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Stress Urinary Incontinence in the Human Female

Gravity and Ecomorphologic Influences on Bladder and Urethral Function of the Human Female

C. Paul Hodgkinson, M.D.*

This study was undertaken to determine if the biped state of the human female constituted a stress force in urethrovesical physiological function. To arrive at realistic conclusions, the ecomorphologic changes incidental to the conquest of gravity by the vertebrates have been reviewed. Accepting the evolutionary precepts as expressed by Hobart Smith that "if all parts of the evolutionary chain were known, it would be impossible to draw a logical distinction between man and nonman, Romer stated "Bone for bone, muscle for muscle, organ for organ, almost every feature of the ape is repeated in the human body. The differences are almost entirely differences in proportions and relations of parts . . . ." Assumption of erect posture by man, as compared to the quadruped, sharply altered urethrovesical relationship. The relative position in the abdominal cavity of the bladder and urethra was changed from a lateral to an inferior position, resulting in an increase in intravesical pressure because the long diameter of the abdominal cavity was oriented vertically. More specifically, the relative position of the urethrovesical function was changed from a lateral to an inferior position when the pressure was the greatest. There is little doubt that this change has played a role in the development of stress urinary incontinence, and there is some evidence to suggest that deficient urethrovesical function to increased gravimetric stress may represent an example of deficient evolutionary adaptation.

Richard Muellner stated that man's ability to void at will was a unique phenomenon of the animal world; that it was as unique as his erect posture, the grasp of his hand, and his remarkable brain.1

Stress urinary incontinence in the human female, from the time it was first identified as a distinct entity, was recognized as being a complication of the erect position. Many favored the names "orthostatic incontinence" or "postural incontinence" for stress urinary incontinence. Although students of human physiology have recognized that the forces of gravitational stress were vastly altered by man's assumption of the erect posture, little emphasis...
Hodgkinson has been placed upon its importance in evaluation of human urinary control.

I will review the general aspect of gravity as an environmental stress in the biologic development of vertebrates, and, specifically, how and if it is an important factor in the human female's urinary control. An effort will be made to correlate morphology and function, the dynamic aspects of which have been embodied and combined in the recent biologic term: ecomorphology.

To begin, let us consider some rhetorical questions: 1) Is gravity a biologic stress? 2) If it is a biologic stress, how much does it affect the bladder and urethra of the human female? 3) Is there evidence that the bladder and urethra have adapted to the biped environment and the increased stress of gravity? 4) If there is evidence of adaptation, how has it been accomplished?

Is Gravity a Biologic Stress?

For evidence that gravity is a biologic stress, it is best to study retrospectively the evolution of the vertebrates.

Man has evolved through evolutionary processes common to all other animals.2 Gravity as a powerful evolutionary stress was recognized by Morton in his monumental work on the “Evolution of Man’s Erect Posture.”3

If vertebrate evolution is reviewed, eight distinct eras of gravity can be recognized. The series begins and ends with weightlessness: with amphioxis and the astronauts. It can be epitomized as follows:

I) water; II) water-land; III) land-water; IV) land-quadruped; V) land-semierect; VI) land-erect—bibrachial; VII) land-erect—bipedal; and for the future, VIII) weightless space.

Sea water has been regarded as the nursery of organic life. Because the specific gravity of the sea water and the animal protoplasm of the first era were essentially equal, it is reasonable to state that organic life began in a state of weightlessness. Gravity as an evolutionary stress was initially neutralized by the water environment.

Five skeletal parameters may be compared for evidence of gravitational stress: skull, vertebral column, free ends of bones, pelvis, and linear skeletal orientation.

Gravity Group I—Water—the Fish

The long axis of the skeleton of the fish was, and still is, disposed horizontally. The skull, oriented in the direction of the long axis of the vertebral column, ends in a snout. The eyes and the fish show little or no evidence of the effect of gravity, beyond the backward slant of the vertebral appendages, due to water pressure from forward motion as the fish always heads “nose on” into the current of flow.
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**Gravity Group II—Water-land, The Amphibians**

The greatest adventure for the vertebrates was their conquest of land. Not only did they learn to survive by breathing air, but they learned the advantages of leg transportation. Romer conjectured that the amphibian developed legs by accident. The Devonian period, when the amphibians first appeared, was a time of seasonable droughts. Legs helped the organism crawl from one pot-hole to another where fish, dying from lack of water, served as an abundant food supply.

