Anthropological Perspectives on Low Back Pain in Homo Sapiens: Correlating Bipedal and Quadrupedal Locomotion

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Abstract

Background. Low back pain (LBP) is a common and significant problem in both clinical and public health settings. Although lower back pain (LBP) is common, a clear knowledge of its cause is still difficult to achieve

Methods. Literature searching was conducted using databases such as PubMed, Google Scholar, and Web of Science using Search terms included "low back pain", "bipedal locomotion”, “quadrupedal locomotion” , “anthropological perspective”. Systematic reviews of peer-reviewed articles, reports, and case studies were chosen.

Discussion. Bipedalism as a pivotal evolutionary development with profound impacts on human anatomy and biomechanics. While it conferred advantages for survival and adaptation, it also introduced challenges, particularly regarding spinal health. Insights from this review illuminate the evolutionary origins of locomotor patterns and inform approaches to addressing modern health issues, such as LBP, stemming from our unique upright posture.

Conclusion. Bipedalism, a key feature of human development, brought about substantial alterations in the spinal column and musculoskeletal system, allowing for upright walking and the liberation of the hands for tool use. Nevertheless, these adjustments also made people more susceptible to lower back pain (LBP) as a result of the distinct pressures exerted on the spine.

Keywords. low back pain, bipedal locomotion, quadrupedal locomotion

Introduction

Low back pain (LBP) etiology is believed to be influenced by several functional components of the lumbar spine, including lumbar curvature, force distribution, musculature, and erect posture. The lumbar forces are influenced by various factors such as external load, trunk center of mass, standing posture, and intra-abdominal pressure. These factors, along with the impact of abdominal and trunk muscles, contribute to the overall effect on lumbar forces[1]

Low back pain (LBP) is not only a substantial health concern, but also imposes a considerable socio-economic burden. The expenses associated with managing lower back pain, in addition to the decrease in productivity caused by employees being absent from work, have a significant economic effect. Research suggests that low back pain (LBP) is one of the primary contributors to disability on a global scale, significantly impacting the overall quality of life and leading to substantial healthcare costs. This highlights the necessity for improved diagnostic techniques and efficient treatment strategies to handle and alleviate LBP.[2]

The development of lower back pain (LBP) is caused by multiple factors, including both mechanical and biological components. Mechanical aspects encompass the positioning and mobility of the lumbar spine, the robustness and suppleness of muscles and ligaments, and the distribution of weight on vertebral discs and joints. Biological factors encompass inflammatory processes, deterioration of intervertebral discs, and hereditary predispositions. Gaining a thorough understanding of these characteristics is essential for formulating effective treatment and preventative measures. Biomechanical research has demonstrated that using incorrect lifting methods and maintaining static postures for extended periods will greatly heighten the likelihood of experiencing lower back pain.[3]

Moreover, lifestyle factors such as exercise, dietary choices, and stress levels significantly influence the occurrence and advancement of lower back pain. The sedentary lifestyles that are widespread in modern culture lead to the weakening of the core muscles that support the spine, hence increasing the likelihood of experiencing lower back pain (LBP). On the other hand, engaging in consistent physical activity and performing exercises that enhance the muscles in the back and abdomen can effectively prevent and relieve lower back pain. Psychological stress can worsen lower back pain (LBP), emphasizing the significance of a comprehensive approach that incorporates mental health care into the treatment plan.[4]

The development of imaging technology, such as MRI and CT scans, has improved our capacity to determine the root causes of lower back pain. These technologies offer comprehensive visualization of spinal components, allowing for more precise detection of problems such as herniated discs, spinal stenosis, and degenerative alterations. However, additional study is required to gain a comprehensive understanding of the intricate relationship between various factors that contribute to lower back pain (LBP) and to devise more efficient and personalized treatment methods.[5]

Methods

Literature searching was conducted using databases such as PubMed, Google Scholar, and Web of Science using Search terms included "low back pain", "bipedal locomotion", "quadrupedal locomotion" , "anthropological perspective". Systematic reviews of peer-reviewed articles, reports, and case studies were chosen.

