion process is absent. The subscapular fossa is deeper and partly separates the two triangular rough areas in the upper third. The glenoid notch is in the anteromedial aspect of the rim. On the posterolateral aspect of the rim, it presents a tubercle for teres minor. The tuber scapula is large and placed further away from the glenoid cavity. (Singh *et al.*, 2013) [Figures 4 and 5]

APES - The glenoid cavity in apes has a considerably more cranial orientation. Apes like chimpanzees, orang-utans, and gibbons have a narrow shape of acromion whereas gorillas have a wide acromion [Figures 6 and 7]. The spine of the scapula is almost vertically oriented in chimpanzees and orang-utans, but in gorillas, it is slanted [Figure 6].

Figure 4: Equine Scapula - Lateral View

Figure 5: Equine Scapula -Absence of acromion process

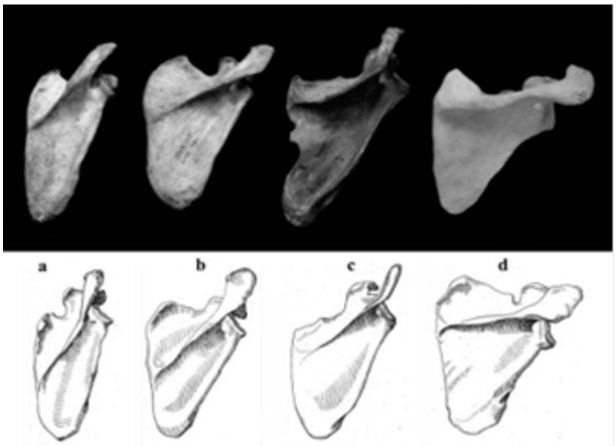

Figure 6: EvolutionaryModification of Scapula
a) Chimpanzee
b) Gorilla
c) Orang-utan
d) Homo sapiens sapiens

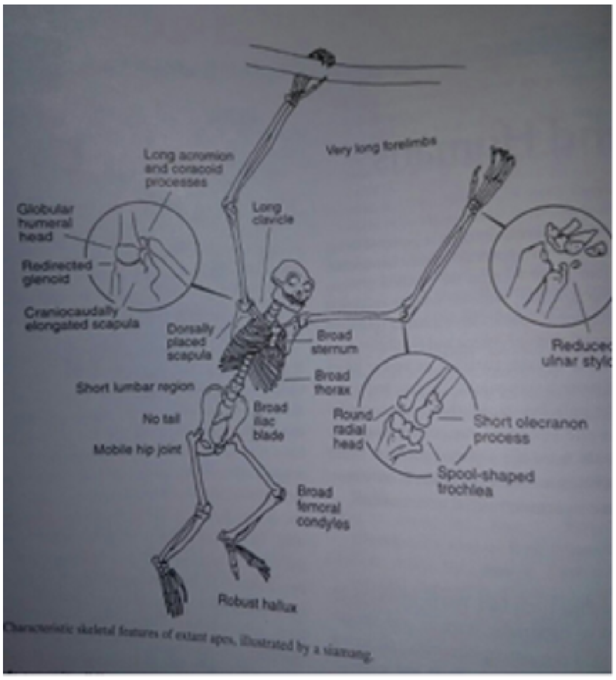

Figure 7: Long Acromion and Corocoid Process

Morphometric analysis

Through this morphometric study of the acromion process of the scapula, it is observed that in humans the hooked type of acromion is very rare and the curved type of acromion is found most common among the population. The acromion process is absent in equines (horses) but is present in bovines (cattle) as well as canines (dogs) with somewhat similar features as that of humans Tables 1, 2 and 3.

Radiographic analysis

Figure 8: X-Ray of a normal swimmer's shoulder

Normal swimmer's shoulder

45 years old male swimmer practicing swimming from the age of 10. He was constant with his practice till the age of 30. Type I (flat) acromion Figure 8.

Non-swimmer's shoulder with impingement syndrome

37 years old male. He was never exposed to many physical activities involving the shoulder. Works in a BPO company. He has limited ROM in shoulder elevation movements. He developed shoulder impingement due to an accident. Type III (hooked) acromion Figure 9.

