Knee Design: Implications for Creation .vs. Evolution

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KEY WORDS

Knee Flexion Contractor, Knee Design, Knee Evolution

ABSTRACT

This paper traces important features in human knee design that allows the unique function of plantigrade bipedalism (walking two legged on the soles of the feet). Concepts of biomechanical importance related to human gait and the problem of knee flexion contracture are discussed. Alleged hominid ancestors would have had to overcome a flexed knee stance to become efficient bipeds. Knees discovered in the fossil record, however, are fully functional. Joint replacement research has carefully followed a reproduction of the original design for a most unique joint - the human knee.

KNEE DESIGN

The human knee is an articulation of the three intra-compartmental bones - femur, tibia, and patella. The knee's unique design allows the most human feature of plantigrade bipedalism.

The distal regions of human femora show distinctive bipedal traits as described by Heiple and Lovejoy [6]. These features include a high bicondylar angle or similar to what orthopedists measure as the quadriceps angle. This angle is formed by a line through the medially inclined femoral shaft to a vertical line perpendicular to the knee joint. Illustration 1.

This angle is most important for placing the knee close to the midline of the body and produces a straight line (called the mechanical axis) between the centers of the hip, knee, and ankle. In humans the bicondylar angle is 8-10° (a range of 4-17°) with females having a slightly larger angle by virtue of a wider pelvis. Increase of this angle produces the visually recognized 'knocked' knee and a decrease of the angle is known as 'bow leg'. Other distal femoral differences include a large anterior rim on the lateral condyle, a deep patellar groove, and flattened contours on the articular surfaces of both medial and lateral condyles. Illustration 2.

The human knee does not rotate on a single axis like a wheel but acts more like a cam with a differential radial curvature. As the knee moves through flexion/extension, the instant centers of rotation also move through the distal femur forming an ellipse that closely parallels the anatomical contour of the femoral condyles. Illustration 3. Kettlekamp [8] has demonstrated that the greatest area of articular contact between the femur and tibia occurs in extension. Illustration 4. This allows for the maximum distribution of forces during any point of load bearing in knee motion.

The fully extended human knee can bear weight and remain stable with little sustained muscular action. This basically is true because in extension the articular design along with the soft tissues (especially the crucial ligaments) effect a twist upon the knee joint. The femoral condyles as viewed down the femoral shaft rotate internally while the tibial plateau rotates externally to an approximate total rotation of about 20°.

As a reemphasis, an important design feature at the distal end of the femur is the anterior enlargement of the lateral condyle. Orthopedists see this radiographically as the sulcus angle. Illustration 5. The lateral condyle helps maintain the patella, as it tracks superiorly in the femoral fossa during terminal degrees of extension. Failure of this development can be one of the causes for maltracking problems for the patella, since most subluxations or dislocations occur near knee extension.

The most distally placed quadriceps muscle called the vastus medialis obliquus is specifically oriented to assist guiding patellar motion during the terminal degrees of extension. Illustration 6. Smillie [19 p.4, 99] believes, "If complete extension of the knee joint is an attribute common only to man, then that component of the quadriceps which produces the last ten degrees of extension must surely possess the most recently acquired function and should thus show the most marked susceptibility to the effect of injury...vastus medialis is the 'key to knee'."

Human Gait

Humans alone enjoy a habitual upright posturing (orthograde meaning straight) gait that Lovejoy qualifies for hominids as striding. By convention, the human gait cycle begins at heel strike with the knee near full extension. Illustration 7. A knee stretched out near full extension allows for a full stride length and allows the trunk and head to remain erect, thus conserving energy. Early activation of the quadriceps allows weight bearing acceptance without knee collapse.

