Discussions

Volume 4 | Issue 1 Article 4

The Natural History of Osteoarthritis

Ashley Quick
Case Western Reserve University

Recommended Citation
Quick, Ashley () "The Natural History of Osteoarthritis," *Discussions*: Vol. 4: Iss. 1, Article 4.
DOI: https://doi.org/10.28953/2997-2582.1090
Available at: https://commons.case.edu/discussions/vol4/iss1/4

The Natural History of Osteoarthritis

-Ashley Quick-

Ashley Quick is a fourth year student majoring in nursing. She is originally from Mansfield, Ohio. After graduation Ashley plans to begin her nursing career in public health, She eventually would like to get her Masters in Public Health. In her free time Ashley enjoys bike-riding and playing tennis.

-Acknowledgements-

I would like to thank Bruce Latimer, Lyman Jellema, and the rest of the staff at the CMNH for all their patience. I would also like to thank the Biology department at Case Western Reserve University, SPUR, and the Howard Hughes Medical Institute for giving me this opportunity.

ABSTRACT

Early signs of vertebral osteoarthritis begin to appear around the age of thirty. By age fifty, almost everyone exhibits some form of osteoarthritis in their spine, and with time the arthritis advances. The examination of a 3.2 million year-old ancestor verifies osteoarthritis' longstanding condition in bipeds. Osteoarthritis in the vertebral column is characterized by osteophyte formation, or "lipping," on any part of the vertebra (Nordin 1989). This comparative study aims to target the location, frequency, and severity of osteophyte formation in the thoracic and lumbar vertebrae of humans as well as the nonhuman primates. Each specimen was taken from The Hamann-Todd Osteological Collection at the Cleveland Museum of Natural History. The human sample comprises 89 specimens and the nonhuman sample 33. Each human and nonhuman specimen was closely examined in an effort to examine a potential relationship between the presence or absence of osteoarthritis in the flexible spinal column of the bipedal human and the largely immobile spinal column of the quadrupedal African apes.

INTRODUCTION

Osteoarthritis (OA), also known as degenerative joint disease, is a condition resulting from progressive erosion of joint cartilage. As a result of this progressive degeneration lesions begin to form (Aufderheide 1998). OA can be seen in numerous joints throughout the body, such as the knee, hip, shoulder, elbow and spine.

OA of the spine, also known as spondylosis, can be extremely debilitating. OA is manifested by lesions that are called "osteophytes,"

which are outgrowths of new bone (See Fig-1). In extreme cases this growth of new bone can lead to the fusion of two adjoining vertebrae (See Fig-1). In humans, range of motion and other movements such as rotation, flexion, and extension can be significantly decreased. If the fusion of two adjoining vertebrae occurs, adjacent vertebral bodies are at greater risk for OA. This stems from the adjacent vertebral bodies compensating for motion restricted in the fused vertebrae. If any movement at any level of the spine is restricted, the spine in turn will counteract by increasing motion at another level (Nordin 1989).

Few mammals possess the spinal flexibility of humans. For example, African apes such as gorillas (*Gorilla gorilla*), and chimpanzees (*Pan troglodyte*), have a stiff, inflexible spine as an adaptation to large bodied arboreality. Anatomically, the apes have decreased the number of lumbar vertebrae to three or four, as opposed to five, the condition most common in the human lumbar spine. The apes also have increased the height of the iliac blades. These two evolutionarily selected characteristics have stiffened the ape's spine to strictly support bridging and climbing. As a result, apes have severely comprised the mobility of their spines.

Although chimps and humans are phylogenetically very close, their vertebral columns differ dramatically. In contrast to the inflexible ape spine, humans possess an extremely flexible vertebral column. The extremely flexible nature of the human spine is a byproduct of our bipedal locomotion. The lumbar columns of early hominids such as *Homo erectus* and *Australopithecus* were comprised of six lumbar vertebrae, as opposed to the five vertebrae of modern *Homo sapiens*. The necessity of six lumbar vertebrae is derived from early hominids' attempt to move the last thoracic vertebrae T13 into a lumbar element, thereby increasing spinal mobility and the ability to balance their torso over the hip joints (Latimer 1993). Habitual bipedality has promoted mechanical demands not seen in the quadruped. These mechanical demands have rendered alterations of vertebral curvatures. Among mammals only humans and our immediate ancestors' genus *Homo* and *Australopithecus* posses sinuous curves which cauterize the bipedal spine. These curvatures are comprised of an anteriorly directed kyphotic curve in the twelve thoracic vertebrae, and a posteriorly directed lordotic curve in the lumbar vertebrae. The reason for this peculiar anatomy is to balance and distribute loading over the hips during locomotion (Latimer 1993).