Figure 9: X-Ray of a non swimmer's shoulder with impingement syndrome

Irregular swimmer's shoulder with impingement syndrome

19 years old male practicing swimming irregularly from the age of 13. He is exposed to many sports, including basketball, valley ball, badminton, and swimming, etc. from the age of 12. Type II (curved) Figure 10.

Normal non-swimmer' shoulder

X-ray of a 20 years old female who is exposed to an average amount of physical activities involving the use of overhead arm movements during the age of 12-18. Type II (curved) Figure 11.

RESULTS AND DISCUSSION

The mean breadth of the right side and left side curved acromion is 24.26 mm and 23.84 mm respectively and for the right side and left side flat acromion it is 25.26 mm and 25.36 mm respectively. In canine, the mean breadth of the right side and left side acromion is 14.87 and 14.34 mm respectively. For bovine, the mean breadth of the right side and left side acromion is 20.33 and 19.94 mm respectively.

Table 1: Human Acromion Measurements

Parameter	Right side curved	Right side flat	Left side curved	Left side flat
Mean length	39.99	42.28	42.21	42.28
Mean breadth	24.26	25.26	23.84	25.36
Mean width	7.55	7.62	7.56	7.62

Table 2: Dog Acromion Measurements

Parameter	Right side	Left side
Mean length	19.98	19.37
Mean breadth	14.87	14.34
Mean width	3.99	4.23
AG-1	35.54	36.05
AG-2	29.31	29.96
Thickness of spine-1	3.46	3.55
Thickness of spine-2	3.37	3.86

Table 3: Cattle Acromion Measurements

Parameter	Right side	Left side
Mean length	33.11	32.22
Mean breadth	20.33	19.94
Mean width	12.92	12.13
AG-1	76.90	75.55
AG-2	75.65	76.75
Thickness of spine-1	16.38	16.88
Thickness of spine-2	5.02	5.33