The knee nears full extension for a second time in the midstance phase when there is single limb support. During this longest phase of the gait cycle (60%, while swing phase covers the other 40%) the body weight forces are distributed over the greatest contact area between the femur and tibia. In the gait of quadrupeds such as the cat, neural reflexes are arranged to dampen quadriceps contraction at foot (paw) strike. Just the reverse is seen in biped humans when strong stimulation reaches the quadriceps to accept full body weight loads. The quantitative differences in this arrangement between cat and man are extremely large, and, as Pierro-Deseilligry [17] noted they are completely out of phase. Therefore, evolving from four limb to two limb ambulation would require a complete reversal of this neural reflex.

Perry [16] noted a dramatic increase in both quadriceps contraction forces and proximal tibial reaction forces as the knee flexion approaches 30°. Illustration 8. Perry also calculated that the maximum quadriceps strength is related to resting muscle fiber length and to the quadriceps lever arm (or moment arm). The maximum strength advantage gain can occur at knee flexion of above 60° and the least advantage is at 30°. Denham [1] found that as knee flexion angles exceeded 25°, the patellofemoral forces exceed tibiofemoral forces. Nisell [15] noted that the moment arm differences between men and women (shorter in women) give higher forces for equally extended moment magnitudes. He theorized that this factor may explain the more frequent patellofemoral osteoarthritis associated with women's knees.

Knee Flexion Contracture

In the human knee, a flexion contracture can become a dehabilitating disorder whether from congenital, developmental, or traumatic origins. The joint mechanical problems caused by an inability to extend the knee during striding can become progressive. When the knee joint is loaded in flexion, quadriceps insufficiency can develop from overstretching. This condition can lead to patella alta (superior displacement) and thereby reduce further the quadriceps lever arm. Finally this may produce instability problems and cartilage erosion as described by Sutherland [21].

Bony abnormalities accompany the flexed knee. Force distribution problems can lead to an overgrowth of the anterior tibial epiphysis which becomes an osseous block to further extension as reported by Tew [22]. Growth arrest of the posterior tibial surface can promote greater flexion contracture. Ambulation on a flexed knee (as one can appreciate by performing a duck-walk) requires a major energy expenditure. Gait progression is halting or shuffling as I observed during gait lab analysis in the Shriners' Hospital for Children in Houston, Texas. Because the stresses on the flexed knee are so significant, Perry [16] noted that contractures beyond 20° greatly compromise ambulation.

Primate and Human Ancestors

Haines [5,p.293] in his classic study of comparative anatomy on the tetrapod knee states that the most primitive type of knee found in living animals today is within the crocodiles. Yet there is a "single joint cavity for the femur, tibia and fibula, and the cruciate and collateral ligaments, the menisci and the femoro-fibular disc are all well developed." No one seems to have informed crocodiles of their primitive knees and then disallow their success in "survival" against more "advanced" species.

Dye [2] reported on a supposed tetrapod ancestor, the extinct amphibian, Eryops (fossils alleged to be 360 million years old). He shows that this creature possessed a well developed bicondylar end of the femur with a differential radius of curvature, a relatively flat tibia and a fibular articulation with the femur. Illustration 9. It appears that "kneeness" has an extremely ancient origin (if the above date were correct), and when first encountered in the fossil record knees have a fully functional form. Dye also says that there appears to be no animal model for human knees but that with further research a commonality may be uncovered in some yet unstudied small ursine (bear) type species.

Jenkins [7] studied the cineradiographic analysis of the gait in Chimpanzees. Illustration 10. At foot strike the knee is flexed 35-40°; body weight never approaches or falls forward to the knee (which would aid extension), and there is always a varus (bow leg) alignment. The bicondylar angle in chimpanzee and gorilla is 1-2° (compared to 10° for man) placing the knee outside the mechanical plumb-line seen in bipedal ambulators.

It is not this author's focus to discuss evolutionary dates or the importance of alleged hominid ancestors. However, the fossil record is supportive of human or human-like knee fossils. Leakey [11] in Africa discovered modern appearing femora which he dated to be 2.6 million years old. He classified these specimens as Homo sapiens, and his photographic evidence shows a femur with a bicondylar angle of 7-8°. Illustration 11.