Comparison of the skeletons of the early amphibians with the fish has revealed little difference except in the pelvic girdle bones: ilium, pubis, and ischium. Usually some parts of the pelvic girdle were not ossified. The legs were feeble and extended laterally from the acetabula. At first the legs served as supports to twisting body locomotion, without raising the body above the ground. The unattached ends of long bones gravitated vertically downwards.

**Group III—Land-water, The Reptiles**

The saga of the dinosaurs is one of the most interesting evolutionary tales of paleontology, and is most exciting in the study of the biologic effects of gravity.

Two groups of dinosaurs—one a permanent quadruped, the other a temporary biped—ruled over the earth for over 100 million years. Reptiles have a peculiar growth habit in that they never cease growing. At the time of sexual maturity their bone growth slows but never ceases. Therefore, it is impossible to state the adult size of any reptile. Some dinosaurs were carnivorous and some were herbivorous. The largest flesh-eating dinosaur, Tyrannosaurus,—the “tyrant reptile”—was a 19-foot-high biped. The plant-eaters were even larger than the carnivora; estimated at weighing 25 to 35 tons.

Comparison of the skeletons of the quadruped and of the biped dinosaurs reveals distinct evidence of the influence of gravity.

**Quadruped** — the vertebral column formed an arch of upward convexity supported by stout hips with femora set in lateral-placed acetabula. The lineal skeletal orientation was horizontal and the free ends of the long bones gravitated downwards. The head was directed in the direction of the long axis of the vertebral column. The face terminated in a massive snout with powerful teeth; jaws were overlooked by eyes set far back in the face.

**Biped** — the effects of gravity on this beast were strikingly demonstrated by comparison of the pelvic bones. (Fig. 1) The quadruped dinosaur had a triradiate pelvis made up of the ilium, ischium and pubis joined at the acetabulum. In the biped dinosaur the ischium and ilium maintained their respective distances, but the pubis rotated downward and backward to lie adjacent to the ischium. In addition, the ischium developed a new bony process which projected forward to support the massive belly. This produced a four-pronged pelvis, similar to the pelvis of birds, and was the first indication that one of the functions of the pubis was to support the weight of the contents of the abdominal cav-
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Figure 1

Tri-radiate pelvis of the quadruped dinosaur is observed on the left. On the right can be compared the pelvis of the biped dinosaur. Illustration from Romer’s “Man and the Vertebrates.”

ity. Evidence of this function has appeared in succeeding vertebrates, including man. The biped dinosaur was nature’s first experiment to orient the vertebral column toward a vertical position in respect to gravity. By placing the weight on the hind legs and raising the forelegs the vertebral column assumed a slanting, head-upward position which was balanced posteriorly by a large heavy tail. The tail grew to such length that it has been estimated that it would have taken about a minute for an afferent sensory pain impulse to reach the brain.

Because of the uninhibited growth potential of reptiles, and because of the lush food supply, these beasts grew to mammoth proportions. Eventually nature’s experiment in bipedalism was defeated by a gluttonous appetite and the inexorable stress of gravity. The beasts outgrew their physical strength to uphold their foreends, and as a result, the bipeds again became quadrupeds (Fig 2). This was a state they were ill-suited to assume, because the forelegs had shriveled to a state of uselessness during the bipedal evolution. There resulted a grotesque-ap­­pearing, clumsy carnivora, no longer able to protect itself by rapid escape. Nature tried, unsuccessfully, to preserve the species by adding on plaques and plates, horns fore and aft, and dorsal spines. But the dinosaurs were doomed to extinction. Some think that the extinction was caused by major geologic changes which resulted from the raising of the mountains, particularly the Rockies. With the swamps and lowlands gone, the climate cooled and the food supply reduced. The herbivorous, then the carnivorous, dinosaurs finally gave up the ghost to become monuments to the relentless progression of evolution.

