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The study of spinopelvic parameters measurement by computed tomography in Scottish cats

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Abstract

Understanding spinopelvic parameters is crucial for diagnosing skeletal and muscular disorders. This study was the first to measure spinopelvic parameters, specifically pelvic incidence (PI), pelvic tilt (PT) and sacral slope (SS) in Scottish cats using computed tomography (CT). the research analyzed twelve Scottish cats (4.00 – 6.00 kg, 2 - 3 years old). The mean values obtained were 48.80° for PI, 26.00° for PT and 22.80° for SS. The *PI = PT + SS* equation was valid in healthy cats but failed in cases with spondylosis and pelvic fractures indicating its potential diagnostic utility. Pearson correlation analysis showed no significant relationship between PI and PT or PI and SS, however, a significant negative correlation between PT and SS was observed. This suggested that as PT increased, SS decreased. The study established baseline values for PI, PT, and SS in Scottish cats and highlighted the potential for using these parameters in feline diagnostics. The failure of the *PI = PT + SS* equation in pathological cases underscored its role in identifying specific conditions such as spondylosis and pelvic fractures. This foundational data was crucial for assessing spinopelvic alignment and diagnosing spinal disorders in cats. The findings suggested that deviations from baseline values could aid in diagnosing musculoskeletal disorders, optimizing treatment and preventing complications. Further research is needed to explore how variations in these parameters relate to different spinal conditions.

Introduction

Computed tomography (CT) scans have become invaluable in veterinary medicine offering detailed images that aid in diagnosing and treating a wide range of conditions in animals. For instance, CT scans are highly effective for diagnosing bone and joint diseases such as fractures, tumors and degenerative joint diseases. This technique provides high-resolution images of bones and joints, enabling veterinarians to accurately assess the patient condition and develops precise treatment plans.[1]

Computed tomography imaging is also essential in the diagnosis of tumors and neoplasms. It enables veterinarians to identify and evaluate various tumors within animal bodies, allowing them to determine the tumor size, location and extent. This detailed information supports the development of targeted treatment strategies.[2] Moreover, CT scans play a crucial role in the evaluation of neurological issues such as intervertebral disc disease, brain tumors and spinal cord injuries. High-definition images of the brain and spinal cord help veterinarians quickly and accurately identify neurological disorders leading to prompt and effective treatment.[3]

This study specifically focused on using CT to measure key spinopelvic parameters in Scottish cats adopting methodologies similar to those in human studies. By establishing baseline data for spinopelvic alignment, we aimed to deepen our understanding of feline spinal alignment, which could enhance the diagnosis and treatment of spinal disorders in cats.

Studies in humans have underscored the importance of sagittal and coronal balance and the interplay between different regions of the spine and pelvis. Research has shown a significant relationship between spinopelvic parameters and sagittal balance.[4] In spinal surgery, especially for degenerative spinal diseases, these parameters are critical for analyzing sagittal balance. Lumbar spine fusion may lead to loss of lumbar lordosis (LL) which can result in compensatory mechanisms such as reduced sacral slope (SS), increased pelvic tilt (PT) and decreased thoracic kyphosis. An increase in PT following

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surgery is linked to postoperative back pain. Additionally, a reduction in SS and/or an abnormal sagittal vertical axis post-fusion heightens the risk of adjacent segment degeneration. High pelvic incidence (PI) increases the likelihood of sagittal imbalance after spinal fusion and is a predictive factor for degenerative spondylolisthesis. Restoring a normal PT post-surgery is associated with better clinical outcomes.[5]

