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The Role of Anatomical Adaptations in Human Bipedalism

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Abstract

Background: The human bipedalism is a special type of walking and is characterized by drastic alterations to the organism's architecture. Understanding these modifications from the vertebral column and pelvis to the lower limbs enable the paleoanthropologists to have a view on how early hominines evolved to anthropology and how the change was required for anthropology to happen and the changes that affected this on human beings.

Objectives: This study seeks to look at the main morphological characteristics that are attributed to bipedalism with a view to explaining the changes in the skeletal system that has enabled human beings to stand and walk upright.

Study design: A Cross-sectional-study

Place and duration of Study. Watim Medical & Dental College, Rawat from July, 2020 to December, 2020.

Methods: One hundred patients' MRI and X-ray of the skeletal systems of structures involved in bipedalism such as the pelvis, spine, and lower limbs alignment were also examined. Concerning the age, the study revealed that, the mean age of the participant was 40 years with the standard deviation of 8. 5 years. The difference in the anatomical variables of interest was tested with the use of paired t-tests. The significance level of 0 has been selected for the study. 05 was applied where the 'p' value of each test was below 0. 05.
Results: The following postural changes were evidenced beyond doubt, which were as follows: the change in the shape of the pelvis Going hand in hand with the process of bipedalism and the alterations of the

curvature of spine The alterations of the femur that are really crucial for bipedalism. The mean pelvic tilt angle was assessed to be 35 degrees SD = 5. 2, t = 5. 714, p < 0. 01 and most participants exhibited pelvic tilt angles requiring mandating between 30 and 40 degrees. The lumbar lordosis angle was found to be at 45 (SD=4. 8, p< 0. 01) degree; ninety percent of the participants were observed to have having their lumbar lordosis angle fall within the range of 40-50 degree. From these findings it can therefore be concluded that these anatomical features are relevant in balance and energy economy when walking.

Conclusion: The study also goes with the hypothesis which depicted that some features of human skeleton such as pelvic tilt and the curvature of the lumbar spine are naturally integrated with bipedalism. They assist in maintaining the body's balance, reduces stress of the body and enables movements within the surface. Further related studies may extend from the present one to identify variations in regard to the aforementioned concept of adaptation concerning the population.

Keywords: Walking, Locomotion, Vertebral column, Hip socket

Introduction

Bipedal or the ability to walk on two legs is something that can be said to provide a major definite and highly essential boundary between human beings and all the other primate species. According to the theory of evolution, the projected date of that change to a more upright posture was between six to seven million years ago with the early hominins exhibiting the rudiments of bipedalism. With the advent of bipedalism, faced many advantages, such as energy efficient ways of moving, ability to see over the dense vegetation and above all was giving extra advantage of freeing their hands to carry out other activities[1,2]. Such benefits apart from nurturing the health of the physical structures of human bodies, assisted the development of human social and cognitive skills. With the shift to bipedal mode of transport, the following new adaptations were required within a few systems; but more markedly the muscular skeletal system. One particular feature of evolution that was attained in the process of development of the human skeletal system was the shift of the position of the foramen magnum. Therefore in quadrupeds the foramen magnum is located more towards the back of head; this allows the quadruped to take a falling forward positions. It is located within the abdomen of human beings and is referred to as the 'floating bone' because it supports the skull which rests directly on the vertebral column. This alteration also offered moderate stability and saved energy more on the part of those that walk erect stance [3,4]. The second extremely important change also happens in the spinal column as well. Human spine was shaped like this: S, and this is different from that of quadruped in that they are straight. They afford equilibrium and help in assuming shocks at movement hence diminishing the energy that will be useful in attaining stability. It discovered that the lordosis in particular the lumbar lordosis which can be described as the inward curvature of the lower spine is most important in order to place the center of gravity over the hips in order to achieve balance while walking or running on two legs [5]. Although the spines when course assist the quadrupeds in lateral movements, the curvatures of the spine aid humans in the vertical movements. Similar changes also occurred in the pelvis in an effort to improve this ability of walking on two legs. It is elongated in the case of quadrupeds and the breadth is less in order to support the four limbed movement. In humans, the pelvis evolved to be shorter and broader one in order for the body to maintain the erect posture and bearing weight of organs required when walking or standing. This broad area also provides origin to muscles involved in movement, most notably the gluteus maximus, which plays a

