Comparison of the Scapula in Human and Laboratory Rat Species from the Perspective of Translational Medicine*

Yasemin ÜSTÜNDAĞ**, Osman YILMAZ***, Mehmet KARTAL****

Abstract

Aim: The aim of the study is to provide anatomical differences between rat and human scapula and definitive information to the literature about which strain is most appropriate for rat modeling, particularly in orthopedics.

Methods: In current study, a total of 40 scapulas belonging to Wistar Albino, Brown Norway, Sprague Dawley and Lewis strains were examined morphologically and morphometrically with each other and with the human scapula. Digital calipers were used to measure parameters for rat scapula. Literature searches were conducted for the measurements of the human scapula, and the obtained literature data was evaluated. A statistical analysis of the observed parameters was conducted using mean values, standard deviations, and One Way Anova Analysis in the IBM SPSS program. The Tukey post hoc test was used to determine the differences between groups that have a statistical difference. A fold ratio was calculated for each parameter based on the average values of all rat and human scapulae.

Results: According to One-Way Anova analysis, there is not any difference between groups for; width of collum scapula, length of cavitas glenoidalis-1, length of cavitas glenoidalis -2, width of cavitas glenoidalis, external width of cavitas glenoidalis, length of processus hamatus, width of processus hamatus, distance between processus coracoideus and incisura scapula, distance between cavitas glenoidalis to acromion at $p<0.05$ level. There is a statistical difference groups for; length of scapula ($p<0.001$), width of scapula ($p<0.001$), length of margo cranialis ($p=0.001$), length of margo caudalis ($p<0.001$), length of spina scapula ($p<0.001$), length of acromion ($p=0.007$), width of acromion ($p=0.001$), coracoacromial distance ($p=0.003$), distance between cavitas glenoidalis and incisura scapula ($p<0.001$), angle of angulus cranialis ($p=0.001$) levels.

Özgün Araştırma Makalesi (Original Research Article)
Geliş / Received: 30.12.2023 & **Kabul / Accepted:** 27.03.2024
DOI: https://doi.org/10.38079/igusabder.1412211

* This study was presented as a part of oral presentation "Comparison of Forelimb Skeletons in Human and Laboratory Rat Lineages" in 5. Ulusal Laboratuvar Hayvanları Bilimi Kongresi, Istanbul, Türkiye, 14-16 September 2023 and only abstract was published in congress book (pp: 147-148).

** (Corresponding Author) Dr., Dokuz Eylül University, Veterinary Faculty, Department of Anatomy, Izmir, Türkiye. E-mail: yasemin.ustundag@deu.edu.tr ORCID https://orcid.org/0000-0002-8836-0371
*** Prof. Dr., Dokuz Eylül University, Vocational School of Health Services, Department of Anatomy, Izmir, Türkiye. E-mail: osman.yilmaz@deu.edu.tr ORCID https://orcid.org/0000-0001-7817-7576
**** Dr., İstanbul Gelişim University, Faculty of Health Sciences, Istanbul, Türkiye. E-mail: mkartal@gelisim.edu.tr ORCID https://orcid.org/0000-0001-7364-0875

ETHICAL STATEMENT: Before starting the study, permission was obtained from the Dokuz Eylül University Local Ethics Committee for Animal Experiments with the decision dated 06.07.2022 and numbered 22.

Conclusions: Wistar Albino, Brown Norway, Sprague Dawley and Lewis rat strains are suitable for orthopedical animal models for especially models including cavitas glenoidalis. Any strain can be used in modeling indiscriminately. However, in modeling where the acromion, spina scapula, and edges of the scapula are important, the most appropriate strain specified in the current study should be selected.

Keywords: Morphometry, rat strains, scapula, translational medicine.

Translasyonel Tıp Açısından İnsan ve Laboratuvar Sıçanı Türlerinde Scapula'nın Karşılaştırılması

Öz

Amaç: Çalışmanın amacı, sıçan ve insan skapulası arasındaki anatomik farklılıkları sağlamak ve özellikle ortopedi alanında sıçan modellemesi için hangi suşun en uygun olduğuna dair literatüre kesin bilgiler sunmaktır.