Figure 12: shoulder abduction

Figure 13: Rows

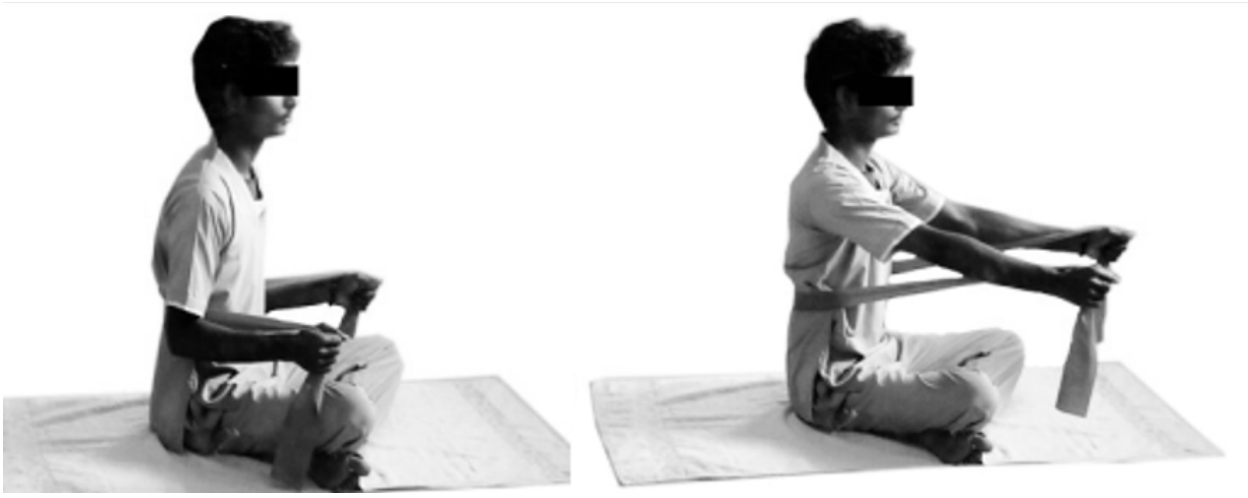

Figure 14: Bear Hugs

Figure 10: X-Ray of an irregular swimmer's shoulder with impingement syndrome

Figure 11: X-Ray of a normal non swimmer' shoulder

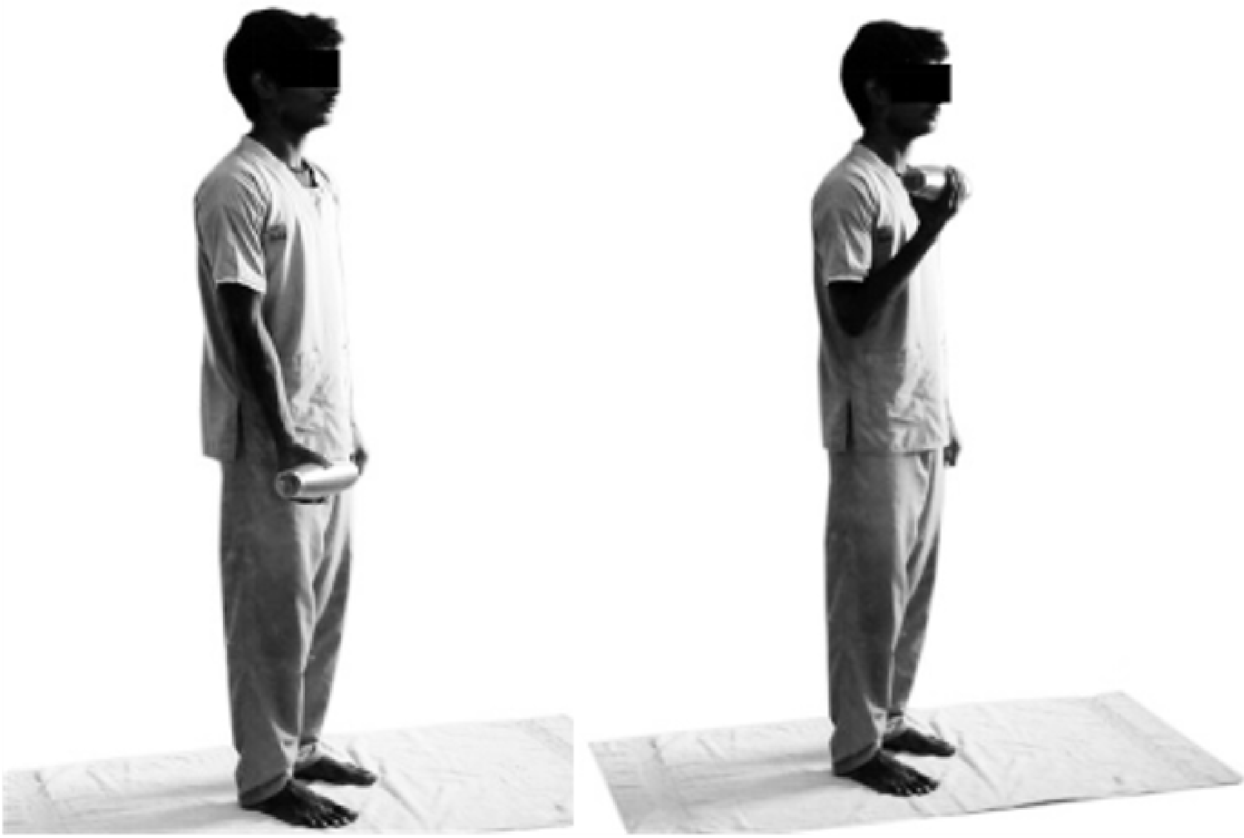

Figure 15: Biceps Curl

Figure 16: Internal rotation against resistance

In canine, the mean thickness of the spine-1 for the right side and the left side is 3.46 mm and 3.55 mm respectively, and in bovine it is 16.38 mm and 16.88 mm respectively. The mean thickness of the spine-2 of canine for the right side and the left side is 3.37 and 3.86 respectively, and for bovine it is 5.02 mm for the right side and 5.33 mm for the left side.

For canine, the mean AG-1 of the right side and left side is 35.54 mm and 36.05 mm respectively and for bovine the right side and left side mean AG-1 is 76.90 mm and 75.55 mm respectively. For canine, the mean AG-2 of the right side and left side is 29.31 mm and 29.96 mm respectively, whereas in bovine it is 75.65 mm and 76.75 mm respectively.

Shoulder impingement syndrome, also called subacromial impingement, painful arc syndrome, supraspinatus syndrome, swimmer's shoulder, and thrower's shoulder is a clinical syndrome which occurs when the tendons of the rotator cuff muscles become irritated and inflamed as they pass through the subacromial space, the passage beneath the acromion. This can result in pain, weakness, and loss of movement at the shoulder (Fongemie *et al.*, 1998).