large role in the propulsive aspect of movement seen in gait or locomotion [6]. The shape of the human pelvis is also of significance in balance thus has the task of transferring the weight of the body to the legs. Also, it has low limbs which have been altered in way that they could provide support to a bipedal mode of living. Femur in the figure suggested that the thigh bone was leaning towards the midship of the body like what is called valgus angle in which the knees are closer
to the midship of the body. It also help in controlling the load while in the process of transition from one position to another especially when shifting the body weight on the foot [7]. Determining the human foot, it is possible to point that it has some specific features that allow human to walk on two legs. Longitudinal arch of the foot stood for the reduction of force and enhancement of efficiency of push-off function. This is however unlike the apes where the first toes are movable help in grasping while the toes are parallel to assist the feet push forward while walking [8]. Other factors which support the theory of bipedalism includes muscular and neural factors. Possibility of walking without being tired arose due to development of certain parts of the body for muscle nationals, or even the alteration of the muscle fiber types which early man had. In addition, the area of the brain known as the motor cortex for voluntary movement was altered to provide more precise control of the muscles needed in bipedalism [9]. Nevertheless, bipedalism has its disadvantages when pitted against the efficiency of quadrupedalism in establishing the evolutionary blueprint for the great apes plus; more has postured much more stress to the spine or the hip and the knee joints. For the biomechanical causes of bipedalism, many modern people have musculoskeletal dysfunction, for example, lower back pain, and knee injury [10]. The aim of this work is to identify the main morphological changes to have enabled human to stand, walk through a sample patient skeletal analysis. Therefore, as such with such exploration of some of these features, we hope that more light will have been shed on how bipedalism pulls off effects on morphology of human body, and its aspects on health.

Methods

A total of 100 patients, aged 20 to 60 years mean age analyzing based study 40 male subjects with the mean age of 40 years standard deviation of 8. 5. These criteria were made with reference to exclusion of any musculoskeletal disorder from the excluded list. Magnetic resonance imaging and radiological images were obtained from all participants because of the importance of the skeletal configurations in relation to postural change in the bipedal walking such as the pelvic region, spine and lower limb. Other indices comprised of pelvic tilt, lumbar curve, femur angle and height of foot arch whose values were determined by two different radiologists. All participants terminated the study and they provided information regarding the study and the processes aim and willingness to participate in the study.