Yöntem: Bu çalışmada, Wistar Albino, Brown Norway, Sprague Dawley ve Lewis sıçan soylarına ait toplam 40 scapula, birbirleriyle ve insan skapulasıyla morfolojik ve morfometrik olarak incelendi. Sıçan scapula'sındaki parametreleri ölçmek için dijital kumpaslar kullanıldı. İnsan scapula'sındaki parametrelerin ölçümleri için literatür araştırmaları yapıldı ve elde edilen literatür verileri değerlendirildi. Gözlemlenen parametrelerin istatistiksel analizi, ortalama değerler, standart sapmalar ve Tek Yönlü Anova Analizi olmak üzere IBM SPSS programı kullanılarak yapıldı. İstatistiksel farklılık olan gruplar arasındaki farklılıkları belirlemek için Tukey post hoc testi kullanıldı. Tüm sıçan ve insan scapula'larının ortalama değerlerine dayanarak her parametre için bir kat oranı hesaplandı.

Bulgular: Tek Yönlü Anova analizine göre; scapula boyu ($p<0,001$), scapula genişliği, margo cranialis uzunluğu ($p<0,001$), margo caudalis uzunluğu ($p<0,001$), spina scapula uzunluğu ($p<0,001$), acromion uzunluğu ($p<0,001$), acromion genişliği ($p<0,001$), coracoacromial mesafe ($p<0,001$), cavitas glenoidalis ve incisura scapula arasındaki mesafe ($p<0,001$), angulus cranialis açısı ($p=0,001$) için belirtiler p değerleri seviyesinde gruplar arasında istatistiksel bir fark vardır. Ancak; collum scapula genişliği, cavitas glenoidalis-1 uzunluğu, cavitas glenoidalis -2 uzunluğu, cavitas glenoidalis genişliği, cavitas glenoidalis dış genişliği, processus hamatus uzunluğu, processus hamatus genişliği, processus coracoideus ve incisura scapula arasındaki mesafe, cavitas glenoidalis ile akromion arasındaki mesafe için gruplar arasında $p<0.05$ seviyesinde herhangi bir fark yoktur.

Sonuç: Wistar Albino, Brown Norway, Sprague Dawley ve Lewis sıçan soyları, özellikle cavitas glenoidalis'i içeren ortopedik hayvan modelleri için uygundur. Herhangi bir soy fark gözetmeksizin modellemede kullanılabilir. Ancak acromion, spina scapula, ve scapula'nın kenarlarının önem teşkil ettiği modellemelerde mevcut çalışmada belirtilen en uygun soy seçilmelidir.

Anahtar Sözcükler: Morfometri, sıçan soyları, scapula, translasyonel tıp.

Introduction

Translational medicine is an interdisciplinary biomedical field that aims to improve disease prevention, diagnosis, and treatment. It integrates various disciplines, resources, expertise, and methodologies within its three key pillars: benchside, bedside, and community. The results of translational medicine directly benefit humanbeing[1-3].

Animal models, particularly mice and rats, play a significant role in the transition of translational medicine from the laboratory to everyday life. These models are used in various areas such as the development of new vaccines and drugs, and the production of new surgical and orthopedic methods. Over 20 million mouse and rat models are still used today[4,5].

Choosing the correct model is crucial in the design of the study. The selection of an inappropriate animal model may lead to incorrect findings, waste of resources, and loss of lives. Rats, with over 400 subspecies, are the primary choice for experimental studies due to their larger anatomical structure, high-quality production, and convenience in surgical-orthopedic animal model manipulation[6]. However, the selection of a suitable animal species for designing an animal model primarily depends on a thorough understanding of the animal's genetic makeup, anatomical structure, and physiological functions. Once the species of animal has been chosen, the second step involves selecting from among the subspecies within that strain. This is because there can be differences within a species or subspecies in terms of genetic predisposition to certain diseases and slight variations in anatomy and physiology that can affect the effect size of the experiments[5,7-9]. For instance, it has been proved that while BB rats, which are one of the outbred of Wistar rats, are prone to develop spontaneous diabetes, Lewis rats are prone to develop type-1 diabetes mellitus[10].

The genus Rattus was described in 4 subgenera. The subgenus Rattus included 36 species of which one is Rattus norvegicus, the brown rat. The common laboratory rat is a member of an albino strain of R. Norvegicus known as Wistar Albino. The other popular two strains are Sprague-Dawley and Lewis strains which are derived from Wistar Albino[11,12].

The aim of the study is to provide anatomical differences between rat and human scapula and definitive information to the literature about which strain is most appropriate for rat modeling, particularly in orthopedics.