This comparative study examined whether the degeneration caused by OA is unique in humans due its evolutionarily selected mobile spine. We examined the flexible vertebral columns of humans as well as the rigid vertebral columns of apes. It is hypothesized that osteoarthritis is specific to humans due to our highly bendable spines. It is moreover further hypothesized that owing to their lack of functional mobility, the apes will not exhibit the extent of OA seen in the humans.

MATERIALS AND METHODS

Sample

Each specimen examined was from the Hamann-Todd Osteological Collection at the Cleveland Museum of Natural History. The human sample consisted of 90 specimens spanning over 6 decades. The breakdown by age category was specimens ranging from ten 20 year-olds, twenty 30 year-olds, twelve 40 year-olds, twenty 50 year-olds, fifteen 60 year-olds, and ten 80 year-olds.

Gender and race were noted as well. Forty-one females were examined (23 black, 18 white) and forty-six males (21 black, and 25 white). One *Australopithecus* (Lucy) was examined. From the African ape collection twelve gorillas (*Gorilla)* (6 male, 6 female) and twelve chimpanzees (*Pan)* (6 male, 6 female) were examined. In addition four orangutans (*Pongo)* (2 males, 2 females), two baboons *(Papio)* and four gibbons (*Hylobates)* were studied.

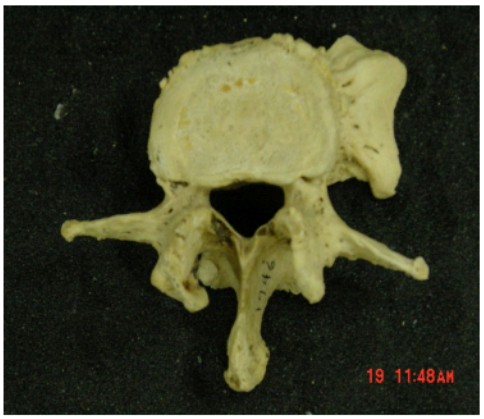


Figure-1 this is a superior view of a L4 element showing prolific osteophyte formation on the vertebral body.

Method

Each specimen's thoracic and lumbar vertebrae were examined for the presence of OA. OA is characterized by the presence of osteophytes. Using a diagram which illustrated a lateral, superior and inferior view of the thoracic and lumbar vertebrae, arthritic development was noted on the facet joints, or the superior and inferior vertebral bodies. Any appearance of "lipping," or osteophyte formation (see Fig-1), was noted on the corresponding diagram. Location, shape, size, and severity were recorded. The presence of Schmorl's nodes (a herniation through the intervertebral disc through the end-plate) (Schmorl 1930), infection, and previously scanned CT bone mineral densities were recorded as well.

After each vertebra was closely examined and all manifestations of OA recorded, the degree of arthritis was then scored on a severity scale from 0-4. Zero indicated no osteophyte formation; one indicated very slight osteophyte formation; two indicated clear osteophyte formation; three indicated prominent osteophytes; and finally, four designates very extensive osteophyte formation, frequently resulting in the fusion of two or more vertebrae.