Mary Leakey [9] later discovered human-like footprints, and the evidence for bipedalism was moved back to 3.6 million years.

Weaver [23, p. 593] envisions bipedal hominids running efficiently 4 million years ago and states, "Our earliest, most distinguishing characteristics were not a large brain, language, or toolmaking, but the ability to habitually walk upright."

McHenry [14] used a multivariate analysis to study the femur in early human evolution. He found the most distinguishing features of Homo femora in order of importance to be the anteroposterior diameter of the lateral condyle, femoral length, and projection of the greater trochanter.

Lovejoy and Heiple [13] reported that Australopithecus showed the highest bicondylar angle (angles of 14-15°) and was significantly larger than the mean for modern human females. Rather than being intermediate between Homo sapiens and the chimpanzee, these values are greater angles than for any known primate. This observation has led some like Reeder [18] to believe that this 'hominid' was a better biped ambulator than modern man. Illustration 12.

The 'why' of bipedalism is still a major question. Many theories have been advanced, and Leakey [10, p.77] notes, "For reasons that still leave us groping in the dark, the pressures of natural selection invented upright walking in our hominid ancestors sometime between 15 million and about 3 million years ago". Lovejoy's [12] lament seems still stark, "Why did these new features arise? It is worth stressing once again that the changes did not arise as part of an inevitable trend towards modern man, evolution does not work in a purposeful or directed manner."

Discussion

When 'knees' are first observed in the fossil record they are fully formed and functional. From one basic design all tetrapods and bipeds employ a vast variety of functions.

As noted here, the human knee extant or fossil, demonstrates design features enabling striding orthograde gait. However, in humans today, the 'atavistic' character of a knee flexion contracture is poorly functional and perpetuates its own disorder. Unlike Boule's prejudiced positioning, (an imagined hunched-over and flexed knee posture of neanderthals), modern investigators have allowed the anatomy of Homo findings to testify to efficient biped ambulation. Illustration 13. Yet Wray [25] noted that today a living primate, the pygmy chimp, appears to be a natural biped. Could these fossil findings be from nothing more than another extinct relative of the pygmy chimp? Zihlman [26] has reported her original observation on the chimplike morphology in new reconstructions of Austrolopithecus (Lucy) skeleton.

Several explanations are available if humans have always been contemporary with life on earth. If so, the fossil record predictably should yield modern human knees in allegedly ancient fossil strata. Also, since 80% of all known life forms are now extinct, it is possible that there could have been mosaic animals with biped capabilities.

In evolutionary terms some quadruped, starting out on flexed knees, required a radical set of morphological changes to make the transition to a modern plantigrade biped. Yet the fossil evidence of this transition is totally lacking and from what we know, the quadruped flexed knee would be disadvantaged for bio-mechanical reasons.

Evolutionists are looking beyond 4 million years ago for an alleged hominid who theoretically was a better biped than ourselves. These imagined pre-biped creatures would need to show evidence of a progressional change in bicondylar angles and enlargement of the lateral condylar process of the femur. And not so easily seen but just as important, they would have had quadriceps adaptions and altered neurological reflexes. The burden to uncover this first biped awaits the turning of another evolutionary spade.

Creationists say 'great design-Greater Designer', but much field research needs to be done on these fossil knee remains. No one has ever seen an australopithecine in a gait lab. Therefore, the theory of their striding behavior is conjecture. Gish's [3,p.104-113] review of the work of Zuckerman and Oxnard shows that some of the evolutionary ideas concerning <u>Australopithecus</u> are incorrect. One wonders if crocodiles were extinct and only known from the fossil record, would the report concerning their knee function describe a creature that we know can successfully survive in the age of mammals?