Material and Methods

In the current study, a total of 40 scapulas belonging to Wistar Albino, Brown Norway, Sprague Dawley, and Lewis strains were examined morphologically and morphometrically with each other and with the human scapula. The ethical committee approval (number 22/2022) for the study was granted by the Dokuz Eylül University

Local Ethics Committee for Animal Experiments. The skeletons were macerated by boiling for 30 minutes. After the maceration process, the soft tissues on the skeletons were carefully cleaned. Then, the bones were soaked in 3% hydrogen peroxide for 5 minutes and dried at room temperature[13].

Among the morphometric measurements, the scapula was used in the current study. Length of scapula, width of scapula, length of margo cranialis, length of margo caudalis, length of margo dorsalis, length of spina scapula, width of collum scapula, length of cavitas glenoidalis -1, length of cavitas glenoidalis-2, width of cavitas glenoidalis, external width of cavitas glenoidalis, length of acromion, width of acromion, length of processus hamatus, width of processus hamatus, length of processus coracoideus, width of processus coracoideus, the distance between the processus coracoideus and the incisura scapula, the coracoacromial distance, the distance between the cavitas glenoidalis and the acromion, the angle of the angulus cranialis, the distance between the cavitas glenoidalis and the incisura scapula were measured[14]. Digital calipers were used to measure parameters for rat scapula. Literature searches were carried out for the measurements of the human scapula, and the obtained literature data was evaluated[15-29]. A statistical analysis of the observed parameters was carried out using mean values, standard deviations and One Way Anova Analysis in the IBM SPSS program. The Tukey post hoc test was used to determine the differences between groups that have a statistical difference. A fold ratio was calculated for each parameter based on the average values of all rat and human scapulae. (Fold Ratio=Human Mean Value/Rat Mean Value)

Results

Comparison of Scapula

In humans, the margo superioris is the shortest and shapeless edge, while in rats, margo cranialis, which is the second longest edge and is convex, extending in the cranioventral direction. Incisura scapula is narrower and significantly deeper in humans compared to rats, where it is wider and relatively shallower. In humans, the margo lateralis is the thickest edge extending anteroposteriorly and generally exhibits a slight concavity. In contrast, in rats, margo caudalis, which is the thickest and longest edge, extending dorsocaudally, and is completely flat. The margo medialis in humans is the flattest, thinnest, and longest edge, whereas in rats, margo dorsalis, which is the thinnest, shortest, and convex edge. It extends in the craniodorsal direction[30,31].

In humans, angulus superior is at the level of 2nd costa, and the angulus inferior is at the level of 7th costa; in the rat angulus cranialis is at the level of the 1st costa, angulus caudalis is at the level of the 5th costa. Collum scapula is short in humans compared to rats. In both species, just below the collum, there is a shallow articular fossa called the cavitas glenoidalis. In humans, the form of the glenoid cavity is variable, but in rats, it consistently resembles the shape of a pear. Processus coracoideus extends anteriorly in humans and ventrally in rats[30,31].

The posterior surface in humans is called facies posterior, while in the rat the laterally situated surface is called facies lateralis. This surface is slightly convex. There is a thick and long spine called spina scapulae on this surface. In humans, the spina scapulae widen medially in the middle of the spine, forming a triangular shape, which is called the trigonum spinae. Trigonum spinae was not observed in rats. In the rat, this spine starts a lower degree from margo dorsalis and shows an ascending course to the neck of the bone, while in humans it starts from the upper 4/5 of this surface and shows a similar course as it is in rats. Spina scapula ends with a protrusion called acromion which extends posterolaterally in humans and ventrally in rats. In rats, acromion resembles the tip of a golf club. In both species, there is a small articular surface at the anteromedial-ventromedial corner of the acromion for the articulation of the clavicle. Facies posterior or facies lateralis is divided into two hollow parts by this spine inferiorly, fossa infra spinata and superiorly fossa supraspinata. While the ratio of fossa supraspinata to fossa infraspinata in humans is 1/3, it is approximately ½ in the rat[30,31].