RESULTS

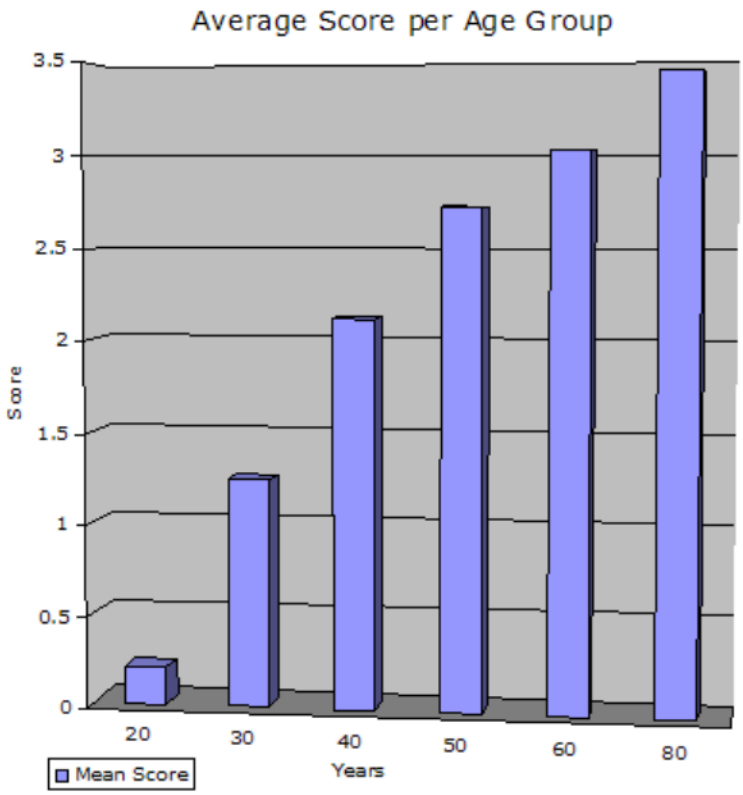


Figure-2 illustrates the relationship between age and severity of osteoarthritis in humans. It is apparent that the severity of OA increases with age.

Age vs. Severity of OA in Humans

The specimens examined were broken into age categories 20, 30, 40, 50, 60, and 80. The severity and preva-

lence of OA gradually increased with each decade. The human specimens began exhibiting minimal signs of OA during the third decade of life, and it progressed gradually up through age 80 (Fig. 2). Of the ten 20 year-olds examined only two (20%) of the ten exhibited any arthritis, both of which scored a 1. This yielded a mean score of 0.2. An increase in ten years results in a definite increase in the amount of arthritis.

Of the twenty 30 year-olds that were examined, sixteen (80%) of the twenty exhibited at least some form of arthritis. When compared to the previous group (20-year olds) a 60% jump in frequency of OA was noted. Of the twenty 30 year-olds, eight scored a 0, eight (40%) scored a 1, seven (35%) scored a 2, and the remaining specimen (5%) scored a 3. This yielded a mean score of 1.25. Of the 40 year-olds, eleven (91.6%) of the twelve specimens exhibited some form of OA. Only one specimen (8.3%) exhibited no arthritis, three (25%) scored a 1, three (25%) scored a 2, five (42%) scored a 3, and one (8.3%) scored a 3.5. This totaled a mean score of 2.13. Again, the arthritis continues to increase in severity from progressive age group to age group.

By the 6th decade of life, all twenty (100%) of the specimens exhibited some form of arthritis. The severity score also rose with a majority of thirteen (65%) out of twenty scoring a 3 or higher. The 50 year-olds had an average severity score of 2.73. Each 60 year-old specimen had arthritis and the mean score climbed to 3.03. Finally, the last age group, the 80 year-olds, as expected, exhibited the most extensive forms of OA. Six (60%) of the 80 year-old specimens displayed the most severe forms of OA, scoring the highest rating, 4. These rates yielded a final mean score of 3.45. These results indicate that OA is age-related, showing a definite increase in frequency and severity with time. (See Fig-2)

OA in Humans

Figure-3 displays the distribution of OA among the thoracic and lumbar vertebral elements. The prevalence of arthritis peaked at T7 which is anatomically located at the depth of the thoracic kyphosis. At T7 arthritis appeared a total of fifty-three (63%) out of eighty-nine times. After T7 the arthritis gradually decreases. However, there is a slight increase in prevalence at L4 and L5.