Discussion

Evolution of Bipedalism

Bipedalism is a phenomenon that can be found in several mammalian species, with each species adopting it for certain reasons. The shift from walking on all fours to walking on two legs in early hominids is seen as a crucial adaptive characteristic of human evolution. There are other ideas that provide explanations for why early hominids developed a specialization in bipedalism, which is a lifestyle that is significantly different from their forebears who walked on all fours. One prevalent hypothesis posits that bipedalism enabled more effective resource collection. Nevertheless, it is important to exercise caution when making comparisons between species. Firstly, comparing the locomotion of different primates may provide only limited insights. Secondly, conclusions about modern analogues should be supported by additional evidence. Lastly, the behaviors of existing primates offer only a narrow glimpse into the variations among extinct species.[6]

The anatomical adaptations linked to bipedalism in hominids involve modifications in the pelvis, lower extremities, and spinal column. The pelvis saw a reduction in length and an increase in width, resulting in a sturdy foundation for the connection of robust gluteal muscles that are essential for bipedal locomotion. The femurs are inclined inward, aligning the knees precisely beneath the center of gravity, so enhancing balance when moving. In addition, the lumbar spine has evolved to have a curvature in the shape of a "S". This curve serves the purpose of absorbing stress and maintaining balance when humans are standing and moving on two feet.[7]

Explanations for the development of bipedalism frequently emphasize environmental and behavioral influences. A prevailing explanation posits that climate change in Africa resulted in the proliferation of savannas, causing a decline in forested regions and necessitating the need for efficient long-distance migration across open terrains. Bipedalism likely provided benefits in terms of energy efficiency, enabling early hominids to cover greater distances in search of sustenance and water. Another explanation suggests that the ability to walk on two legs, known as bipedalism, allowed for the hands to be used for tasks such as using tools, carrying goods, and interacting with the surroundings. This would have provided major advantages for survival.[8]

Evolution of Quadrupedalism

The analysis of the movement patterns of the Hominidae and their anatomical implications indicate that some physical characteristics of African apes have been utilized to support their strong evolutionary connection with Homo sapiens. Nevertheless, the significance of these qualities in determining the attributes of the Hominidae during the Miocene epochs has consistently been subject to doubt. Research has provided evidence that ancient human-like creatures engaged in quadrupedal locomotion and a form of movement known as "knuckle-walking," indicating that African apes may have regained their ability to walk on all fours. The study of the selective benefits of quadrupedal mobility in early representatives of Pan, as well as the mechanisms behind the development and evolution of the distinctive anatomy of African apes, is essential for gaining insights into evolutionary perspectives.[9]

Quadrupedalism, specifically knuckle-walking, is a unique manner of movement found in contemporary African apes, such as chimpanzees and gorillas. This locomotion entails ambulating on the metacarpophalangeal joints of the hands and the plantar surface of the feet, furnishing stability and reinforcement for their substantial anatomical structures. The anatomical modifications for knuckle-walking consist of sturdy carpal bones, enlarged phalanges, and strengthened ulnar joints, which aid in weight distribution and alleviate strain on the limbs.[10]

It is widely thought that the evolutionary process that led to knuckle-walking in African apes conferred numerous advantages in their particular ecological habitats. Knuckle-walking enables efficient locomotion on the ground and in trees, making it easier to reach a variety of food sources. Furthermore, this mode of movement facilitates the ability of these primates to sustain their substantial body sizes, allowing them to cover extensive distances in their quest for food while preserving their stability and equilibrium.[11]

Comparative analyses of fossil evidence indicate that early hominids, such as Australopithecus afarensis, exhibited a combination of characteristics related to walking on two legs and walking on all fours. These hominids exhibited characteristics that allowed them to walk erect and climb, suggesting a transitional stage in their movement abilities. Their skeletal structure exhibited characteristics like as a partially modified pelvis for walking on two legs and elongated, curved fingers well-suited for gripping branches, which indicated their adaptable capacities for moving about. The transitional forms exemplify the intricate evolutionary chronicle of movement in the Hominidae family.[12]

Studying how early hominids walked on all fours is crucial for understanding the specific factors and environmental conditions that influenced the development of walking on two legs. Researchers can reconstruct the ecological and behavioral settings that affected the genesis of bipedalism in our ancestors by comprehending the adaptive importance of various kinds of movement. This information also enhances our comprehension of the anatomical and functional adjustments that support contemporary human movement.[13]