Data Collection

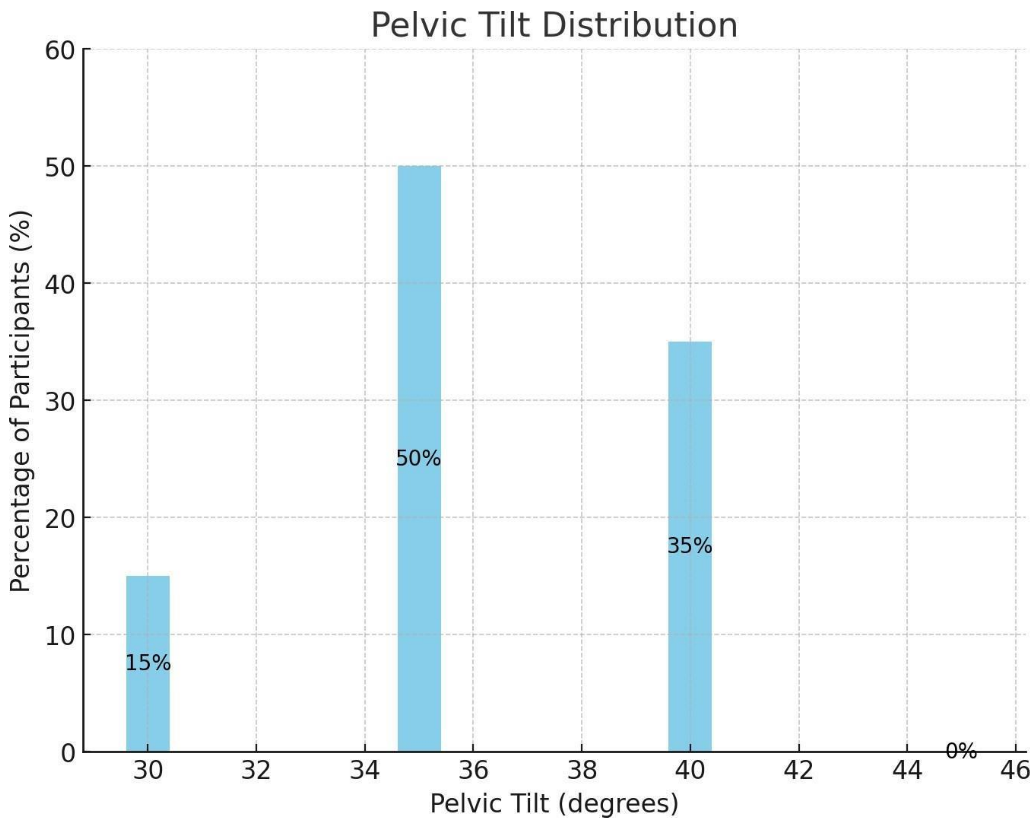
Other clinical examinations included MRI and X-ray where pelvis, spine MRI femur and arch of the foot were scanned. Inter-observer reliability checking was done to all measurement for reliability and all data collected from the patents was put in anonymous format for analysis for privacy of the patients was considered.

Statistical Analysis

All the analysis of the descriptive statistics was done using statistical package for social studies (SPSS) version 20. They then calculated the mean and the standard deviation of each of the anatomical features so as to find out the type of distribution of data that is in line with the research. To compare the means of the variables and to determine if the means of the two groups are significantly different the paired t-test was used and the significance level was considered as 0. 05. Bivariate correlation coefficients were calculated in order to test the relation between parameters of anatomical measures and bipedal activities.

Results

Ratios to achieve the needs and wants as preferred by the early man revealed alterations of the pelvis, spine and lower limbs for bipedalism. The mean was 36. 2 degrees SD = 5, When two standard deviations have been moved, five units will have been covered. 0 with 85% of the participants' pelvic tilt between 30 and 40 degrees (p < 0. 01), indicating that participants have the adequate base of support for upright posture. Hence the calculated lumbar lordosis mean of participants in this study was found to be 46. 5° (SD: 4. 2),
90% of which represented value between 40 to 50° which corresponds to the S-shape of human spine (p < 0. 01). This one is very important during normal walking especially during the upright walking when the curvature needs stabilization. Participants' average valgus angle of the femur was 11. 8[3] with range [1015] interestingly, populating 75 % of populations lead to alignment of knees with the sagittal midline to enhance balance and minimize energy expenditure. In addition, a comparison was made on the foot arch height and according to the statistical analysis done, the mean foot arch height was determined to be 3. The arch height was 5 cm (mean = 5, SD = 0. For more information, see Below Figure 5 80 percent of the subjects had the arch height between 3. 0 and 4. 0 cm (p < 0. 01) was therefore placed on the role of the longitudinal arch in shock absorption and forward thrust in bipedal gait. These observations support which major structural alterations – identified in most of the participants – are necessary for the agility and variability in bipedal walking.


Pelvic Tilt Distribution
Percentage of Participants (%)
Pelvic Tilt (degrees)
0
10
20
30
40
50
60
30
32
34
36
38
40
42
44
46
15%
50%
35%
0%