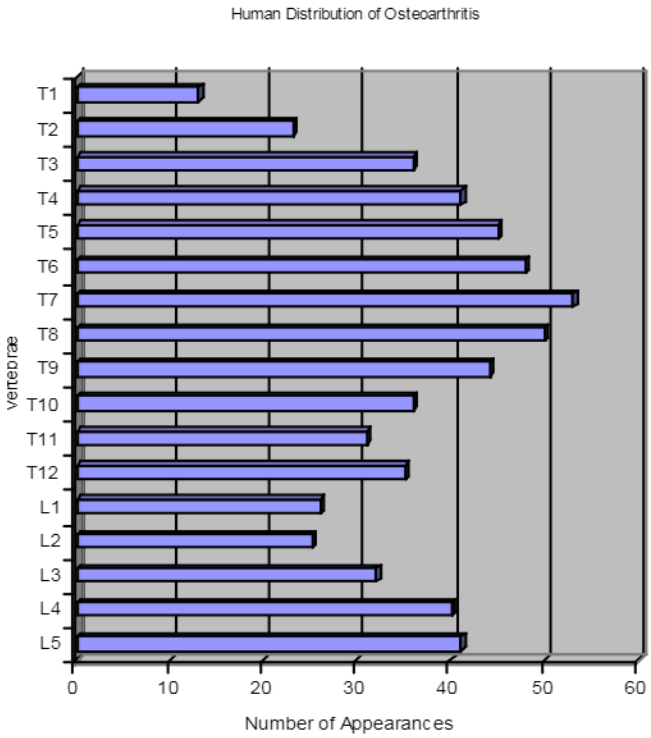


Figure-3 illustrates the distribution of OA among the thoracic and lumbar elements. It is apparent that at T7 the frequency of OA is more prevalent.

Figure-4 shows the distribution of relative moment arms among the various thoracic and lumbar vertebrae while under compression. The reason for the distribution seen in Fig-4 can be explained by looking at the human thoracolumbar column in lateral view. The vertebra subject to the greatest loads was T7. All other elements T1-L5 were measured with a moment arm relative to T7. Under compressive loading the mid thoracic spine