The vertebral column of cats is similar to that of other mammals. Most domestic cats have 53 vertebrae. This increase in the number of vertebral segments compared to humans, who have 52, is due to the presence of caudal vertebrae (tail vertebrae). These additional tail vertebrae contribute to increased mobility and flexibility of the vertebral column in cats.[6] Cats have seven cervical vertebrae, 13 thoracic vertebrae, seven lumbar vertebrae (L), three sacral vertebrae (S), and typically 20 - 23 tail vertebrae. The first sacral vertebra forms a strong connection with the ilium bone of the pelvis.[7] The treatment of spinal deformities requires a precise understanding of the natural parameters of the spine in various dimensions. In humans, the spine should have no curves in the coronal plane, whereas, in the sagittal plane, it has four curves: Sacral kyphosis and thoracic kyphosis which are present at birth and cervical lordosis and LL which develop as the infant grows and begins to walk. Each of these curves efficiently transfers body weight. Abnormalities can affect both regional and global alignment of the spine. Understanding these parameters is essential for diagnosing, treating and predicting the outcomes of spinal deformities.[8]

One neurological disorder in cats is Cauda Equina Syndrome which involves the destruction of the horse tail nerve roots also known as lumbosacral disease, and this condition is rarely recognizable in cats. Any injury in the L5 - 6 disc space in cats causes equine neuropathy.[9] Additionally, relative lumbosacral luxation is a problem in the sacral region of cats, primarily caused by degeneration of the lumbosacral intervertebral disc and joint instability. This condition can lead to difficulties in walking, jumping or climbing stairs, resulting in pain and decreased mobility which ultimately affects the cat overall quality of life.[10] The main parameters of the sacroiliac joint in human include PI and SS.[11]

This value is fixed and it is believed that it represents the fundamental angle upon which all other spinal curves are based. Pelvic incidence is increasingly recognized as a critical anatomical parameter for assessing sagittal balance in humans with higher PI values correlating with increased lordosis. Elevated PI values are also observed in isthmic spondylolisthesis, a condition characterized by the anterior displacement of one vertebra over another, primarily due to a defect in the pars interarticularis of the vertebra. The altered biomechanics of the spine may lead to compensatory changes in pelvic alignment. This defect can result from repetitive stress or trauma leading to instability in the spinal column. Understanding the reciprocal relationships between the lumbosacral and pelvic regions and their impact on overall balance has become increasingly important. Emerging evidence suggests that sacral-pelvic correlations are primarily established with spinal segments adjusting to maintain balance.[8] This parameter indicate the position of the sacrum within the pelvis.[12] PI is considered an important anatomical parameter for assessing the sagittal balance of the human body. An increase in PI is associated with increased lordosis.[13] Changes in this parameter in humans are associated with spinal disorders, pain, disability and alterations in quality of life.[14]

There is a mathematical relationship in humans: $PI = PT + SS$, between these spinopelvice parameters indicating that the spinal column and pelvis should be aligned and balanced to minimize energy consumption.[5]

Based on the points mentioned and the similarity of vertebral column structures between humans and other mammals, this study was conducted after human research. In human studies, it has been established that the PI is a crucial anatomical indicator for assessing sagittal balance. Access to pelvic parameters aids in preventing complications following the treatment of spinal column abnormalities. Building on these studies and the significance of pelvic parameters, we investigated and measured the PI index along with other pelvic parameters (PT and SS) in the sagittal plane using CT in Scottish cats.

Materials and Methods

In this descriptive study, a CT scanner (six-slice; Siemens, Munich, Germany), Slice Thickness: 3.00 mm, Voltage: 110 kV, Current: 26.00 mA, Field of View: 15.00 cm was used. Due to the device sensitivity to motion artifacts, the study group was anesthetized to minimize movement artifacts. The intramuscular (IM) anesthesia protocol for cats involved a ketamine (5.00 mg kg^{-1}, IM; Alfasan, Woerden, Netherlands) combined with medetomidine hydrochloride (80.00 μg kg^{-1}, IM; Syva, León, Spain). After completion of the CT scans, if necessary, atipamezole hydrochloride (20.00 - 50.00 μg kg^{-1}, IM; Syva) was used as an antagonist to reverse the anesthesia.[15]

Study population. Scottish cats, with an average weight of 5.00 kg and an age range between 2 to 3 years were included considering that our study primarily focused on the examination of spinopelvic parameters and we also took gender into account. Among the subjects studied, one cat was female while the remaining were male. This inclusion allowed us to acknowledge any potential gender-related differences in the measured parameters.