From an orthopedic perspective, we have had several decades to 'design' a better knee. Thus, in their research on total knee replacement, the manufacturers' favorite claim for a new prosthesis has been 'anatomic'. The more similar an implant is to the natural (created) part, the better its survivability and function. The best research has been forced to respect the original design.

ACKNOWLEDGEMENTS

Questions for Future Study

(1)   What adaptive forces would have worked (if any) to change a quadruped varus limb into a biped valgus limb?

(2)   Could the adductor muscles play an important role in evolutionary terms for a more midline knee position? What osteological evidence has been investigated (i.e., the adductor tubercle on the femur, pelvic origins of the adductor muscles, etc)?

(3)   Would a study of the morphology of the pygmy chimp show similarities to human knees?

(4)   A review of the fossil intercondylar notch dimensions, which house the crucial ligaments, would be helpful. It is known from modern surgery that if this notch is not adequate or correctly spaced then damage can be brought to the cruciate ligaments, especially at full knee extension.

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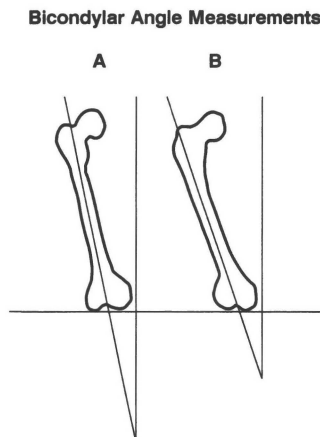
ILLUSTRATIONS

Bicondylar Angle Measurements

A   B

Illustration 1. *Redrawn from Lovejoy and Heiple [13], (A) showing the bicondylar angle in* **Homo sapiens** *and (B) showing the reconstruction for* **Australopithecus.** *The human femur is reduced in size for comparision. Note the greater angle for (B) (20° in his drawing and 15° for man with the actual normal value for humans at about 10o').*

View of Left Femoral Condyles

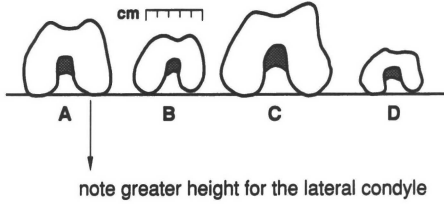
note greater height for the lateral condyle

Illustration 2. *Redrawn from Heiple and Lovejoy [6], ends of femurs. Note the greater anterior dimensions of the lateral condyle in humans to assist patellar tracking near full extension. (A)* <u>*Homo sapiens*</u>*, (B)* <u>*Australopithecus*</u>*, (C)* <u>*Homo sapiens Neanderthalensis*</u>*, and (D)* <u>*Chimpanzee.*</u>
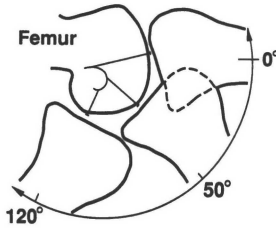
Instant Center of Rotation

Illustration 3. *Redrawn from Freeman [4, chapter 9], the center of rotation at any one position of flexion moves along an elliptical curve within the distal femur. Notice how this ellipse closely patterns the contour of the condylar surface.*

Articular Contact Between Femur and Tibia
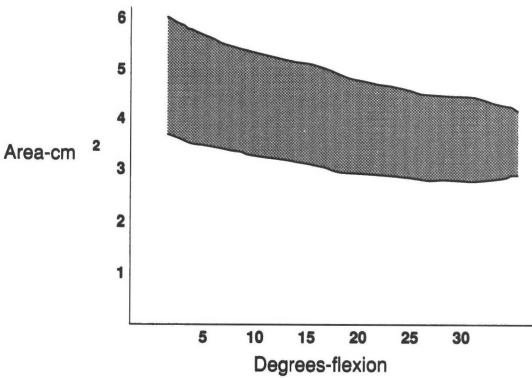
Illustration 4. *Redrawn form Kettlekamp [8], showing the greater contact area between tibia and femur in extension. The contact area is decreased by 1/2 at about 30° of flexion.*