Figure 1. Lateral view of rat and human scapula[31]

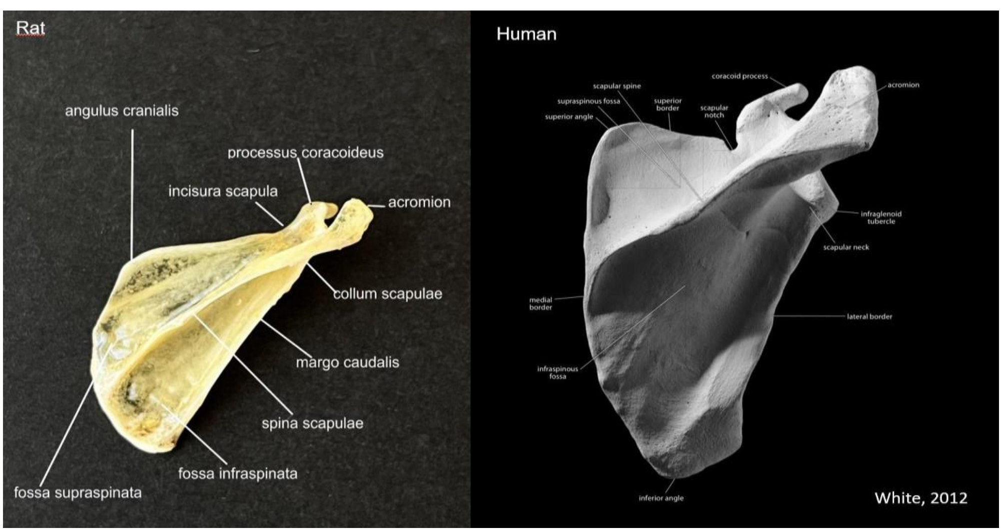
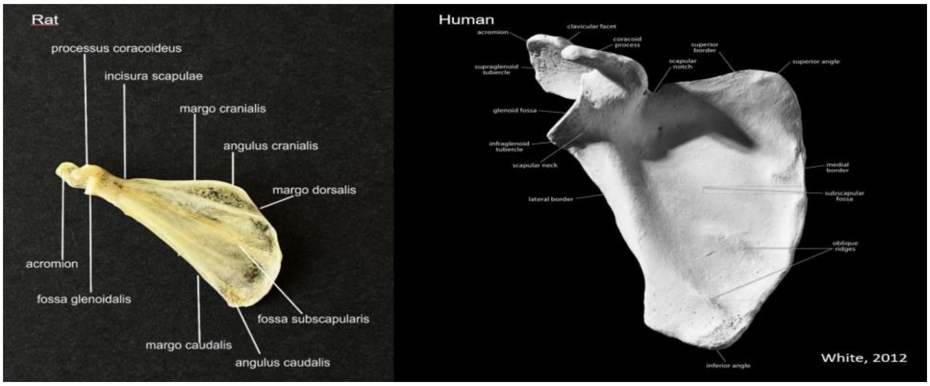


Figure 2. Medial view of rat and human scapula[31]



Statistical Results

The homogeneity analysis reveals a normal distribution across all values at $p>0.05$ level.

According to One-Way Anova analysis, there is not any difference between groups for, width of collum scapula, length of cavitas glenoidalis-1, length of cavitas glenoidalis -2, width of cavitas glenoidalis, external width of cavitas glenoidalis, length of processus hamatus, width of processus hamatus, distance between processus coracoideus and incisura scapula, distance between cavitas glenoidalis to acromion at $p<0.05$ level.

The groups that have a statistically significant difference between them are explained below:

Length of scapula at $p <0.001$, mean square: 6.005, dF:3, sum of square: 18.014, F:8.723. Wistar Albino shows statistical differences compared to other groups.

Width of scapula at $p<0.001$, mean square: 2.879, dF:3, sum of square: 8.637, F:15.226. Wistar Albino shows statistical differences compared to Brown Norway and Sprague Dawley; Brown Norway shows statistical differences compared to Sprague Dawley and Sprague Dawley shows statistical differences compared to Lewis.

Length of margo cranialis at $p=0.001$, mean square: 11.643, dF:3, sum of square: 34.930, F:6.590. Lewis shows statistical differences compared to Sprague Dawley.

Length of margo caudalis at $p<0.001$, mean square: 20.602, dF:3, sum of square: 61,806, F:27.738. Wistar Albino shows statistical differences compared to Brown Norway and Sprague Dawley; Brown Norway shows statistical differences compared to Wistar Albino and Lewis; Sprague Dawley shows statistical differences compared to Wistar Albino and

Lewis; Lewis shows statistical differences compared to Brown Norway and Sprague Dawley.