We should ask, why the biped stand for dinosaurs? Why did they go to the effort to defy gravity? Romer theorized that it was the dinosaurs’ forelegs and plates, horns fore and aft, and dorsal spines. But the dinosaurs were doomed to extinction. Some think that it was caused by major geologic changes which resulted from the raising of the mountains, particularly the Rockies. With the swamps and lowlands gone, the climate cooled and the food supply reduced. The herbivorous, then the carnivorous, dinosaurs finally gave up the ghost to become monuments to the relentless progression of evolution.

Land-water

Birds and their cousins of the class of bird
that it was advantageous for those dinosaurs which survived by stealing the eggs and the young of other dinosaurs. Bipedalism made possible greater speed and mobility and so they became more efficient thieves and can­ nibals. One skeleton of a bird-like dinosaur with a crushed skull was found in the dinosaur nesting grounds; it does not take too much imagination to guess that it was caught in the act. Whether thievery is an accessory evo­ lutionary trait to bipedalism is a matter for contemplation.

**Land-water, The Birds**

Birds are direct descendants and first cousins of the ruling reptiles. The pelvis of birds and of some dinosaurs are almost identical. The upward, slanting vertebral column and the downward migration of the pubis are similar.

**Group IV Land-quadruped—The Mammals**

To better adapt to gravitational strain, the mammals have made adjust­ ments of major importance in skeletal relationships. The four limbs, swung fore and aft, were placed directly beneath the weight of the torso, so that the elevated position was maintained by balance, rather than by muscular strength. This freed the muscles for propulsion.

In the contemporary quadruped mammal the skeleton is oriented hori­ zontally. The skull terminates in the
snout with a mouth to eat and teeth to bite, and the eyes overlook the snout and orient in the linear direction of the skeleton. Generally the free ends of the long bones are directed downward in line with the force of gravity.

The pelvic bones are larger and are fused to the skeleton and to each other. Thus, they form a ring of bone through which passes the terminal ends of the alimentary, reproductive, and urinary systems. The pelvic inlet tends to be round and vertically oriented. The pubis is flat and horizontally disposed.

**Group V Land-semierect—**

**The Lower Anthropods—the Monkeys**

The monkey, normally a four-footed walker, sits upright and uses its forelegs for prehension.

The skeleton is oriented to a slanting upward direction. The skull terminates in the top of the cranium with the face shortened and ventrally oriented in a direction almost at right angles to the linear disposition of the vertebral skeleton. The vertebral skeleton is arched dorsally like that of the quadruped mammal.

Ventrally the ribs are attached to a sternum, and the anterior ends tend to be dislocated to a slightly lower level in relation to the vertebrae than in the quadruped mammal. The chest cavity shows a slight tendency to be flattened in the anteroposterior direction.

The pelvis has become fused to itself and to the vertebrae. The ilium is long and narrow; the pubis is relatively small and faces dorsally (Fig. 3).

![Figure 3](Image)

**Figure 3**

Pelvic relationships of the lower anthropods—baboon. From Elftman: "Evolution of Pelvic Floor in Primates."
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Group VI Land-erect—
Bibrachial (suspension)
Higher Primates—Great Apes

From the point of view of gravity, the great apes present many highly interesting features which are incidental to their type of locomotion and arboreal existence. On the ground the great ape prefers to be four-footed, albeit in a slanting-upwards position. In the trees, it is erectly postured by hanging with its long arms from a suspended point of security. Instead of being bipedal, the great ape is bibrachial; it travels by swinging from limb to limb, suspended by its forelimbs, by a method of locomotion known to biologists as brachiation.

The force of gravity tends to lengthen and straighten a suspended object, so that the vertebral column of the great ape becomes straight rather than convexly curved upward as in the quadrupeds and it is oriented vertically (Fig 4). The skull terminates in the crown of the head and the eyes and face are oriented ventrally at right angles to the linear direction of the vertebral column. The snout has become flattened and the lower jaw is only slightly more prominent. The rib ends, attached to a sternum, tend to drop downwards. The chest is flattened and there are prominent clavicles.