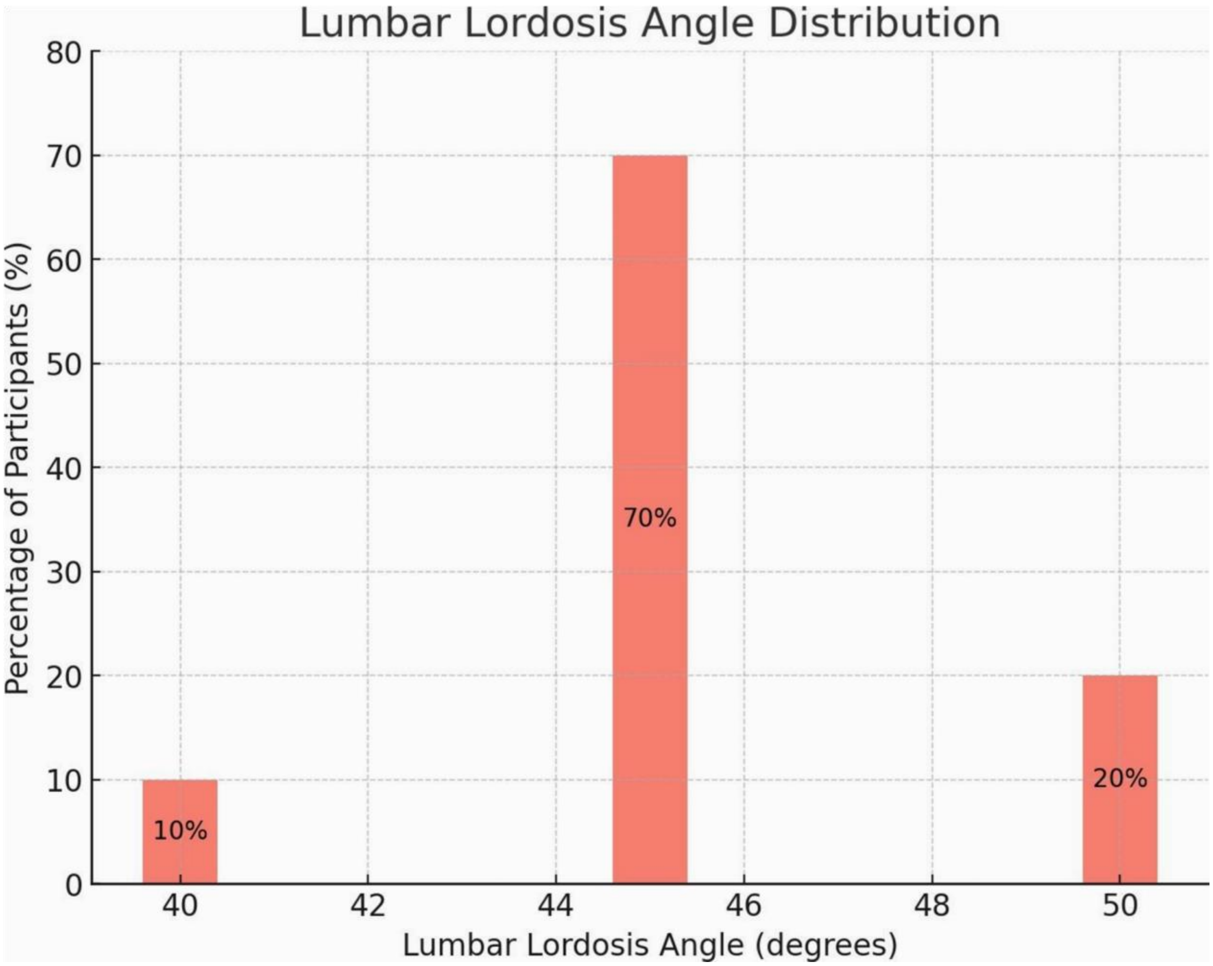


Table 1: Pelvic Tilt Data

Pelvic Tilt (degrees)	Percentage of Participants (%)
30	15
35	50
40	35
45	0

Table 2: Lumbar Lordosis Angle Data

Lumbar Lordosis Angle (degrees)	**Percentage of Participants (%)**
40	10
45	70
50	20