Sampling method. Initially, the study animals were discussed with their owners in a face-to-face session regarding the research objectives and methods. They underwent clinical health examinations and consent was obtained from the owners for anesthesia. The general health of all 12 selected cats was assessed before and after the study. The anesthesia dosage used was under the supervision of the advisor and the CT were performed under the supervision of both the advisor and a radiology specialist, following standard conditions to minimize the absorbed dose in the animals. Ethical approval for this study was obtained from the Ethical Committee of Islamic Azad University, Karaj Branch (Approval No. IR.IAU.K.REC.1402.148, Date: 2024-02-20).

Inclusion criteria and data collection method. Scottish cats were included in the study based on their phenotype specific to this breed. After anesthesia induction, CT of the lumbar and pelvic regions was obtained. Initially, axial and spiral CT images were acquired. A topogram from the L5 to the first caudal vertebra was taken. Subsequently, images were processed in three-dimensional from the sagittal body section. The PI, PT, and SS indices in the sagittal section were measured using the software integrated into the CT scanner computer system. Pelvic incidence, or pelvisacral angle, was defined as the angle between a line perpendicular to the sacral plate at its midpoint and a line connecting the same point to the center of the bicoxofemoral axis.[8] Pelvic tilt was the angle between the vertical line passing through the midpoint of the femoral head and a line connecting the midpoint of the sacral superior endplate to the midpoint of the femoral head.[16] Sacral slope was the angle between a line parallel to the endplate of the sacrum and a horizontal line. To measure PI in the sagittal plane of a CT image, we first, identified the coordinates (x1, y1) of the right femoral head on sagittal slices where it appeared as the largest circle using the Leonardo Viewer coordinate system. Second, the coordinates (x2, y2) of the left femoral head were similarly identified. The mean X and Y values ((x1 + x2)/2, (y1 + y2)/2) were then calculated to determine the midpoint of the hip axis on the midsagittal images. Using this midpoint, measurements of PI and PT were taken (Fig. 1).

On other sagittal slices where the femoral heads appeared smaller, the centers of the circles had identical coordinates due to the assumption that femoral heads were perfect spheres and the sagittal slices were parallel to each other.

Statistical analysis. In this study, which measured spinopelvic parameters using CT in Scottish cats, comparisons of measurements including PI, PT, and SS based on frequency patterns and non-parametric statistics such as Wilcoxon, Chi-square and Pearson were analyzed using SAS Software (version 9.4; SAS Institute, Cary, USA).

Results

This study was the first to investigate spinopelvic parameters in Scottish cats providing baseline values for key indices such as PI, PT, and SS. The findings offered valuable insights into diagnosing and managing skeletal and pelvic disorders in these cats. The spinopelvic parameters, measured in 12 Scottish cats, are presented in Table 1. After performing the CT, the number 11 cat was diagnosed with spondylosis L7 - S1 (Fig. 2). In the number 12 cat which was referred for CT due to a pelvic fracture, spinopelvic parameters were measured during the procedure (Fig. 3).

Baseline measurements. The average values for PI, PT, and SS in healthy Scottish cats were 48.80°, 26.00°, and 22.80°, respectively. The equation $PI = PT + SS$ was valid for all healthy cats indicating that this relationship could be used as a diagnostic criterion for identifying lumbar and pelvic issues.

Abnormal cases. In cases with spondylosis and pelvic fractures, the equation $PI = PT + SS$ did not work suggesting that deviations from this equation could not help identify abnormalities.