The pelvis (Fig 5) is straight and the oval-shaped pelvic inlet slants sharply downward from the sacrum as though pulled from its moorings. These relationships contrast sharply with the pelvis of the quadruped. The symphysis pubis has been located far below the promontory of the sacrum but has not become rotated so as to face upwards and inwards as in man.

Because the great ape has lost his
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tail and has incorporated the coccygeal segments of the vertebral column into a pelvic closing mechanism, it is profitable to compare the pubococcygeal relationships of the other members of the great ape family to those of man. The first evidence of ventral concavity of the sacrum (Fig 6) is observed in the chimpanzee and it is most marked in the orangutan. In an ascending order there follows a tendency for the coccygeal segments of the vertebrae to follow a curved line arching ventrally toward the symphysis pubis—a bony arrangement which tends to narrow the pelvic outlet.

The linear orientation of the skeleton of the great ape varies. In the trees, the skeleton is oriented vertically. On the ground, because of the very long arms, the skeleton is oriented in a slanting-upwards position because the preferred method of ground locomotion is quadrupedal.

Group VII Land-Erect—Bipedal
Homo sapiens—Man

Man is the only true biped. Against the force of gravity he maintains the erect posture through balance of his combined factors of height, weight, and body configuration. In man, the forces of gravity are supported from the feet up, in contrast to the above-down suspension effect noted in the great apes. In man, the force of gravity tends to compress; in the great apes it tends to lengthen. In man, the vertebral column, directed perpendicularly, is no longer straight, as noted in the great apes, nor is it dorsally arched as in the quadrupeds. The spine of man shows a marked sacro-coccygeal concavity, a lumbar convexity, a dorsal concavity, and a cervical convexity.

Figure 6
Pelvic relationships of the higher primates.
a. Chimpanzee  b. Orangutan
Spinal curvatures are unique to man; they are due to the powerful force of gravity being balanced from below up, with the tendency to compress and curve. The skull terminates in the crown of the calvarium. The face is directed at right angles to the perpendicular. The snout has been lost and a chin has been developed in the lower jaw.

Probably the greatest change in bone stress is evident in the pelvis (Fig 7). It has been rotated backwards; the sacrococcygeal vertebrae have been curved sharply forward; and the coccygeus is directed along a curved line which, if projected, leads toward the symphysis. The symphysis is located at the lowest level of the abdominal cavity and faces upwards and inwards. The ilium has enlarged greatly and the acetabulum has become larger and stronger.

The unattached ends of long bones, such as the ventral ends of the ribs, have gravitated downwards; this relationship makes the nipples in man lower than in the other two-breasted mammals. The chest has flattened and broadened and the clavical has become heavy and long.

The linear orientation of the body is vertical except for the face which is oriented to the horizontal.

*Gravity—Nature’s Greatest Challenger — How does it affect the urinary bladder?*

If gravity is an important biologic stress, how much does it affect the bladder and the urethra of the human female? This review has emphasized that the force of gravity is a powerful determinant in biologic morphology. Also, it has exemplified how nature has adopted and experimented with many different anatomic arrangements to make biologic life compatible to gravitational force.

The mongrel dog probably represents as refined a degree of perfection as any of the four-footed mammals. In the dog the perineum is located postero-laterally. The bladder and the urethra are disposed in a horizontal direction at right angles to the force of gravity. The urethral exit is located on the postero-lateral side of the bladder wall. The bladder is an abdominal organ and it rests upon the horizontal muscular sling of the abdominal wall suspended between the pubis and the chest. The urethra is supported from below by the symphysis pubis (Fig 8).

However, in homo-sapiens the erect
posture has altered, increased, and complicated the effects of the stress of gravity on biologic processes. Because hydrostatic pressure is a direct function of height, orientation of the long axis of the abdominal cavity to the vertical has increased by several-fold the pressure on the pelvic floor. That man’s adaptation to the augmented stress of gravity has been less than perfect is attested by the many defects of morphology known to complicate his biologic economy: abdominal hernia, uterovaginal prolapse, scoliosis, spondylolisthesis, excessive flattening of the chest, and visceroptosis.