Length of margo dorsalis at $p<0.001$, mean square: 3.094, dF:3, sum of square: 9.281, F:5.995. Wistar Albino shows statistical differences compared to other groups.

Length of spina scapula at $p<0.001$, mean square: 23.340, dF:3, sum of square: 70.019, F: 41.867. Wistar Albino shows statistical differences compared to Brown Norway; Brown Norway shows statistical differences compared to Wistar Albino and Sprague Dawley; Sprague Dawley shows statistical differences compared to Brown Norway and Lewis; Lewis shows statistical differences compared to Brown Norway and Sprague Dawley.

Length of acromion at $p=0.007$, mean square: 2.230, dF:3, sum of square: 6.691, F: 4.785. Wistar Albino shows statistical differences compared to Brown Norway.

Width of acromion at $p=0.003$, mean square: 0.081, dF:3, sum of square: 0.243, F: 5.656. Wistar Albino shows statistical differences compared to Brown Norway; Brown Norway shows statistical differences compared to Wistar Albino and Lewis.

Coracoacromial distance at $p=0.003$, mean square: 0.549, dF:3, sum of square: 1.647, F: 5.739. Brown Norway shows statistical differences compared to Sprague Dawley; Sprague Dawley shows statistical differences compared to Brown Norway and Lewis; Lewis shows statistical differences compared to Sprague Dawley.

Distance between cavitas glenoidalis and incisura scapula at $p<0.001$, mean square: 1.491, dF:3, sum of square: 4.474, F: 8.222. Wistar Albino shows statistical differences compared to Brown Norway; Brown Norway shows statistical differences compared to Wistar Albino and Sprague Dawley; Sprague Dawley shows statistical differences compared to Brown.

Angle of angulus cranialis at $p =0.001$, mean square: 73.662, dF:3, sum of square: 220.985, F:6.370. Wistar Albino shows statistical differences compared to another group.

Table 1. Measurements of rat and human scapula with a fold ratio

Measurements	Rat	Human	Fold Ratio
	X±SD	X±SD	
Length of scapula	26.24±1.04	156±16	5.945122
Width of scapula	12.48±0.62	108.45 ±18.5	8.689904
Length of margo cranialis	18.89±1.58	77.98 ±3.75	4.12811
Length of margo caudalis	22.23±1.50	137.9± 4.34	6.203329
Length of margo dorsalis	14.44±0.84	101.5±0.71	7.029086
Length of spina scapula	19.80±1.51	16.8±2.56	0.848485
Width of collum scapula	1.69±0.43	10.95±1.78	6.47929
Length of Cg-1	2.47±025	28.6±2.76	11.57895
Length of Cg-2	1.38±0.13	19.35±4.3	14.02174
Width of Cg	2.78±0.22	34.8±5.79	12.51799
External width of Cg	4.09±0.26	36.4±4.90	8.899756
Length of acromion	6.02±077	44.81±5.43	7.443522
Width of acromion	0.58±0.13	21.9±3.45	37.75862
Length of Ph	3.85±0.65	43.6±4.86	11.32468
Width of Ph	2.15±0.46	10.6±1.98	4.930233
Length of Pc	3.69±0.55	50.7±5.76	13.73984
Width of Pc	1.62±0.20	27.1±2.89	16.7284
Distance between Pc and Is	7.14±0.47	15.5±3.75	2.170868
Coracoacromial distance	4.12±0.36	36.1±2.5	8.762136
Distance between Cg to acromion	4.92±0.18	31.8±2.7	6.463415
Angle of angulus cranialis	78.97±4.04	21.9±3.45	0.277321
Distance between Cg and Is	4.43±0.53	43.6±4.86	9.841986

Abbreviations: Cg: Cavitas glenoidalis Ph: Processus hamatus, PC: Processus coracoideus, Is: Incisura scapula

Discussion

Animal species ranging from to mammals like mice, rabbits, rats, cats, dogs, pigs, and monkeys, are the most preferred species in biomedical researches due to their genetic proximity or ease of manipulation[7]. Rats, rabbits, macaque monkeys, and dogs are commonly preferred in orthopedic experimental studies[9,32,33]. However, despite their anatomical suitability and trustworthy results, dogs and macaque monkeys are often avoided due to ethical considerations and constraints. Rats, which are easy to manage and feed and align with ethical rules, are popular choices as experimental animals[7,34].