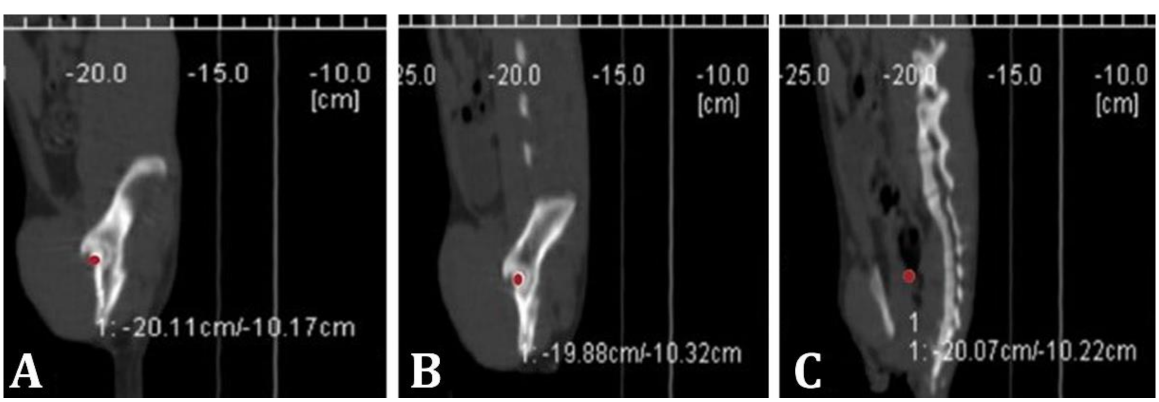

Fig 1. A) Sagittal slice of pelvic computed tomography (CT) image of the Scottish cat showing coordinates of the right femoral heads; **B)** Sagittal slice of pelvic CT with coordinates of the left femoral head; **C)** Midsagittal CT slice of the patient. The point with average coordinates of the femoral head center determines the midpoint of the hip axis.

Table 1. The spinopelvic parameters for the Scottish cats (Numbers 12) are measured in degrees.

Case No.	Sex	Pelvic Incidence	Pelvic Tilt	Sacral Slope
1	Male	49.00	17.00	32.00
2	Female	49.00	25.00	24.00
3	Male	49.00	38.00	11.00
4	Male	51.00	28.00	23.00
5	Male	49.00	29.00	20.00
6	Male	47.00	21.00	26.00
7	Male	46.00	24.00	22.00
8	Male	47.00	22.00	25.00
9	Male	51.00	20.00	31.00
10	Male	50.00	36.00	14.00
11	Male	46.00	2.00	55.00
12	Male	63.00	21.00	37.00

Between PI and PT: The correlation coefficient was 0.25074 with a p-value of 0.4847 indicating no significant relationship between PI and PT. Between PI and SS: The correlation coefficient was –0.00398 with a p-value of 0.9913 showing no significant relationship between PI and SS. Between PT and SS: The correlation coefficient was – 0.96905 with a p-value less than 0.0001 indicating a strong and significant negative relationship. A p-value of 0.0008 confirmed a significant relationship between PI and the sum of PT and SS.

Likelihood Ratio Chi-Square with a p-value of 0.0213 and Mantel-Haenszel Chi-Square with a p-value of 0.0027 also supported the significance of this relationship. A p-value of 0.0611 suggested that while not formally significant at the 0.05 level, the relationship between PI and the sum of PT and SS might be of practical interest.

Discussion

This study represented the first examination of spinopelvic parameters in Scottish cats, providing significant insights into the diagnostic potential of these indices. As no previous studies have been conducted on animals, and based on methodologies adapted from human research, we established baseline measurements for PI, PT, SS in this breed.

In human studies, the relationship between sagittal balance and clinical outcomes in the surgical treatment of degenerative spinal diseases has been investigated. The findings of these studies indicated that spinal fusion led to changes in lumbar pelvic indices. Moreover, these indices are utilized as guidelines for surgical interventions and for restoring PI to its normal average, which yields positive clinical outcomes. Therefore, it is essential to compare