Nature’s evolution in response to biologic stress is gradual and progressive. With the evolution of the orthograde posture (erect posture) not a single new muscle was introduced in the spinal series; yet all became modified. The diamond-shaped outlet of the human pelvis is made up of rectal and urethral triangles. Taken on the basis of the evolutionary timetable, the posterior, rectal, or ischial triangle of the outlet is old; the anterior, urethral, or pubic part is new. In the pronograde monkey the ischial tuberosities are almost in contact; the posterior part represents the whole outlet, only a rudiment of the anterior space is present. The first evidence of an anterior or urethral space is seen in the man-like apes: orangutan, chimpanzee, and gorilla. It is important to realize that in the quadruped, the perineum has been placed on the posterior surface of the body; the roomy outlet looks backward, and the symphysis is the most inferior surface of the pelvis. The levators form a posterior wall rather than a floor, and they function to flex the tail, rather than to support the

Figure 8
Urethro-vesico-pubic relationships of the canine.

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hydrostatic pressure of the intraabdominal contents.

In man the posterior triangle of the pelvic outlet has been strengthened and diminished in size by the forward curvature of the sacrum and the coccyx and by the sacrosciatic ligaments. The sacrosciatic ligaments are present only in the orthograde primates.

However, the human pelvis, and particularly the female pelvis, has been weakened anteriorly by wide separation of the ischii and by the development of the anterior pelvic floor triangle. The symphysis pubis has been tilted to face upward and inward, and in comparison to the relative position of the coccyx, it occupies a higher level than in the primate apes. The levator ani muscles have a more horizontal position so that in man they form the support for the pelvic floor. Man has the strongest pelvic floor of all primates, and according to Keith, this comes about with the evolution of the orthograde posture. In all pronograde quadrupeds, and in human infants and children until adolescence, the bladder and uterus are mainly intra-abdominal organs; they undergo a natural visceroptosis and become pelvic organs when adolescence is reached. How many changes in morphology augment the pressure to the pelvic floor in humans was succinctly expressed by Keith. He stated: “No doubt the opening up of the subpubic space and the tilting up of the pubic part of the pelvis to bring the vulva towards the ventral surface of the woman’s body has weakened the vaginal and vesical areas of her pelvic floor. But the chief causes of woman’s disability to prolapse have to be sought for, as in the case in all hernial formations, in the high and varying degrees of pressure generated within the abdominal cavity in consequence of the plantigrade posture. As already pointed out, when we sit or stand the column of abdominal viscera becomes the core within a compressing cylinder of postural musculature. Every movement of the arms, every cough or strain, sets going a multitude of water-hammers within the abdominal and pelvic cavities which search out the weak points in the pelvic walls. Just over the vaginal passage is the fluid-containing bladder; every intra-abdominal impulse sets the bladder knocking at the vaginal exit. At the upper end of the vagina is set the cervix of the uterus; it too responds to intra-abdominal pressures and strains, beating downwards into the passage. It is the continual repetition of small forces, more frequently than the sudden application of a great effort, which wears down the vaginal defense.”

When the changes in morphology incidental to the assumption of the erect posture by man are applied to the bladder and urethra, it will be seen that the alterations are both relative and specific. By changing the relative position of the bladder and urethra from a lateral to an inferior position in the abdominal cavity, the overall effect is an increase in environmental pressure since the long axis of the abdominal cavity has shifted from a horizontal to a vertical position. However, specific changes in urethrovesical relationships are evident when cystourethrographs, obtained while the patient is “on all-fours” (Fig 8) with her spinal axis horizontal, are compared with those obtained when the patient and her spine are erect. The urethra now joins the bladder on the inferior,
rather than on the posterior surface; it has moved from an area of negative, or near negative, pressure to an area of relatively high pressure. Also, in its inferior position, the internal urethral meatus becomes subject to the widely vasceillating high and low ranges of pressure arising both from within and without. The importance of the inferior position of the urethra to the base of the bladder is emphasized by observing the urethrocystographic relationships in patients with utero-vaginal prolapse: relationships of the urethra and bladder which are not associated with stress urinary incontinence, but rather, excessive urinary continence. Similar impressions can be gained from observing alterations in urethrovessical relationships incidental to retropubic urethropexy operations. (Fig 9) Analyzed from aspects of hydrostatic pressure, the urethrovessical relationships of stress urinary incontinence are simply modifications of those which occurred when the change was made from the quadruped to the biped posture. These relationships are now considered to be normal for the human biped.

