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Review Article

Backache as Evolutionary Compromise to Bipedalism

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Abstract

Background: Adaptation to bipedalism provided dexterity, clear sight, perspicacity, and speech and locomotion capacity to our hominid ancestors. Backache is the price we pay in exchange to the advantages we gained by adapting bipedalism.

Objective: To describe the evolutionary causes of backache and, to revise and compare the proximate and ultimate causes of spinal pathologies.

Method: Following a comprehensive screening of the published manuscripts relating the subjects of evolution or backache, the articles which were considered to be significant by the author were chosen and analyzed.

Results & discussion: In exchange to this novel feature which is characteristic only to human, "heavy" costs were to be paid as evolutionary compromises: the load of our growing brain weighing on our bizarrely-shaped backbone which was traded-off in exchange to bipedalism, causing backaches, disc hernias and spinal injuries, in addition to dystocia and lower extremity conditions which are exacerbated by our over nano-techno-sedentary life style.

Conclusion: To overcome these so-called civilization disorders, their evolutionary origins should be kept in mind while pharmaceuticals and surgical interventions are being administered.

Keywords: Bipedalism; Compromise; Backache; Osteoporosis; Spinal injuries

Introduction

Little time passed since our ancestors became bipedal and we still have not adapted to this evolutionary novelty. We ache from head to toe and face numerous health problems. Our strangely shaped backbone also plays its part as being the connection structure of our aching head [1] and troubled feet [2]; there exists almost no one who has not suffered backache [3]. Moreover, the sedentary life style we adapt [4] prolongs our life span [5] and have rendered us vulnerable to a series of evolutionary mismatches [6]; osteoporosis being one of them [7] and our bones, primarily our vertebra, become inclined to fractures especially during the second half of our lives [8]. This article will examine these main pathologies which effect the human backbone from an evolutionary perspective. Assimilation of this evolutionary perspective by the people who suffer of backache and the health professionals who treat them, can be helpful in coping with these conditions.

Backache is the price we pay for generations in exchange to the nutritional and reproductive advantages we gained by adapting bipedalism. Biped gait have brought along these disadvantages which emerged by prolonged human lifespan. All evolutionary adaptations are the results of trade-offs between the selective advantages and disadvantages; thus, the compromise of bipedalism is fragile bones [9]. Evolution cannot destroy defective structures to reconstruct existing organisms that natural selection can only function on. In other words, most of the specifications of our body are indeed results of temporary and improvised solutions. These imperfect specifications are usually enough to operate but we can only recognise the compromises in human structure when problems begin to emerge [10]. Evolutionary fitness is how well a species is able to reproduce in its environment [11].

Proximate causes include hereditary, developmental, structural, cognitive, psychological, and physiological aspects of a health condition. Ultimate causes of a disease include its evolutionary origins and the selective processes that have shaped its past and current functions [12]. A lumbar disc prolapsus causes pain, paraesthesia and motor dysfunction by damaging the nerves which innerve the legs. These problems intensify with the development of osteoarthritis and osteoporosis [13]. According to the evolutionary/ultimate explanation, backache is the redemption of bipedalism. Transference from quadripedalism to erect posture has occurred rather late in the evolutionary history of primates and the fitness redemption acquired thanks to

this transference constitutes a load which weighs on the intervertebral discs and the sacroiliac joint [14]. This extra load imposed on our vertebra by our upright posture, turns it into a factor which causes backache. The advantage gained by walking upright seems to have created the backache specific to humans. Backache effects our ape cousins which show knuckling gait remarkably less than humans, because they are not exposed to the extra load imposed by the erect gait [15].

Evolution does not select for perfection and all the important evolutionary adaptations represent the compromises and trade-offs between selective advantages and disadvantages. Humans are unique mammals with their strange upright gait with longer hind legs. In short, what lies under most of the troubles that effect human musculoskeletal health is our locomotion structure [16]. If we live long enough we all suffer from backache which is a result of bipedalism. Intervertebral disc hernia, fractures of vertebra, spondylolysis, scoliosis and kyphosis are observed only amongst humans; including our ape ancestors, we are the only species amongst mammals who suffer from these problems [17]. Bipedalism has contributed to energy prolificacy however the long-distance walking and running ability of the humans has brought along a compromise: bones that can easily be broken [18].

Ancestral Posture

Hominin lineage should have transferred to bipedalism either from the knuckling gait or quadrumanous climbing [19]. Either way, the expectations from the capacity limits of the vertebra should also change. Selection should have operated in a manner that develops the ability of the vertebra to cope with such new expectations. The structure of the human vertebra is similar to the vertebra of our hominoid ancestors who were not completely adapted to bipedalism; therefore, the pathologic human vertebra is atavistic; shows similarities with the ape vertebra [20]. The ancestral vertebra structure which causes this spinal pathology indicates that bipedalism have evolved rapidly amongst hominines, therefore adversely affect human health [21].