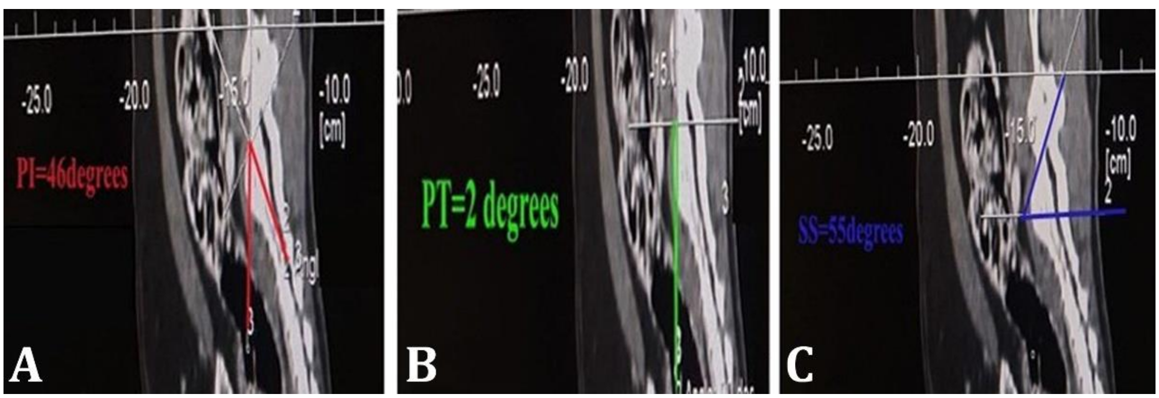

Fig. 2. Spinopelvic parameters in a Scottish cat with spondylosis. **A)** Pelvic incidence (PI) index measured in the sagittal plane of the Scottish cat; **B)** Pelvic tilt (PT) index measured in the sagittal plane of the Scottish cat; **C)** Sacral slope (SS) index measured in the sagittal plane of the Scottish cat.

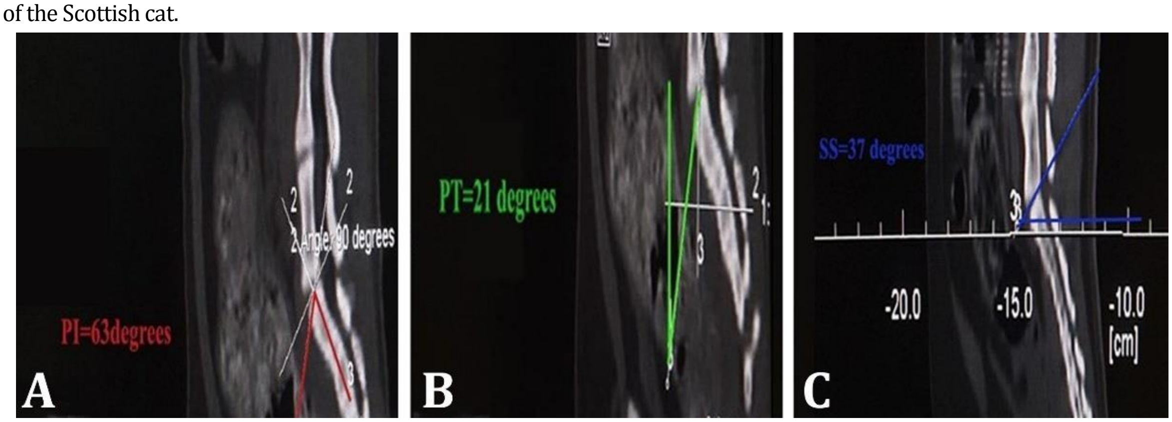

Fig. 3. spinopelvic parameters in a Scottish cat with a pelvic fracture. **A)** Pelvic incidence (PI) index measured in the sagittal plane of the Scottish cat; **B)** Pelvic tilt (PT) index measured in the sagittal plane of the Scottish cat and **C)** Sacral slope (SS) index measured in the sagittal plane of the Scottish cat.

these parameters before and after surgery and to assess the degree of disability, pain and quality of life.[5] In case number 11, where spondylosis was diagnosed at L7 and S1, measurements of PI = 46.00, PT = 2.00 and SS = 55.00 were obtained, while the averages for healthy cats were PI = 48.80, PT = 26.00 and SS = 22.80. It appears that in the cat with spondylosis, both PI and PT were decreased compared to the average, while SS was increased. However, due to the limited sample size, further investigation is warranted. Additionally, in case number 12, where a pelvic fracture was diagnosed, measurements of PI = 63.00, PT = 21.00 and SS = 37.00 were obtained indicating that both PI and SS were increased compared to the average, while PT was decreased. Given the low sample size, further study is necessary.