Anatomy of the Bipedal Spine

The spinal column in humans has undergone major evolutionary changes from its quadrupedal ancestors. The mammalian trunk consists of thoracic, lumbar, and sacral segments, each having unique anatomy. The thoracic segment has a restricted number of segments, but the lumbar section is capable of autonomous movement because it lacks ribs. The ilio-lumbar ligament strengthens and partially connects the final lumbar and three subsequent sacral segments. The number of lumbar vertebrae in quadrupeds can vary significantly, even among species that are closely related. This variation is frequently regarded as a distinguishing feature of aberrant conditions in mammals and may impact the overall development of body regions in vertebrates.[14]

The human spine is specifically designed for walking on two feet. The spine's S-shaped curvature, consisting of cervical, thoracic, and lumbar curves, aids in the dispersion of mechanical forces during upright locomotion such as walking and running. The lumbar curvature, also known as lordosis, is highly prominent and functions to align the center of mass directly above the hips, so assisting in maintaining balance and minimizing the energy expenditure during movement. Furthermore, the vertebrae in the lumbar area of humans are larger and stronger in comparison to those of four-legged animals, which indicates the greater weight-bearing requirements of standing upright.[15]

Intervertebral discs in humans are specifically designed to mitigate the impact of trauma and enhance the suppleness of the spine. The discs consist of a resilient outer layer called the annulus fibrosus and a gel-like center known as the nucleus pulposus, enabling them to endure compressive forces. Nevertheless, the erect stance and walking on two legs also make people more susceptible to particular spinal problems, such as herniated discs and degenerative disc degeneration. Bipedalism entails some trade-offs in evolution, such as an elevated susceptibility to spinal diseases.[16]

The musculature that supports the spine for walking on two legs has also developed in order to meet the requirements of upright movement. The erector spinae muscles, located along the whole length of the spine, play a vital role in maintaining proper posture and enabling movement. The abdominal muscles enhance the functionality of these muscles by offering stability and assistance to the lower back. The interaction among these muscle groups is crucial for effective bipedal locomotion and the well-being of the spine.[17]

Anatomy of the Quadrupedal Spine

The lumbar regions of the vertebral columns of living quadrupeds exhibit variation in the diversity of individual segments. Accessory processes strengthen specific segments in certain mammals. Quadrupeds with flexible spines typically exhibit a gradual change in the angle of the joint surfaces across different segments. Some four-legged animals have an additional muscular segment that strengthens their spine. This segment develops from a part of the psoas or iliacus muscle. Identifying these comparable characteristics can assist in the future analysis of ancient hominoids or human progenitors.[11]

Quadrupedal animals generally have a straighter spine in contrast to the curved spine of bipedal humans. This alignment facilitates the effective distribution of weight over all four limbs, hence minimizing the burden on any individual segment of the spine. In quadrupeds, the thoracic and lumbar areas are adapted to maintain a horizontal body posture. The vertebrae in these regions are very similar in size and shape, unlike the unique lumbar vertebrae found in humans.[18]

The structure and function of intervertebral discs in quadrupeds differ from those in humans. These discs are often flatter and less susceptible to herniation because the mechanical loads are spread more uniformly. Moreover, the existence of supplementary muscles, such as the multifidus and the longissimus dorsi, enhances the stability and reinforcement of the spine when in motion. Quadrupeds have developed these adaptations to preserve their flexibility and agility while minimizing the chances of spinal injury.[19]

The development of the four-legged spinal structure has been shaped by the requirement for efficient and adaptable movement. Quadrupeds frequently partake in a range of locomotive actions, such as walking, running, climbing, and digging. The animals' ability to engage in a wide range of locomotor activities is facilitated by the flexibility of their spine and the muscular tissues that provide support. For instance, the cheetah's elongated and flexible spine enables it to attain remarkable speeds, while the bear's sturdy and stable spine provides the necessary support for its impressive burrowing and climbing capabilities.[20]

Biomechanics of Bipedal Locomotion

The ongoing interaction between the foot's sole and the ground while walking is intricate, encompassing several tasks throughout the stance phase. Humans benefit greatly from the dexterity of their hands, which allows them to manipulate objects in a highly versatile manner. Bipedal locomotion encompasses the kinetic and kinematic elements of movement in the lower and upper limbs. In a symmetrical gait pattern, the left foot's stepping movement aligns with the right hand's movement, and vice versa. This mechanical link refers to a rhythmic movement that is essential for maintaining stability, especially when support is briefly weakened.[21]