When the humans rose, they took on a strong vertebra which was evolved to climb and move between the trees [22]. This vertebra had to curve inwards, shaping our dorsal concavity, in order to balance our body without blocking the birth canal; this is why our vertebra has a "S" shape [23]. This concavity and the weight of the overlapping head is the cause of the pressure which leads to backaches [18]. Another problem group seen only amongst elderly humans is osteoporosis and there is a high probability that it also is connected to our bipedalism [7]. Bipedalism of the humans represent an evolutionary transition. Upright gait has brought along a series of unpleasant disorders in exchange of the advantages it provided by liberating the arms from participating to locomotion. The load which divided into four in quadruped animals, weighs only on legs in the human gait. We have taken over the musculoskeletal system of the quadruped animals as it was but have also begun implementing a new and quite different loading regime on this system [22]. However, the problems related to upright gait began to emerge with the elder ages we are able to reach, without effecting our reproductive fitness [24].

Bipedalism

Bipedalism is the central characteristic that separates the first hominids from the apes. Why the upright gait has evolved amongst hominids is one of the most crucial questions relative to human evolution. The argument that defines bipedal upright gait as the central characteristic of the hominid lineage is commonly accepted. However, attempts of bipedalism are observed amongst almost all vertebrates except for fish. Partial bipedalism, interchanges between biped and quadruped locomotion is common amongst most of the primates, bears being an example. Amongst frogs, locomotion is almost completely left to the hind legs, we know reptiles which run on their hind legs, jerboa, birds and kangaroos use their hind legs only to mobilise on land, numerous large and small species like the prairie dogs and dinosaurs take on the bipedal upright gait for different reasons like pry about or locomotion [25]. Liberation of the front legs from locomotion seems to provide a selective advantage for these animals [26]. The difference between these listed examples and the humans can be seen as a difference of degree; however, it is the humans only who benefited with such efficiency from the bipedal locomotion advantage. The bipedal gait is the landmark of our lineage [27].

Humans are engineered freaks with a compensating bipedal locomotion advantage: this advantage enables rapid position changes in all directions and allows instant acceleration or deceleration when needed; it provides advantage in watching of the surroundings with a clear view and most importantly, it minimizes energy loss in the locomotion. These specifications that compensate postural instability might have provided an important advantage of selection and survival [27].

Backache

At least half of the people have a backache and/or intervertebral disc hernia history. Backache effects people from all ages. With the third decade of life, the passive structures of the vertebra begin to show degenerative changes [28]. As our life styles become more sedentary, the progressive muscle degeneration caused by the changes in the distribution of the weight of the body, conflicts with control systems and predictable weight limits, thus leads to changes in movement control strategies and causes backache. Obesity which also emerges in this stage, also contributes to the problem with excessive weight load on intervertebral discs [29].

Human vertebra is composed of numerous joints and muscles. Despite the fact that we have transferred to bipedalism, there has been very little evolutionary changes like the shortening of only the lumbar vertebra; enlargement of the pelvis; thinning of the lumbar extensor muscles and emergence of lumbar lordosis [30]. This complex structure is unstable; the thoraco-lumbar vertebra deprived of muscles bends under pressure. Under this circumstance, the protective reflexes which provide the control of articulation of the vertebral column get involved in a harmful way. Motor adaptations which kick off during the acute pain period of a spinal injury can become permanent once the pain is overcome and play a central role in the relapse of the symptoms. In other words, the previous backache history is the best predictor of the relapse [31].

Osteoporosis

Osteoporosis is a systemic skeletal disorder which is characterized by loss of total bone mass and degeneration of the micro structure; this diminishes the mechanical endurance of the bones and even the low-energy-traumas can cause fractures [32]. With aging, we develop osteopenia and osteoporosis; this leads to high risk of fractures in the neck of femur and the ver-

tebra. Mortality related to femur neck fracture is a significant problem especially in societies with elderly populations [7].

Modern people do not exhibit physical activities as much as the apes in the nature and the first hominids, and we might conclude that the loss of bone density and strength is caused by sedentary life style. Modern people might be less active compared to the pre-industrial revolution people, however the medieval skeletons which are expected to be more active, also show osteopenia [33]. The nutrition history of the humans also plays a crucial role in the development of osteoporosis; even amongst different species of apes, nutrition habits vary. We assume that the apes living in the wilderness don't have the opportunity to feed better than the modern people but an agriculture-based diet has a role in the decrease of the human bone mass [34].

The ultimate cause of osteoporosis does not lie in our bones but in our history. As mentioned above, the crucial division between the lineage which led to humans and the one which led to our closest genetic neighbour Pan troglodytes took place 5-8 million years ago [35]. The human species rose in Africa; so, they should have had pigmented skin like todays Africans in order to adapt to high ultraviolet (UV) lights in low latitudes. Our migration from Africa to North, have exposed the ancestors of the Europeans to a selective pressure in favour of having light-coloured skin [36]. People who do not produce enough melanin in their hair follicles, namely those whose hair turn grey in earlier ages and their first-degree relatives, show a lower bone mineral density [37].