The unique shape of the scapula, which plays an important role in the movement of the shoulder girdle, has attracted the attention of human anatomists[16]. Because the scapula can be subject to fractures, dislocations, rheumatism, tumors, and developmental abnormalities, however, anatomical interpretations of the scapula are central to understanding certain abnormalities, such as rotator cuff injuries and glenohumeral dislocations. On the other hand, many surgical procedures have been described for the scapula, including arthroplasty and arthrodesis for the glenohumeral joint, internal fixation for fracture stabilization, acromioplasty or acromionectomy for rotator cuff disorders, and scapulothoracic tenodesis for wing. Detailed anatomy of the scapula is important for surgical procedures of the aforementioned conditions, including arthroscopic procedures[14]. From a translational perspective, it has been observed that the distal part of the rat scapula has many resemblances to the human scapula especially those have a pear shape and can be used in models. It has also been noted that any of these four rat strains could be selected. For instance, in total shoulder replacement, understanding the bone parameters of the glenoid is of great importance to provide important guidance for designing implant size and improving material fit. For this purpose, implant size could be rearranged for the rat's glenoid cavity size by using the calculated fold ratios in the current study. Therefore, accurate measurement of preoperative angle, glenoid position, and degree of postoperative healing is vital for pathological evaluation and successful total shoulder replacement. Moreover, the degree of glenopolar angle recovery may be an effective indicator for prognosis assessment for surgical success. Changes in the length of the glenoid cavity and changes in its diameter and depth of the glenoid cavity are strongly associated with glenoid joint instability[35]. The literature informs us that most studies were conducted on fossa glenoidalis diameters for this purpose. For example, Reverse Total Shoulder Arthroplasty, developed by Grammont et al. in France, is a reversal of the restrictive designs introduced in the 1970s for the treatment of painful arthritis with rotator cuff deficiency. In order for this operation to be performed successfully in Japan, the fossa glenoidalis dimensions of the CT images obtained from the Japanese were compared with the data obtained from Western countries. Likewise, Rosales-Raosales et al. investigated the normal structure of the fossa gleoidalis in the Spanish population[20,36]. While Nasr el-Din and his colleagues conducted a morphometric study on the variations and shapes of the acromion and fossa glenoidalis in the Egyptian population, Chen et al. revealed the parameters about the shape of the fossa glenoidalis in their study on 501 scapulae in Chinese population[17,26]. Considering the variations in the scapulae of people living in different countries, as seen in the literature, it is thought that the data and findings obtained from the current study will not be suitable, especially for scapulae with non-pear-shaped cavitas glenoidalis.

The scapular glenoid angle and position are important for shoulder mechanics and the interpretation of diseases such as glenohumeral instability and rotator cuff tear but are also essential for shoulder replacement surgery planning. But considering angle of angulus cranialis in rat, choice of rat scapula is controversial due to having more greater degrees than humans and statistically differences they have between four strains.

Also located in the scapular region is emphasizing the presence of the n. suprascapularis, it has been observed that morphological variations in the region may predispose people to compression of this nerve. Due to the anatomical complexity and importance of the surrounding structures in the compression of n. suprascapularis, Poljug et al. examined the incisura suprascapularis shapely and morphometrically, while Sangam et al. examined the morphology of the incisura scapula and its distance from the fossa glenoidalis[19,37]. Similarly, Akın Saygın et. al. discussed the morphometric anatomy of the margo superioris of the scapula, especially in terms of the incisura scapula[27]. Because the shape and size of the n.suprascapularis and the transverse scapular ligament in the region are the most important factors that play a role in the etiopathology of nerve compression. The said ligament together with the incisura it creates a hole through which the n.suprascapularis passes. Orthopedists state that compression and damage to this nerve occurs most in this region. Considering incisura scapula, morphological difference between human and rat scapula is important while designing compression of n. suprascapularis. As mentioned before, humans have a narrower incisura scapula, but rats have a wider incisura scapula, and this difference may affect the compression ratio of the nerve.

Conclusions

Wistar Albino, Brown Norway, Sprague Dawley and Lewis rat strains are suitable for orthopedical animal models for especially models including cavitas glenoidalis. Any strain can be used in modeling indiscriminately. However, in modeling where the acromion, spina scapula, incisura scapula and edges of the scapula are important, the most appropriate strain specified in the current study should be selected.

REFERENCES

1. Wehling M, ed. *Principles of Translational Science in Medicine From Bench to Bedside*. United Kingdom: Academic Press Elsevier; 2021.