There are two types of subacromial impingement

Figure 17: Internal rotation using thera band

Figure 18: External rotation against resistance

Figure 19: External rotation using thera band

Figure 20: Scaption

Figure 21: Posterior deltoid stretch

Structural impingement

Impingement due to a reduction of the subacromial space. The structural impingement can be caused by bone growth, inflammation of tendons, osteophytes or calcifications.

Functional impingement

Can be caused by glenohumeral instability and muscle imbalance. Functional impingement is a secondary consequence (Thurner *et al.*, 2013).

The morphometric study of the acromion is very important as the acromion process shows much variation in its morphology and also has various types that depict a great connection to impingement syndrome (Singh *et al.*, 2013).

In this study and most of the other morphometric studies done by Susmita Saha et al., Paraskevas et al., Singh et al. it is observed that the type II (curved) of the acromion is most common whereas the type III (hooked) acromion is less common. In this study, the overall ratio of type II (curved): type I (flat) acromion was 3:1. The type III (hooked) acromion was not found in this study.

A few previous studies have investigated the association between factors such as age, sex, body mass index (BMI) or smoking status with this condition. Smoking has been proven to be a preventable risk factor associated with several health conditions such as chronic lung disease, cardiovascular disease, and low back pain. This could be related to the fact that nicotine can affect sensory thresholds, impair vascularisation to tendons and disturb tendon healing capacity. Other than these factors osteoporosis, nutritional deficiency, and the decubitus sleeping position can also be one of the causes of impingement syndrome. Sleeping in decubitus position showed a 3.7 times greater risk compared with sleeping in the supine position. Repetitive overload from bodyweight during sleeping might cause the impingement of the tendon against the acromial arch, resulting in tendon degeneration and inflammation (Tangtrakulwanich and Kapkird, 2012).

Osteoporosis is a disease that causes thinning of bone and tissues and can affect the shoulder bones resulting in bone pain and an increased risk for fractures. Vitamin D helps in the absorption and utilization of Calcium to keep bones and connective tissue strong. Therefore, the deficiency of vitamin D causes osteoporosis, which in turn can cause impingement syndrome.

This study gives an idea about the morphometric as well as comparative information of human and vertebrate acromion process and its relation with impingement syndrome. We observed the scapulae of canine, bovine and equine, and found that equines do not have an acromion process and the morphological features of canine scapula were highly similar to that of humans. Due to this similarity, canines were used as models to study about rotator cuff injury in humans. In canines supraspinatus tendinopathy occurs due to repetitive activities such as quick turns, jump-turn combinations, slipping on wet surface and weave poles. This places the shoulder near its end range of abduction, which in turn leads to medial shoulder instability (Canapp, 2007b). Medial shoulder instability of canines is similar to rotator cuff injury in humans, which is often accompanied by impingement syndrome. In a study, a total of 327 dogs were diagnosed with supraspinatus tendinopathy from the year 2006-2013. In a study, Ronald Ailsby says, large animal veterinarians face acute and chronic repetitive strain injuries daily to their upper extremities (Ros *et al.*, 1996)

In a comparative study, the rotator cuff muscle architecture of animals such as dogs, rats, pigs, sheep, cows, and primates was compared with humans. It was found that the architecture of dogs and primates was more similar to that of humans (Mathewson *et al.*, 2014).

This comparative study might help the veterinary doctors as well as orthopaedists to adapt a better treatment protocol for shoulder related problems in animals and impingement syndrome in humans.

During the study of evolutionary perspectives of the acromion, we found that throughout man evolution, the scapula as a whole has modified to a great extent. Based on the activities done by early man and modern man, the spine of scapula had modified from almost vertical to almost horizontal in position, and so is the case with the acromion.

Since scapulae of apes were not available, we referred some of the previous studies regarding the human acromion viewed from an evolutionary perspective and observed the scapula of chimpanzee, gorilla, and orang-utan. It is found that the spine of the scapula is vertical in chimpanzee and slanted in gorilla and orang-utan. And the acromion is narrow, the glenoid cavity is facing cranially, and it is oval in all the apes (Voisin *et al.*, 2014).