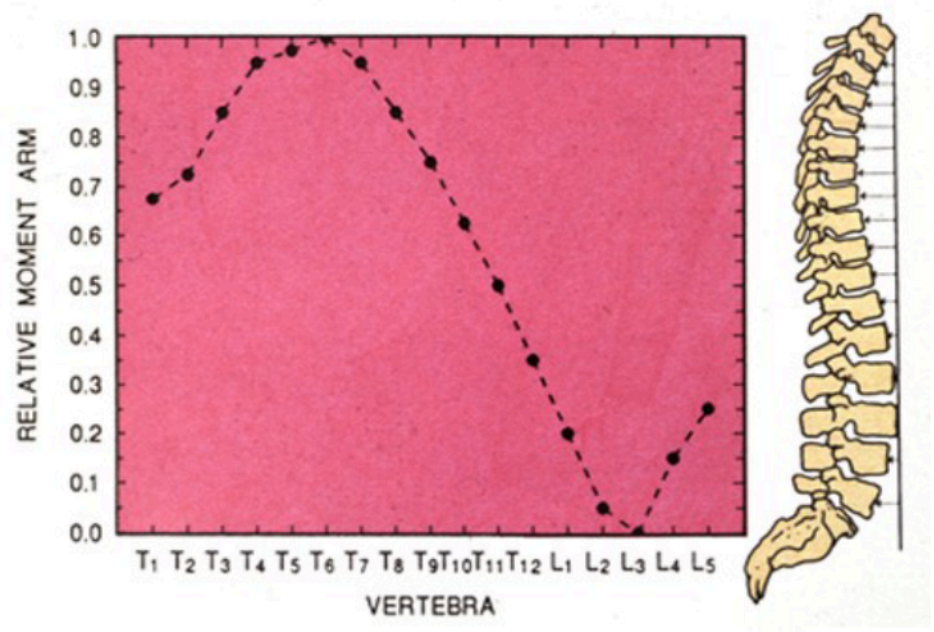


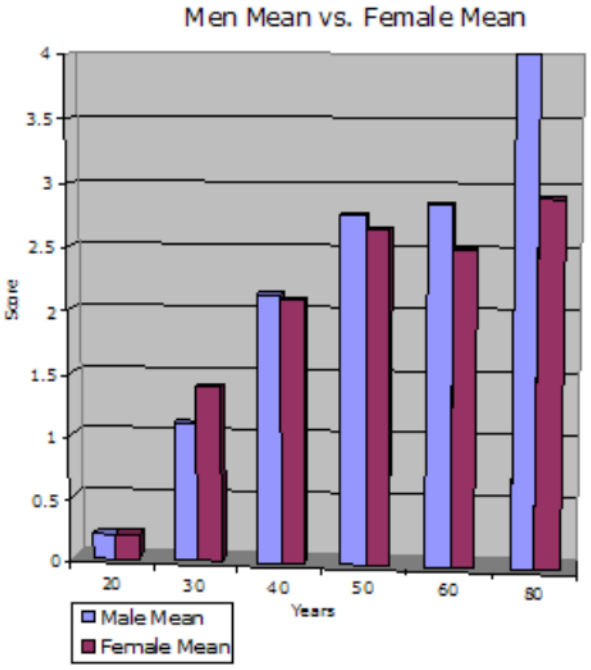
Figure-4 (above) shows the moment arm's measurements of each vertebra under compression in relation to the T7th element. The moment arm is perpendicular to the bodyweight vector.

bears the greatest bending stress. Interestingly, Figure-4's graph of the thoracic and lumbar elements essentially mimics that of the OA distribution graph seen in Figure-3. They both peak at T7 and then drop off. However, there is a slight increase at L4 and L5 due to the lumbar lordosis.

Gender and OA in Humans

The specimens were examined to see if gender played a role in OA. Results indicated that men had more extensive OA than females (See Fig-5). The total male population consisted of forty-six specimens, and the total female population consisted of forty-one specimens. Gender differences were examined by taking the mean severity scores per decade of the male population versus female population. At age 20 both males and females had the same severity average, 0.2. At age 30 the females scored 1.4 and males 1.1. This gave the female population the lead with a differential of 0.3. At ages 40, 50, and 60, the male population exhibits higher severity scores, and by the 9th decade of life the average severity score for the males is 4.0, females 2.9. At 80 years-old this yielded a significant differential of 1.1 (See-Fig-5).

Figure-5 (below) shows the male average severity score versus the female average severity score per decade. The male population exhibits more OA than the female population in every group except 30.



OA in Australopithecus "Lucy" (A.L.288-1)

A cast of the 3.2 million year-old *Australopithecus* "Lucy" was examined for signs of OA in the same manner noted above. Lucy exhibited osteophyte formation at the T10 element projecting superiorly from the vertebral body. An additional thoracic vertebra was present with slight osteophyte formation: the exact location of this thoracic vertebra in the column is unknown (Johanson 1982). Figure-6 shows the cast of Lucy with lipping.

Figure-6: This is a superior view of the specimen "Lucy". The red arrow is pointing to superior lipping present medially on the specimen's superior vertebral body

OA in Gorillas and Chimpanzees

The chimp and gorilla sample consisted of 24 specimens which were examined for OA in the same fashion as the human sample. After studying twelve gorillas (*Gorilla)* and twelve chimpanzees (*Pan)* it was obvious that the African apes do not demonstrate human-like patterns of OA. Indeed, the ape pattern differs dramatically from that in the human sample. From the twelve Gorillas examined three (25%) of the twelve showed no sign of arthritis, scoring a 0 out of 4. However, three (25%) of the twelve did show OA scoring a 2. Half the gorillas, six (50%) out of twelve, showed minimal arthritis, scoring a 1.Not one gorilla exhibited enough OA to score a 3 or 4. Thus, the total mean severity score among the gorillas was 0.54 out of 4.0. Of the chimps, one (8%) out of twelve displayed minimal arthritis scoring a 1; the other eleven specimens showed no sign of OA. This yielded the chimpanzees a mean severity score of 0.08 out of 4.0. These findings identify the Lowland Gorilla as the ape most susceptible to arthritis, yet the severity remains extremely low, not even reaching 1.0.

After differentiating the chimp and gorilla sample for gender, results indicated that among the gorillas, both males and females had equal mean severity scores of 1.0. However there was a difference between male and female chimps. The male chimps averaged a severity score of 0.2 while the female chimps exhibited no arthritic development averaging a 0. The apes were seriated for age by dental wear, but no correlation between age and arthritic development was found. The additional nonhuman primates, orangutans, gibbons, and baboons were each examined, but the sample sizes were small and no OA was noted.