2. Casmatos D, Chow SC. *Translational Medicine: Strategies and Statistical Methods*. In: Casmatos D, Chow SC, eds. Translational Medicine: Strategies and Statistical Methods. 1st ed.New York: CRC Press; 2009:1-8.

3. Worboys M, Timmermann C, Toon E. Before translational medicine: Laboratory-clinic relations. *HPLS*. 2021;43(2):48. doi: 10.1007/s40656-021-00379-6.

4. Heckerman N, Benirshcke K. DeBakey ME, Dodds WJ, Ginzton EL. National Research Council (US) and Institute of Medicine (US) Committee on the Use of Laboratory Animals in Biomedical and Behavioral Research. Use of Laboratory Animals in Biomedical and Behavioral Research. Washington (DC): National Academies Press (US); 1988. doi: 10.17226/1098.

5. Robinson NB, Krieger K, Khan FM, et al. The current state of animal models in research: A review. *Int J Surg*. 2019;72:9-13. doi: 10.1016/j.ijsu.2019.10.015.

6. Gill TJ, Smith GJ, Wissler RW, Kunz HW. The rat as an experimental animal. *Science*. 1989;245(4915):269-76. doi: 10.1126/science.2665079.

7. Mukherjee P, Roy S, Ghosh D, Nandi SK. Role of animal models in biomedical research: A review. *Lab Anim Res*. 2022;38(1):18. doi: 10.1186/s42826-022-00128-1.

8. Domínguez-Oliva A, Hernández-Ávalos I, Martínez-Burnes J, Olmos-Hernández A, Verduzco-Mendoza A, Mota-Rojas D. The importance of animal models in biomedical research: current insights and applications. *Animals (Basel).* 2023;13(7):1223. doi: 10.3390/ani13071223.

9. Tung WL, Zhao C, Yoshii Y, Su FC, An KN, Amadio PC. Comparative study of carpal tunnel compliance in the human, dog, rabbit, and rat. *J Orthop Res*. 2010;28(5):652-6. doi: 10.1002/jor.21037.

10. Pandey S, Dvorakova MC. Future perspective of diabetic animal models. *Endocr Metab Immune Disord Drug Targets*. 2020;20(1):25-38.

11. Nowak RM, Paradiso JL. *Walker's Mammals of the World*. 2 Volumes, fourth ed. The Johns Hopkins University Press. Baltimore and London;1983.

12. Maynard RL, Downes N. *Anatomy and Histology of the Laboratory Rat in Toxicology and Biomedical Research*. London: Elsevier;2019.

13. Pazvant G, Kahvecioğlu KO. Kobaylarda ön ve arka bacak uzun kemiklerinin homotipik varyasyonları üzerine araştırmalar. *Vet.Med Istanbul Univ J Fac*. 2013;39(1):20-32.

14. von Schroeder HP, Kuiper SD, Botte MJ. Osseous anatomy of the scapula. *Clin Orthop Relat Res*. 2001;(383):131-9. doi: 10.1097/00003086-200102000-00015.

15. Giurazza F, Del Vescovo R, Schena E, et al. Stature estimation from scapular measurements by CT scan evaluation in an Italian population. *Leg Med (Tokyo)*. 2013;15(4):202-8. doi: 10.1016/j.legalmed.2013.01.002.

16. Singal G, Rathod H, Patel A, Modi P, Prajapati S, Rohitkumar P. A study on measurements and indices of human scapula at Jamnagar Medical College. *Int J Res Med*. 2013;2(1);65-68.

17. Nasr El-Din WA, Ali MH. A morphometric study of the patterns and variations of the acromion and glenoid cavity of the scapulae in Egyptian population. *J Clin Diagn Res*. 2015;9(8):AC08-11. doi: 10.7860/JCDR/2015/14362.6386.

18. Oladipo GS, Aigbogun Jr. OE, Akani GL. Angle at the medial border: The spinovertebra angle and its significance. *Anat Res Int*. 2015;2015:986029. doi: 10.1155/2015/986029.

19. Polguj M, Majos A, Waszczykowski M, et al. A computed tomography study on the correlation between the morphometry of the suprascapular notch and anthropometric measurements of the scapula. *Folia Morphol (Warsz)*. 2016;75(1):87-92. doi: 10.5603/FM.a2015.0072.