Another previous study done by J.M. Potadu et al. on subacromial space in African great apes has proved that the acromion was more curved, and the occurrence of the impingement syndrome in apes was not possible (Potau *et al.*, 2007).

For more evidence regarding absence of impingement syndrome in apes Arignar Anna Zoological Park, Vandalur, Chennai was visited, and the wildlife veterinarians were interviewed, and it was concluded that impingement syndrome was never found in apes and that their shoulder abnormalities were very rare due to their functionally and genetically modified scapula and acromion. Based on the theoretical evidence and wildlife veterinarian's experience and practical knowledge it was concluded that apes do not have shoulder impingement due to the vertical orientation of the acromion process along the spine of the scapula and its curved and narrowed feature.

For the investigations of impingement syndrome among the swimmers' population, various swimming academies were been visited, and the swimmers of various age groups and their coaches were interviewed with various questions regarding there starting age of swimming practice, its regularity and any experience of shoulder related pain or disability. The question session gave a clear idea for supporting our hypothesis. Other than swimmers, we also went through a case of shoulder impingement in a fisherman who was practicing his profession for 20 years. He was subjected to a repetitive cycle of abduction, flexion, and extension during sailing his boat. This case also gave evidence supporting our hypothesis.

The influence of physical activities on the growth of acromion into its various types was studied with the help of radiographs of some swimmers and non-swimmers who were subjected to different sets and forms of physical activities during the ossification and fusion stage of the acromion. These radiographs were compared with each other and correlated to the amount and type of shoulder related physical activities done by them and with the radiographic evidence it was concluded that physical activities of shoulder done during the ossifying and fusing stages of the 4 ossification centers of acromion, which is between 12-25 years, does influence the modification of acromion into its various types. Excessive physical activities involving shoulder done during 12-25 years of age provides more restriction to the bone growth, and hence the acromion stops it's growth by flat or curved process and does not grow to its complete form as a hooked process.

Prevention

Impingement syndrome can be prevented by strengthening the rotator cuff muscles and other shoulder muscles by exercises [Figures 11, 12, 13, 14, 15, 16, 17, 18, 19, 20 and 21]

Exercise techniques used to strengthen these muscles are

1. Active movements without resistance
2. Exercises against resistance
3. Thera band exercises
4. Shoulder stabilization exercises

Impingement syndrome can also be prevented by encouraging shoulder movements involving activities and sports like swimming, throwball, basketball, etc., that involves a lot of overhead arm movements, during 12-18 years of age. As this age involves the ossification of the acromion, activities done during this age will modify the ossification of bone into a type that will easily allow overhead arm movements without serving many restrictions to the movement.

This kind of practice will modify the acromion process's ossification into type I (flat) or type II (curved), which are not prone to develop impingement syndrome unless the shoulder experiences an excessive trauma. And it also prevents the growth of the bone into type III (hooked), which is the most prone type of acromion to develop impingement syndrome.

CONCLUSION

Shoulder impingement does not occur in apes as their glenoid cavity is more cranially oriented and their spine of scapula and acromion process is almost vertical in its orientation, which provides unrestricted over-head arm movements. Whereas humans have a wide, horizontally oriented acromion above a laterally oriented glenoid cavity which provides a considerable amount of restriction to overhead abduction activities. Thus, humans have developed impingement syndrome due to these modifications during evolution. Besides the type-III (hooked) acromion being more prone to develop impingement syndrome the type II (curved) acromion though rarely but can also develop impingement syndrome in cases of trauma. Physical activities done during the ossifying and fusing stage of acromion does influence the modification of the bone into its three various types, hence exercises given during the ossifying stage of acromion can prevent its growth as type III (hooked) acromion which is most prone to develop impingement, being one of the major causes of prevalence of impingement syndrome.

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Author contributions

Ayesha parveen - Contributed in, developing the concept of the study, formulating the hypothesis, data collection, analysis and interpretation and drafting the article.

V.nivedha - Contributed to the acquisition of data, building the study design and drafting the manuscript.

Yuvaraj maria francis - Contributed with ideas for the progression of the study, the suggestion of topic and critical revision of the manuscript.

Senthil kumar - Contributed in the final revision of the article and its approval and guided in the submission of the article in the journal.

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