In another human study, 100 participants were evaluated out of which 41 were male. Analysis of the data revealed that lumbar pelvic indices including PT, PI and LL were significantly lower in females, while PI, PT and PI-LL were increased and LL was decreased in older age groups.[3]

In our research, the gender of the studied groups was also examined. Among the 10 healthy cats evaluated, nine were male and one was female. The average measurements for healthy male cats were PI = 48.70, PT = 26.10 and SS = 22.60. For the female cat, the values were PI = 49.00, PT = 25.00 and SS = 32.00. Due to the small sample size for the female cat, further research is needed. However, it seems that the SS value in the female cat is higher than the average in male cats, while PI and PT showed minimal variations and remained close to the average of male cats. Given the findings from human studies, it is essential to further investigate and analyze the lumbar pelvic indices separately for male and female cats.

A mathematical relationship (*PI = PT + SS*) exists between lumbar pelvic indices in humans, indicating that the spine and pelvis should be aligned and balanced to reduce energy expenditure.[12] In this study, the aforementioned mathematical relationship held true for healthy cats, however, it was disrupted in cases with abnormalities. This suggested that the average PI and its relationships with PT and SS could serve as a useful tool in diagnosing lumbar and pelvic issues in cats.

Regarding baseline measurements, the average values obtained were 48.80° for PI, 26.00° for PT and 22.80° for SS that were aligned with expected anatomical norms for a healthy population of Scottish cats. The validity of the equation *PI = PT + SS* in these healthy cats suggested that this formula could be a reliable tool for assessing spinopelvic alignment in felines. This relationship mirrored findings in human studies where PI was a key determinant of sagittal balance and was largely constant throughout life. Applying this concept to veterinary medicine is a significant advancement.

Our study highlighted the value of the *PI = PT + SS* equation as a diagnostic criterion, especially when deviations from this equation occurred. In cases with spondylosis and pelvic fractures, the failure of the equation to hold true underscored its potential in identifying pathological changes. These findings suggested that deviations in spinopelvic parameters could serve as indicators of underlying skeletal abnormalities, which is crucial for early diagnosis and intervention.

The lack of a significant relationship between PI and PT or PI and SS (*p*-values of 0.4847 and 0.9913, respectively) suggested that changes in these indices did not directly impact PI. This might be due to the inherent stability of PI throughout an individual life, making it less responsive to variations in PT and SS.

The strong negative relationship between PT and SS (correlation coefficient of −0.96905, *p*-value < 0.0001) indicated that as PT increased, SS decreased significantly. This inverse relationship was consistent with the principles of spinal and pelvic alignment, where increased PT often leads to a compensatory decrease in SS.

The significant p-value of 0.0008 confirmed that the relationship between PI and the sum of PT and SS was statistically significant. This finding reinforced the validity of the *PI = PT + SS* equation as a diagnostic tool in healthy cats. Additional support from the Likelihood Ratio Chi-Square (*p*-value = 0.0213) and Mantel-Haenszel Chi-Square (*p*-value = 0.0027) further validated this relationship suggesting robust consistency across different statistical methods.

Although the *p*-value of 0.0611 did not reach conventional significance levels, it indicated a near-significant relationship. This suggested that while the equation *PI = PT + SS* might not always be statistically significant in every instance, it still was a practical value and warrants further exploration.

The baseline values and relationships established in this study offered a new diagnostic framework for assessing lumbar-pelvic health in Scottish Fold cats. The ability to identify deviations from the *PI = PT + SS* equation could aid veterinarians in diagnosing and managing conditions such as spondylosis and pelvic fractures. This research also underscored the importance of developing breed-specific diagnostic criteria as the anatomical variations in Scottish Fold cats might influence the application of standard human-based indices.