Evidence of Biologic Adaptation?

The human infant is born with the inherent capability of retaining and expelling limited quantities of urine; it is not born with the ability to voluntarily control the time when, and the place where, voiding occurs. Urethrovessical function in the normal human newborn is automatic and responds to physiologic needs—it is a visceral reflex phenomenon.

The development of socially acceptable urethrovessical control does not involve the training of the bladder and urethra to perform their inherent physiologic functions; it involves the establishing of willful domination over inherent urethrovessical function which is primarily visceral reflex in nature. This is a neat trick; it is like asking man to control the size of the pupil of his eye, the rate of his heart, or the peristalsis of his bowel. The psycho-neuro-muscular complexity involved in the establishment of socially acceptable urethrovessical function is, as yet, poorly understood.

It is proper to inquire into the efficiency of urethrovessical control of the average human. Is the normal adult female able to control her urinary function perfectly? Or, are there variations in the efficiency of control function between different individuals. And, are there variations between the same individual when under different degrees of physical stress?

According to Smith, the modern concept of the mechanism of evolution is called synthetic hypothesis. It is a synthesis of the naturalist’s observations and the geneticist’s knowledge and it is necessary to know the range of variation and the alteration of this range, through successive generations of human organisms, for it to be valid or practical. Although knowledge of the efficiency of urethrovessical function in the human female is not available to the degree necessary to satisfy the precepts of the evolutionists, the results of the studies by Nemir and Middleton, and by Keller, are basic and informative. Their studies showed that over 50% of normal adult non-parous women had urinary incontinence on occasions of stress, and that the degree of incontinence varied from mild to severe.
Comparison of the urethro-vesico-pubic relationships of the human female: erect position shown on left; at right, the same patient when placed in the “all-fours” position with the spinal axis oriented horizontally. Large bead chain defines the axis of the vagina; the wire shows the location of the uterine cavity; the small bead chain demonstrates the urethovesical relationships.
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Appraised according to the standards of the evolutionist, this information on the natural frequency of stress urinary incontinence has indicated a strong background influence which is universally applied and to which different individuals react in variable ways. The fact that it is essentially a disability of erect posture strongly suggests that the inimical background influence with which we were dealing is the force of gravity. Also the variabilities between different individuals, both in incidence and in severity, suggest that the deficiency of adaptation is morphologically influenced. Further, it is evident that the normal standards established by man for the urinary control of man’s woman arc based upon what are considered to be social ideals and not upon realistic knowledge of the efficiency of her actual performance.

The modern concept of urethrovesical function probably should include as basic the following generalizations:

1. The muscle of the entire bladder and the entire urethra is smooth or involuntary.
2. The muscle of the bladder passes uninterruptedly to the distal end of the urethra.
3. No circular muscle sphincter exists.
4. Skeletal muscle derived from the constricting muscles of the vaginal introitus intermingle in an unprecise fashion with the smooth muscle fibers of the distal one-third of the urethra.
5. The bladder and the urethra function as a unit.
6. Both the bladder and the proximal half of the urethra are subject to changes in intra-abdominal pressure, although the response in each organ is not necessarily equal.
7. Urine is retained in the bladder because the tone of the smooth muscle of the urethra maintains a state of closure.
8. The bladder is capable of containing increasing volumes of urine under pressures which are essentially unchanged because the detrusor progressively expands with a minimal increase in the tone of its wall.
9. Involuntary voiding results from simultaneous, and essentially identical, increases in vesical and urethral pressures which are incidental to pure detrusor contraction.
10. Voluntary voiding is the result of a complex of changes in intravesical and intraurethral pressures which are derived from the combined effects of transmitted intrabdominal pressure (extrinsic) and from intraurethrovesical pressure (intrinsic).