20. Shimozono Y, Arai R, Matsuda S. The dimensions of the scapula glenoid in Japanese rotator cuff tear patients. *Clin Orthop Surg*. 2017;9(2):207-212. doi: 10.4055/cios.2017.9.2.207.

21. Sarı A, Dinçel YM, Günaydın B, Çetin MÜ, Özçaglayan Ö, Bilsel K. Assessment of the glenoid morphology based on demographic data in the Turkish population. *Biomed Res Int*. 2020;10:2020:5736136. doi: 10.1155/2020/5736136.

22. Sahu D, Joshi M, Rathod V, Nathani P, Valavi AS, Jagiasi JD. Geometric analysis of the humeral head and glenoid in the Indian population and its clinical significance. *JSES Int*. 2020;4(4):992-1001. doi: 10.1016/j.jseint.2020.06.008.

23. Singh R. Surgical anatomy of the glenoid cavity and its use in shoulder arthroplasty among the North Indian population. *Cureus*. 2020;12(12):e11940.

24. Guan H, Zhang B, Ye Z, Deng X, Zhang Y. Glenoid bony morphology along long diameter is associated with the occurrence of recurrent anterior shoulder dislocation: A case-control study based on three-dimensional CT measurements. *Int Orthop*. 2022;46(8):1811-1819. doi: 10.1007/s00264-022-05463-5.

25. Arenas-Miquelez A, Karargyris O, Graham PL, Hertel R. High correlation between inner and outer glenoid circle diameters and its clinical relevance. *Knee Surg Sports Traumatol Arthrosc*. 2023;31(1):199-205. doi: 10.1007/s00167-022-07050-y.

26. Chen Y, Xiong J, Chen W, et al. Morphological classification and measurement of the glenoid cavity using three-dimensional reconstruction in a Chinese population. *Folia Morphol (Warsz)*. 2023;82(2):325-331. doi: 10.5603/FM.a2022.0017.

27. Akın Saygın D, Türkoğlu FN, Aydın Kabakci AD, Alpa S, Yilmaz MT. A morphometric and morphological analysis of superior border of dry scapulae. *Med Records*. 2023;5(1):115-25.

28. Akhtar MJ, Kumar S, Chandan CB, et al. Morphometry and morphology of the acromion process and its implications in subacromial impingement syndrome. *Cureus*. 2023;15(8):e44329. doi: 10.7759/cureus.44329.

29. Senol GT, Kurtul I, Ahmetoglu G, Ray A. Clinical significance of the morphometric structures of the scapula with the emphasis on the glenoid cavity. *Med Records*. 2023;5(2):304-8.

30. Arifoğlu Y. *Her Yönüyle Anatomi*. 3. Baskı. İstanbul: İstanbul Tıp Kitap Evi; 2021:39.

31. White TD, Black MT, Folkens PA. *Human Osteology*. Third Edition. California; Elsevier Academic Press; 2012:166-174.

32. Rempel DM, Diao E. Entrapment neuropathies: pathophysiology and pathogenesis. *J Electromyogr Kinesiol*. 2004;14(1):71-5. doi: 10.1016/j.jelekin.2003.09.009.

33. Roll SC, Evans KD, Volz KR, Sommerich CM. Longitudinal design for sonographic measurement of median nerve swelling with controlled exposure to physical work using an animal model. *Ultrasound Med Biol*. 2013;39(12):2492-7.

34. Andersen ML, Winter LMF. Animal models in biological and biomedical research - experimental and ethical concerns. *An Acad Bras Cienc*. 2019;91(suppl 1):e20170238. doi: 10.1590/0001-3765201720170238.

35. Zhou Y, Van Niekerk M, Hirner M. Reverse shoulder arthroplasty with metallic augments to preserve bone and restore joint line in patients with glenoid bone loss. *Seminars in Arthroplasty*. 2022;32:824-833.

36. Rosales-Rosales L, Rosales-Varo AP, García-Espona MA, Roda-Murillo O, Montesinos I, Hernandez-Cortés P. Anthropometrical study of the human glenoid in a normal Spanish population. *Rev Esp Cir Ortop Traumatol (Engl Ed)*. 2019;63(5):327-335. doi: 10.1016/j.recot.2019.04.005.

37. Sagnam MR, Devi SSS, Krupadanam K, Anasuya K. A study on the morphology of the suprascapular notch and ıts distance from the glenoid cavity. *Journal of Clinical and Diagnostic Research*. 2013;7(2):189-192.