This study represented the first investigation of spinopelvic parameters in Scottish cats. The results indicate that: 1. The equation *PI = PT + SS* holds true in healthy cats: In healthy cats, the equation *PI = PT + SS* was well-established and could be used as a criterion for diagnosing lumbar and pelvic issues. In cases where cats had abnormalities such as spondylosis or pelvic fractures, the equation did not work suggesting that changes in spinopelvic parameters could assist in identifying these problems. 2. Negative correlation between PT and SS: The strong and significant negative correlation between PT and SS suggested that an increase in PT was significantly associated with a decrease in SS. This relationship could lead to a better understanding of how these indices influence each other. 3. Gender Analysis: This study aimed to investigate the relationship between spinopelvic indices in Scottish breed cats, while also examining the gender of the study groups. Among the 10 healthy cats assessed, nine were male and one was female. The results indicated that the SS was higher in the female cat compared to the average in male cats, while the PI and PT showed little variation and were close to the average values in male cats. However, due to the small sample size of female cats, further investigation is warranted. The study emphasized the need for future research with larger sample sizes and diverse breeds to refine diagnostic tools and enhance veterinary care for various feline populations.

Conflict of interest

None to declare.

References

1. Ohlerth S, Scharf G. Computed tomography in small animal-basic principles and state of the art applications. Vet J 2007; 173(2): 254-271.
2. Whatmough C, Lamb CR. Computed tomography: principles and applications. Compend Contin Educ Vet 2006; 28(11): 789-800.
3. Adams WH. The spine. Clin Tech Small Anim Pract 1999; 14(3): 148-159.
4. Rezaee H, Bahadorkhan G, Ehsaei M, et al. Spinopelvic parameters among healthy volunteers in Iran. Arch Bone Joint Surg 2020; 8(5): 620-624.
5. Le Huec JC, Faundez A, Dominguez D, et al. Evidence showing the relationship between sagittal balance and clinical outcomes in surgical treatment of degenerative spinal diseases: a literature review. Int Orthop 2015; 39(1): 87-95.
6. Brown S. The Cat: a natural history.1st ed. London, UK: Ivy Press 2020; 38-39
7. Dyce KM, Sack WO, Wensing CJG. Textbook of veterinary anatomy - ebook. 4th ed. St. Louis, USA: Elsevier Health Sciences 2009; 407-409
8. Errico TJ, Petrizzo A. Introduction to spinal deformity. In: Errico TJ, Lonner BS, Moulton AW (Eds). Surgical management of spinal deformities - ebook.1st ed. Philadelphia, USA: WB Saunders 2008; 3-12.
9. Scott H, McLaughlin R. Feline Orthopedics.1st ed. London, UK: CRC Press 2006; 312.
10. Kamen D. The well-adjusted cat: feline chiropractic methods you can do. Vancouver, Canada: CCB Publishing 2013; 38-39.
11. Philippot R, Wegrzyn J, Farizon F, et al. Pelvic balance in sagittal and Lewinnek reference planes in the standing, supine and sitting positions. Orthop Traumatol Surg Res 2009; 95(1): 70-76.
12. Le Huec JC, Aunoble S, Philippe L, et al. Pelvic parameters: origin and significance. Eur Spine J 2011; 20(Suppl 5): 564-571.
13. Legaye J, Duval-Beaupère G, Hecquet J, et al. Pelvic incidence: a fundamental pelvic parameter for three-dimensional regulation of spinal sagittal curves. Eur Spine J 1998; 7(2): 99-103.
14. Lafage V, Schwab F, Patel A, et al. Pelvic tilt and truncal inclination: two key radiographic parameters in the setting of adults with spinal deformity. Spine (Phila Pa 1976) 2009; 34(17): E599-E606.
15. Mathews KA, Grubb T, Steele AM. Physiologic and pharmacologic application of analgesia and anesthesia for the pediatric patient. In: Mathews KA, Sinclair M, Steele AM, et al. (Eds). Analgesia and anesthesia for the ill or injured dog and cat. Hoboken, USA: John Wiley & Sons 2018; 342
16. Roussouly P, Pinheiro-Franco JL. Biomechanical analysis of the spino-pelvic organization and adaptation in pathology. Eur Spine J 2011; 20(Suppl 5): 609-618.