From this list of characteristics, two facets hold interest from the viewpoint of urethrovesical ecomorphology: voluntary versus involuntary voiding, and lack of automatic contractility of the detrusor.

If the subject can voluntarily void and if contraction of the detrusor is essential to initiate this act, then it is necessary to conclude that man can will the smooth muscle of his bladder to contract. If this is true, it is an anomalous physiologic fact because willful control is not one of the natural and the inherent properties of smooth muscle. Either one must conclude that willful contraction of the detrusor does
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Lateral Views

PREOPERATIVE

POSTOPERATIVE

NON STRAINING

STRAINING

Figure 10
Alterations in urethovesical relationships by retropubic urethropexy—vaginal wall technique.
not occur, and therefore, that it is not an initiating part of voluntary voiding, or accept the fact that willful contraction of detrusor does occur and for some strange reason the smooth muscle of the bladder has been modified so that it now has some of the physiologic properties of both smooth and striated muscle. Experimental studies by Peterson, Kellberg, and Dhuner, care­fully performed with electronic methods, confirmed the observations made by Dortenmann and Bauer, and later Lapides, Sweet, and Lewis, that voiding upon command was possible after paralysis of all skeletal muscle with succinylcholine. Although the results of these studies showed inconsistent individual reactions, one must conclude that contraction of the detrusor by willful command is highly probable in some subjects.

The second facet of interest is the loss of automatic and rhythmic contractility of the detrusor. This, also, is a change in a basic physiologic property, a change in the rules nature established for the behavior of all other smooth muscle. Direct urethrocystometry, using electronic methods, has shown beyond doubt that the normal adult female has lost the property of automatic and rhythmic contractility of her detrusor muscle. Such studies have shown that if this property is not lost, acceptable urinary control can not be achieved and, to her embarrassment, she voids unconsciously and intermittently without regard for time or place.

If Nature Adapts—How:

Any change from the norm to accomplish more advanced function in the youngest, and currently the high-
est, species of vertebrate evolution commands high priority in ecomorphic interest. Man's voluntary control over the smooth muscle of his urinary bladder and the loss of automatic and rhythmic contractility from the same muscle are two examples of anomalous function. They were essential changes permitting the bladder and urethra to adapt to the rules set down for acceptable urinary function. Considered in this cadence of the paleontologist, these two anomalies of basic physiologic behavior may represent extant examples of evolution. If so, this is almost as exciting as the astronauts and their trips in outer space.

The main question is whether these two examples can be properly categorized as examples of biologic progress. Is it reasonable to think that they serve nature in its effort to comply to the demands of man: to stand on his two hind legs and yet not to evacuate the contents of his bladder unless he commands it?

It is customary to think that smooth muscle can not be willfully directed and that it responds in an independent way after the manner of visceral reflex activity. However, the behavior of smooth muscle can be conditioned, and by conditioning, can be indirectly controlled. Conditioning can be positive or negative—it can train to perform an act or it can train to inhibit an act.

Are these anomalies of smooth muscle function simply conditioned reflex phenomena? On casual examination, one might say yes, but appraisal of pertinent knowledge indicates that the answer is no. There is other evidence that nature has tried to change the smooth muscle of the bladder.

If Nature Adapts—How:
Carey\textsuperscript{11} in 1921 caused the smooth muscle of the bladder of the dog to acquire cardiac muscle-like striations by subjecting the muscle to an increased tensional stimulus comparable to that of the heart. Moreover, there is evidence which suggests that there is variation in the capability with which the human bladder muscle responds to the training process. Some humans (bed-wetters) fail to lose the property of automatic and rhythmic contractility while others seem to lose it easily with a minimum of training. This suggests a fundamental difference which goes deeper than immediate environmental pressures. The evolution of biologic adaptation must be equated upon the fundamentals of genetics, and not upon developments which are incidental to the pressures of the immediate environment. How environmental pressures influence genetic development has been explained but never completely understood. Darwin\textsuperscript{12} conceived natural selection to be the expression of survival of the fittest—that advantageous mutations survived because of superior ability to compete.