Environment triggers evolution; there is an interaction between the genome of a species and the environment it lives from one generation to another [38]. So, which environmental impact causes the weakening of our bones? Western sedentary life style is the proximate cause of most of the common diseases [39]. We are no longer as active as our Stone Age ancestors; even our grandparents lead a more active life hundred years ago. Decrease in the size, density and strength of the bones were not observed during hunter-gatherer period. Agricultural revolution is the beginning of the changes in the mechanical forces which shapes the today's human skeleton. Skeletons of ancient people do carry signs of osteoporosis, however osteoporotic fractures they exhibit are not wrist or proximal femur fractures but as vertebral compression fractures [13].

Elongation of the expected life span of humans, resulted in the expansion of the elderly layer of human populations, thus the number of people who suffer osteoporosis due to age also increased together with the risk of fractures. Humans live longer than any other primate. In modern societies, the primary determinant of osteoporosis maybe related to the evolution of human longevity [40]. Women in post- menopause are effected most from osteoporosis. These women can no longer contribute to the gene pool but do participate in the continuation of their genes, so the longevity genotype keeps on being selected. Hunter-gatherer mothers used to be active in providing food, thus protected their bone mass, this contradicts with today's old women's life style [41]. These demographic biases have turned the once positive bipedal adaptation into a significant series of pathologies for modern elderly people. Bone loss is the result of decrease in mobility, which is a bi-product of bipedal life style. Osteoporosis emerges after reproductive period so it is not possible to define it as a protective role of natural selection. Natural selection cannot have played a dominant role in optimising the bone structure since the beginning of Homo sapiens [42]. Not only the strong, but also weak children reach maturity and live long enough to have their own children. It means that selection of strong bones does not constitute an obvious advantage. Natural selection operates on genes according to the benefits they provide during reproductive period [43].

Spinal Injuries

Factors that contribute to the development of osteoporosis vary significantly from one individual to another, and the risk of developing a vertebral fracture stem from adaptation to bipedalism [44]. Spontaneous vertebra fractures are the most common osteoporosis-related fractures [45]. Upright posture gradually causes dangerous falls with age due to the unsteady movements and balance [46]. Half of the spinal injuries are observed on cervical vertebras; however, some risk factors render the thoracic vertebra more vulnerable to injuries: vascular sustention in the thoracic portion is unstable and arteries are narrower; whereas lumbar portion's vascularity is more favourable [47].

Humans exhibit much more degenerative and traumatic spinal pathologies than any other primate [48]. It is certain that humans have become more susceptible to osteoporosis and related fractures because of evolutionary adaptations. Even though causes of bone loss related to aging like menopause are observed only in humans, bone loss due to longevity is also observed amongst apes living in the wilderness [49]. However spontaneous vertebral fractures are not reported amongst apes living either under captivity or in wild, even if they suffer from severe osteoporosis. But the young mature human vertebra is also fragile than the vertebra of a young mature ape. Bone morphology and strength of young mature human and apes show that spinal fractures have developed as a result of evolutionary adaptations [8]. Even before the bone loss related to age begins, the mechanical and structural differences between humans and apes, might explain why humans are the only species who suffer vertebral fractures in elderly ages: a price paid in exchange of erecting gait [8].

Conclusion

Adaptation to bipedalism in the human lineage required a reorganisation in the quadrupedal ancestral musculoskeletal system. Bipedalism provided certain benefits for fitness however this reorganisation which led to erect posture and long steps also brought along certain compromises. Like many other human disorders related to age, the weakening of the vertebra due to osteoporosis has not been exposed to selective pressure because it had little effect on the reproduction of ancient hominins; backache and especially osteoporotic spinal fractures emerge long after reproductive ages. The life span of modern humans has prolonged, however bone loss due to aging makes the human vertebra which is porous per se as a compromise to bipedalism, vulnerable to pain and fractures [50].

Recommendations

Active life style should be understood as regular and intense exercise and it suggests stronger bones. However, adapting an active life style after the age of 40 might be too late [51]. Even so, instead of pharmacologic preparations, we may adapt better protective behaviours in order to strengthen our bones and decrease the risk of fractures, like consuming vitamin D

and calcium, adopting regular physical exercise and quitting tobacco and alcohol [52]. Even simple stretching exercises, if repeated regular enough, are effective on increasing bone endurance. The heavy body building exercises which are applied unregularly, are not as effective as simple but regular physical stretching activities like standing up [53]. Exercise is the most effective and cheap way of preventing fractures, at least for the youngster. Exercise that includes all the possible movements is the most effective way to adjust the skeleton against adversary factors and protecting bones [54].

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