Sulcus Angle for the Left Femur
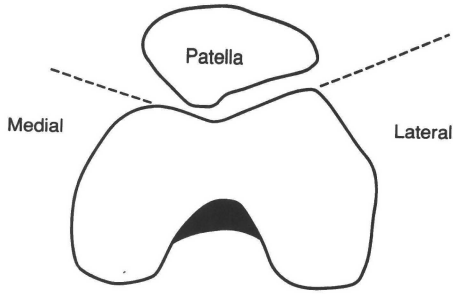
Illustration 5. *Redrawn from Weissman [24, p. 515], the sulcus angle helps determine the depth of the femoral fossa for patellar tracking. Shallow sulcus angles are related to patellar instabilities. Here the common normal angle is about 140°.*
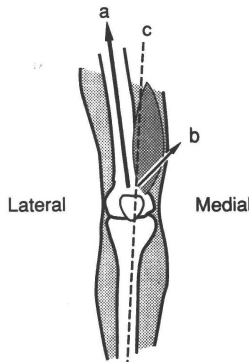
Vastus Medialis Obliquus

Illustration 6. *The vastus medialis obliquus (vmo), labeled (b), is developed in man to assist in terminal extension and to stabilize the patella. The major pull of the quadriceps (a) is altered by the vmo (b) to give the resultant (c) which centralizes patellar motion.*

Human Gait Cycle
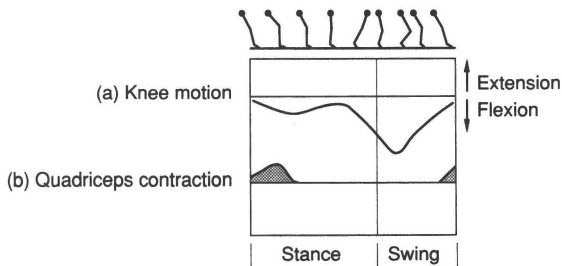
Illustration 7. *Redrawn from Pierro-Deseilligry [17], note on (a) the knee nearing extension at heel strike and in midstance. The major quadriceps action (b) occurs after heel strike to accept weight bearing and prevent knee collapse.*

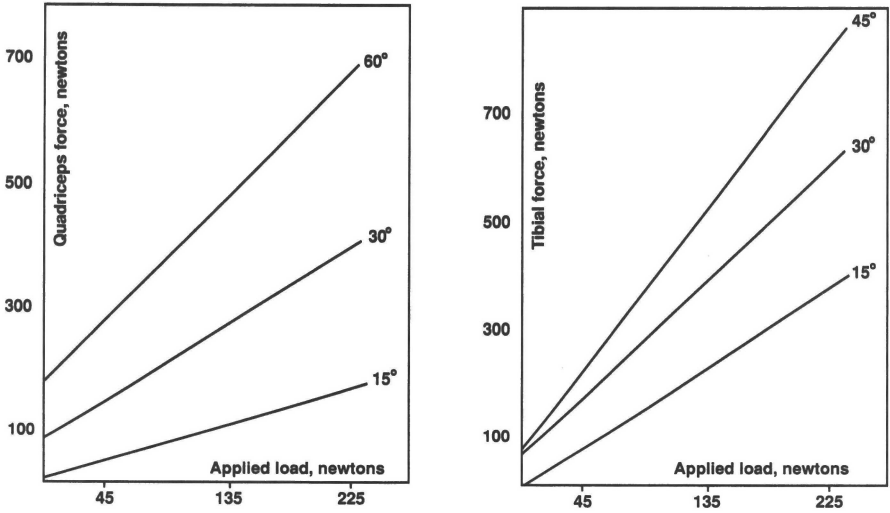## Quadriceps Contraction Force and Tibial Surface Loads