Discal Infection in Chimpanzees and Gorillas

While very little arthritis was seen in the nonhuman primate collection, it became apparent that many of these apes suffered from a problem other than OA. A large portion of the chimp and gorilla sample exhibited intradiscal infections, seven out of twelve (58%) gorillas, and five out of twelve (42%) chimpanzees. See (Fig-7) for illustration of an intradiscal infection in one of the examined gorillas.

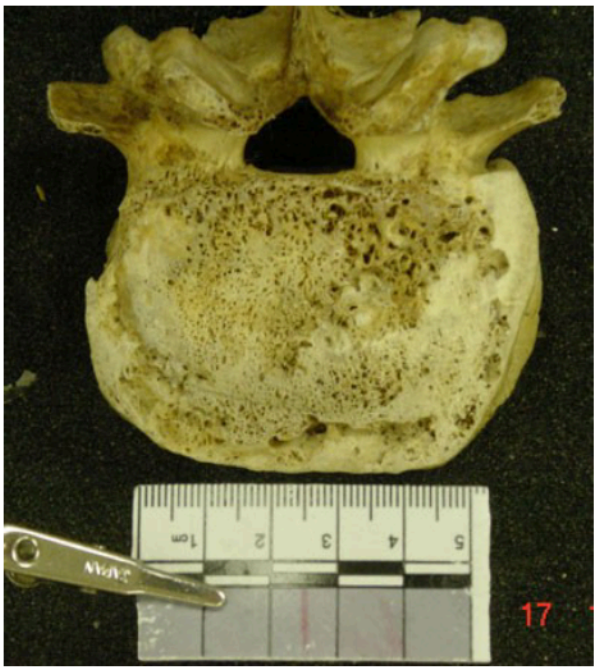


Figure-7 shows the inferior view of an intradiscal infection on the L1 element of a female gorilla.

OA in Apes vs. Humans

It is difficult to gauge the distribution of OA from the ape sample, because little was present. There were distinct differences between the arthritic distributions in humans and apes. The frequency in which arthritis appeared in the gorillas and chimpanzees was predominantly concentrated from T1-T9. At T2, T4, and T5 the arthritis reaches its peak, appearing only four times. From T10-T13 there is no arthritis present. At L1, L2 it appears only 1-2 times. The highest frequency of arthritic development in the ape is located in the portion of the spine that is adjacent to the highly flexible cervical spine, as opposed to the human where the high frequency of arthritic development is located at the mid-thorax. Figure-8 compares the distribution and frequency of OA in chimpanzee and gorilla sample to that of the human sample.