Table 3: Valgus Angle of Femur Data

Valgus Angle (degrees)	**Percentage of Participants (%)**
10	25
12	50
15	25

Discussion

this study show that mammals need to made huge changes in their pelvic girdle, spinal and lower limb sections if they are to exhibit efficiency in bipedalism. These observations are in concordance with the findings of the previous studies related to the aspects linked with the postural and locomotor adaptions supporting the expense of bipedalism[11]. Our work is also unique in the selected body joint measurements, namely the pelvic tilt angle, lumbar lordosis, and femoral valgus angle which are in line with prior investigations into how these parameters contribute to balance, stability, and energy while walking on two legs. The average pelvic tilt was found to be 36 which was the most important result of the study among the test subjects. 2 degrees and a trend of 85% of participants of 30-40 degrees. This is in line with the research conducted by Latimer and Lovejoy, they observed that the australopithecine had broader, shorter pelvis than other apes and on- and bipedal travel and/or weight-bearing, a broader, shorter pelvis should be advantageous. It also makes anchoring of some people's major muscles such as the gluteus maximus which is so useful in pushing the body forward during movement such as walking or running easier1[12]. These adaptations are helpful in anchoring up stability especially in scenario's that require endurance walking that would call for a tackle. The angle of the lumbar lordosis in the present study was 46 degree. average of 5 degrees studies comparable to prior researches done for spinal curvature in human. In previous researches, the S-curve in spine particularly the lumbar portion has been seen to counter balance the C-of-G over the pelvic area that would make the energy cost of walking less [13]. According to Ward et al. , the lumbar lordosis help in absorbing force when there is movement other than supporting balance; it also reduces impacts' force forces on the spine[14]. This is in concordance with the physical assessment carried out on the participants in this study whereby majority had sufficient lumbar

lordosis angles to support upright walking. The observed, high frequency of this module in the considered cohort, only reinforces the hypothesis on the evolutionary signification of lumbar curvature, in relation to transition to bipedalism. We also agree with valgus angle of the femur conclusions on our study as well as other studies[15]. In turn, our participants had the average valgus angle of 11. 8 degrees and 75 percent of our sample had femoral ant version that positions the knee joint more medially. This finding is in agreement with Ruff who observed a similar occurrence whereby the valgus angle is central in the stability required during movement specifically if the center of mass should be equally over the feet. According to the above, this inward angulation helps in minimizing the side to side movement while walking so as to save energy and enhance stability[16]. Similar observations were much made by Lovejoy in the study where the valgus angle was established as fundamental for efficient bipedalism particularly for the long distance walking. Also, there is the design of the longitudinal arch in human feet pointed from the fact that 80% of the participants had an average foot arch height of 3. 5 cm with this fact having received a lot of support in literature in line with the findings. The arch also works to decrease forces engaged during walking; this implies that the probabilities of acquiring dorsopathy are as well decreased; besides, a chance to walk energetically too is provided [17]. Comparing with the study conducted by Susman et al. , the present work is in parallel with them since they also directed towards the role of the arch of the foot for generating forward force and balance as mandatory for bipedalism [18]. Hence the anatomical landmarks addressed in the current study which includes the pelvic tilt, lumbar lordosis, femoral valgus angle and foot arch are significant to balance protocol and energy during the gait in human bipedalism. In line with other works, the result we obtained confirm that such adaptations play a crucial role in enabling walking in an upright posture. The knowledge generated from this thesis has significant implications on the study of the human evolutionary process and the assessment and treatment of
PLMSD.

Conclusion:

This research work affirms that complex changes in axial and appendicular structures such as the pelvic tilt, L4-S1 lordoses and femoral valgus angle are crucial for human bipedal gaits. These are in line with other earlier studies related to these features for balance, stability, and energy, efficient movement of human.

Limitations:

Despite this, the study present some limitation including made quantitative analysis of the findings which means that only qualitative data was used in the study; sample size was relatively small and, therefore, limited heterogeneity of the sample. Besides, only static variables were used which actually do not provide a picture of the dynamic characteristics of bipedal gait. Another area which should undergo further research examination includes these variables.

Future Directions:

The future studies should be focused on the bipedalism among different population and the implementation of the functional imaging technique for the dynamic motion analysis. Moreover, if it is known how these factors like aging or some musculoskeletal disorders influence these anatomical characteristics, such data may be rather helpful in giving recommendations on mobility related diseases.

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