Illustration 8. *Redrawn from Perry, [16], observe the greater quadriceps force required to stabilize the knee at angles 30° or greater. Also note at these same angles the tibial surface loads double.*
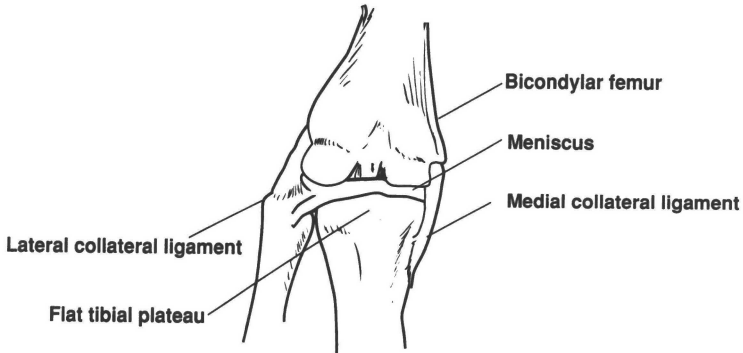
Eryops Right Knee Anterior View

Illustration 9. *Redrawn from Dye [2], __Eryops__ an alleged ancestor of all knees; yet note the classic design and form.*
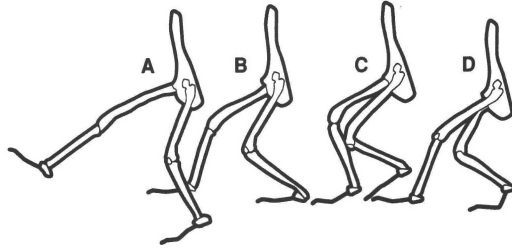
The Bipedal Gait of Chimpanzee

Illustration 10. *Redrawn fron Jenkins [7], the chimpanzee attempting bipedal ambulation with the knee in flexion at 35° at weight acceptance (B). Regard also the body weight never progresses anterior to the knee joint throughout the entire gait cycle. This condition places high stress if the quadriceps demanding sustained musclar action.*
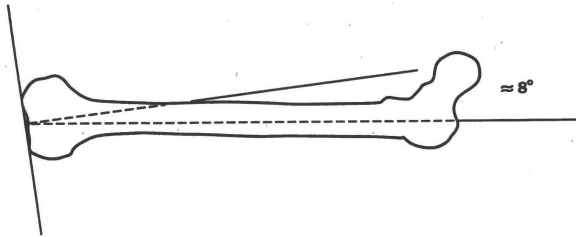
East African Femur

≈ 8°

Illustration 11. *Redrawn from Leakey [11], this modern appearing femur from East Africa shows a bicondylar angle of about 8°.*

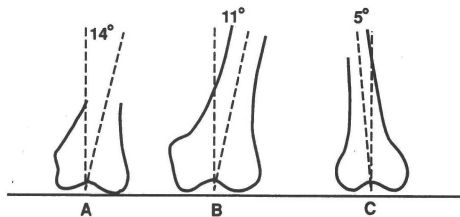## Bicondylar Angles in Primates

14°   11°   5°

A   B   C

Illustration 12. *Redrawn from Lovejoy [13], measurements of bicondylar angles in (A) Australopithecus, (B) Homo sapiens, and (C) Chimpanzee. The greater angles in Australopithecus are higher than for any known living or fossil primate; therefore the australopithecines fulfil no intermediate role between humans and 'alleged' ancestors.*

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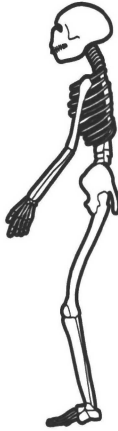### The Old Stance of Neanderthal

Illustration 13. *Boules reconstruction of neanderthal with prejudiced posturing (note the knee flexion) has since been "straightened" out. This picture was redrawn from Stringer [20, p. 25].*

Editor's Note:

Illustrations redwrawn from author's sketches by ICC artist James Hilston.