Bipedal locomotion requires the synchronized execution of a series of actions that include many joints and muscle groups. The gait cycle comprises two primary phases: the stance phase, during which the foot is in contact with the ground, and the swing phase, during which the foot is raised and propelled forward. During the stance phase, the weight of the body is shifted from the heel to the toes, which generates forward motion. During the swing phase, it is necessary to exert accurate control in order to readjust the position of the foot for the subsequent step, all while ensuring balance is maintained.[22]

Bipedal walking biomechanics also entail substantial rotating motions. The pelvis undergoes rotation along the vertical axis, hence contributing to the elongation of the stride and enhancement of walking efficiency. The rotation is offset by opposing motions of the thorax and upper limbs, which enhance overall stability and minimize energy use. Ensuring the synchronization of these rotating movements is crucial for achieving seamless and effective bipedal locomotion.[23]

Running presents further biomechanical complexities and adjustments. Running exerts significantly greater impact forces compared to walking, which requires a stronger capacity for shock absorption and energy storage. The Achilles tendon and plantar fascia have vital functions in the storage and release of elastic energy, hence improving running efficiency. Precise coordination of muscle contractions and joint movements is necessary to effectively handle the amplified stresses and ensure stability during high-speed locomotion.[24]

Biomechanics of Quadrupedal Locomotion

Humans occasionally exhibit quadrupedal movement, such as when changing between lying and standing positions or when transporting goods. Animal studies indicate that quadrupedal motions are deeply rooted in fundamental brain control and structure, owing to our primate ancestry. Quadrupedal movement imposes distinct biomechanical strains on the lumbar spine. Quadrupeds generally have limbs that are more parallel to each other, along with a horizontal spine. This arrangement helps to minimize twisting forces and decreases the requirement for massive muscles to provide support. When humans engage in quadrupedal mobility, the same biomechanical and developmental concepts are relevant.[25]

Quadrupedal locomotion employs distinct biomechanical principles in contrast to bipedalism. Quadrupeds exhibit several movement patterns, known as gaits, which include walking, trotting, and galloping. Every stride possesses distinct kinematic and kinetic attributes. Quadrupeds exhibit a diagonal limb coordination during walking, meaning that their opposite limbs move simultaneously. Trotting is characterized by the coordinated movement of diagonal pairs of limbs, which allows for a harmonious combination of speed and stability. Galloping, the swiftest pace, is distinguished by the simultaneous movement of limbs and necessitates substantial muscular strength and coordination.[26]

Quadrupeds have spinal mechanics that are specifically suited to their way of moving. The presence of a horizontal spine reduces the impact of gravitational forces on individual segments of the spine. During locomotion, the spine experiences flexion and extension, which is particularly noticeable during fast gaits such as galloping. The animal's agility and speed are enhanced by the increased range of motion provided by this flexibility. The musculoskeletal and ligamentous components of the spine offer the essential support required to endure these dynamic stresses.[20]

Furthermore, the study of how animals move on all fours emphasizes the significance of coordinating their limbs and conserving energy. The coordination of limb movements is optimized to achieve maximum efficiency and reduce energy use. The presence of elastic storage in tendons and muscles, as observed in the legs of kangaroos and the spines of cheetahs, is crucial for improving locomotor efficiency. Quadrupeds have developed these adaptations to efficiently travel vast distances, evade predators, and collect prey while using as little energy as possible.[27]

Conclusion

This review investigates the anthropological viewpoints on low back pain (LBP) by analyzing the evolutionary shift from walking on all fours to walking upright on two legs and its effects on the structure and mechanics of the human body. Bipedalism, a key feature of human development, brought about substantial alterations in the spinal column and musculoskeletal system, allowing for upright walking and the liberation of the hands for tool use. Nevertheless, these adjustments also made people more susceptible to lower back pain (LBP) as a result of the distinct pressures exerted on the spine. A comparative comparison of bipedal and quadrupedal movement demonstrates that quadrupeds exhibit a more uniform distribution of weight throughout their limbs, whereas bipedal humans have a greater load on the lumbar area, resulting in an increased susceptibility to spinal diseases. By comprehending the evolutionary roots and mechanical requirements of walking on two legs, we may obtain useful knowledge about the causes of lower back pain (LBP) and devise more efficient methods for preventing and treating it. Ultimately, our goal is to reduce the impact of LBP on individuals and society.

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