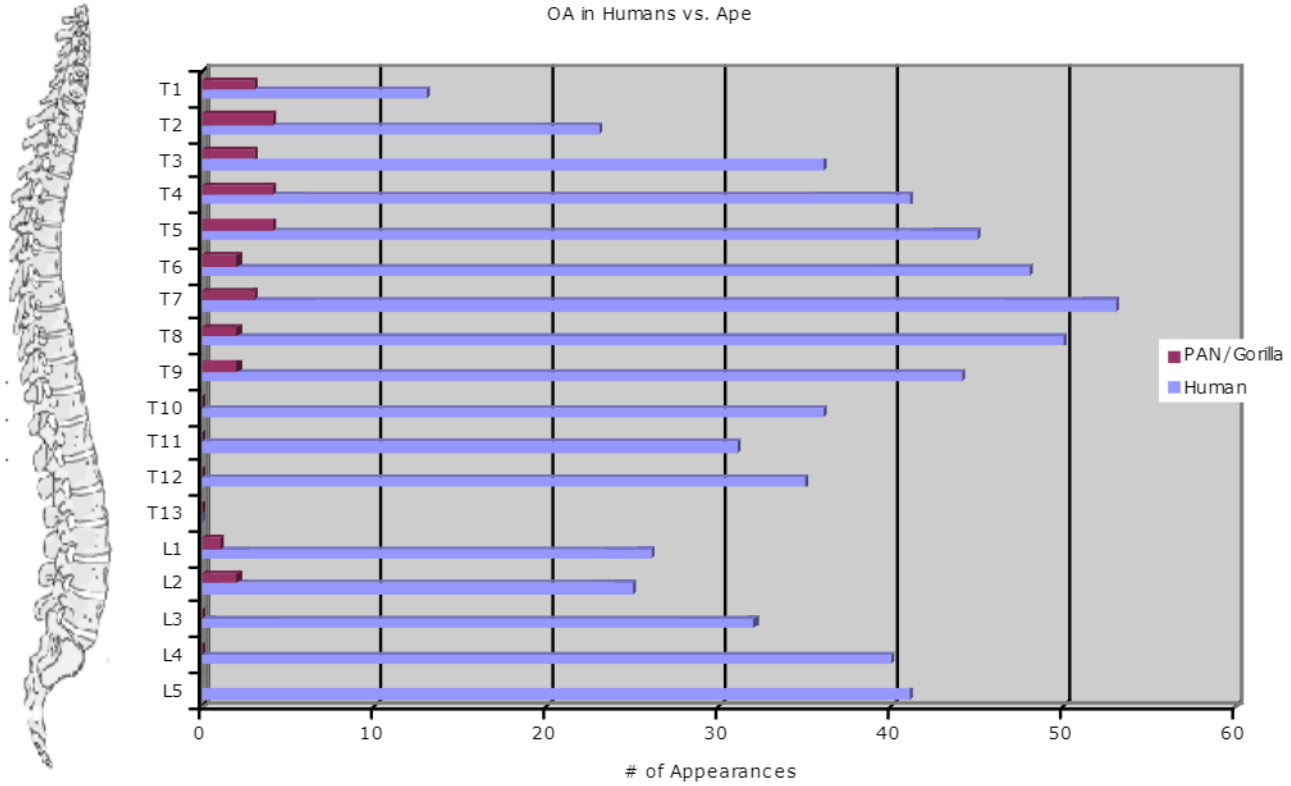


Figure-8 compares the distribution of OA between humans and chimpanzees/gorillas. NOTE: Humans do not have a T13, and apes do not have an L5.

DISCUSSION

This study sought to compare the nature of the flexible human spine to that of the inflexible ape spinal column in relation to OA. The humans exhibited dramatically greater numbers and a more advanced arthritis than the apes. Not a single ape demonstrated enough arthritic damage to warrant a 3 or 4 severity rating. This data indicates that it is the biomechanical loading of the uniquely curved human spine that results in OA. Given that OA is seen in Lucy's mid-thoracic column, the evidence indicates that OA has been a problem among the bipeds over the ages.

Plotting arthritis in relation to age signifies that OA is age-related. Spondylosis begins to appear in its minimal form around age 20 and continues to increase in frequency and severity with time. The increase in the incidence is attributed to the increased wear on the vertebrae over time. Averaging scores among gender and race attributes OA to be more common and severe in males likely due to activity.

This study rendered numerous results proving the role and type of movement in relation to spondylosis. However, the nonhuman primate sample revealed numerous manifestations of infections, thus indicating that the lack of mobility in the vertebral column may predispose one to infection. The intradiscal infection may arise from the lack of adequate perfusion to the intervertebral disc.

This comparative study supports the fact that our evolutionarily selected highly movable spine has disposed the human to spinal OA as a byproduct of locomotion. Although OA will likely develop in all humans with time, our highly mobile spine has decreased a predisposition to the intradiscal infections seen in the African apes.

REFERENCES

Aufderheide, A. C., Rodriguez-Martin, C: 1998. The Cambridge Encyclopedia of Human Paleopathology. Cambridge, Cambridge University Press, pp. 93-97.

Frankel, H.V., Nordin, M.: 1989. Basic Biomechanics of the Musculoskeletal System. 2nd Ed. Philadelphia, Lea & Febiger, pp. 191.

Johanson, D. C., Lovejoy, C. O. Morphology of the Pliocene Partial Hominid Skeleton (A.L. 288-1) From the Hadar Formation, Ethiopia: American Journal of Physical Anthropology. A Wistar Institute Press Journal. 1982: pp. 403.

Latimer, B., Ward, C.: 1993. The Nariokotome *Homo Erectus* Skeleton. Cambridge, The Belnap Press of Harvard University Press. Chapter 12, pp. 266-293.

Schmorl, G.: Die Pathogenese der Juvenilis Kyphose. Fortschr Geb Rontgenstr 41: 359-383, 1930.