L. A. Orbeli\textsuperscript{13} explained adaptation according to a theory known as adaptive-trophism. He conceived that the development of organ control went through various stages. The first, and most primitive, was when contractile tissue was under the chemical stimulation of its environment—here the action was direct. The second stage occurred after the organ had acquired a primitive nerve supply and had suppressed environmentally induced activity. The third was characterized by the beginning or partial regulation of contractile activity through local nervous control. The fourth and most advanced stage, was when muscular function was totally dominated by central or cerebral innervation. Obeli conceived the means for inducing adaptive-trophic influences to be through the sympathetic nerves and stated that it was “through the process of adaptive-trophism that general human experience is accumulated and . . . transmitted hereditarily from generation to generation.”

In the human it is interesting to speculate whether the loss of rhythmic and automatic contractility of the bladder muscle, and its occasional ability to respond to will, are examples of adaptive-trophism. That is, the ability to overcome the inexorable influence of gravity and to comply with the psycho-neuro-muscular complex of influences which are generated by the human demands for socially proper urethrovessical control. Perhaps the detrusor of the bladder and urethra has been forced to adopt different properties of function for improved efficiency. It is rational to believe that man (in this case man’s woman), because he is Nature’s youngest evolutionary experiment, is still in the process of perfecting the mechanism for urethrovessical control. It has been shown that stress urinary incontinence is an affliction of the normal female; one whose bladder has lost the property of automatic and rhythmic contractility and one whose urinary function is otherwise normal. It is not an affliction of the patient with neurogenic urethrovessical dysfunction. This, coupled with the knowledge that more than 50\% of adult nonparous females have subclinical stress urinary incontinence, suggests that stress urinary incontinence may be an expression of man’s evolutionary immaturity.
For the answer to this question we will have to wait another half million years. (By then, if the history of evolution holds, the human race will be approaching extinction.)

Gravity Group VIII Weightlessness, "Environment—Astronaut"

Morton² in commenting upon Man’s posture, stated that the change from water to land existence caused “body weight” to become the most powerful mechanical stress to organic structures. This change in environment made apparent the difference between the specific gravity of the biologic organism and the air. With man’s invasion of outer space, aptly termed “environment—Astronaut,” this difference in specific gravity or weight in air again has been neutralized. Thus, man has returned to a gravity-free environment, like the sea-water from whence biologic life began.

Although the mechanisms are quite different whereby the influence of gravity is neutralized, the over-all effect upon physiologic function should be about the same. The question pertinent to this discussion is how “environment-astronaut” might affect urethrovessical function, particularly urethrovessical function in the human female. Until more study is done upon female astronauts hurled into outer space, direct answers to this question must be deferred. However, considerable information of a general nature is available for study, both from research in aerospace medical physiology and from the detailed reports of the experience of the astronauts.

Ward, Hawkins, and Stallings³ reported upon 26 males subjected to zero gravity induced by parabolic flight for 30 to 40 seconds in an F9A-C starfire jet. They concluded that in weightlessness there was a marked loss of awareness of full bladder. They inferred that the weight of the urine on the floor of the bladder may be necessary for the sensation of urgency. It was suggested that urination in space might have to be a scheduled affair.

These observations were somewhat different from those made using direct urethrocystometry. These studies have indicated that it is the stimulation of increased wall tension, rather than any quantitative degree of bladder fullness, that stimulates the sense of urinary urgency. It is certain that the urge to urinate is not caused by increased intravesical pressure or by increased urine volume. Possibly this can be explained according to the Law of Laplace. It states that wall tension increases in proportion to the ratio of the cube while hydrostatic pressure increases according to the ratio of the square.

John Glenn and other astronauts settled some of the questions because they experienced no difficulty in urination during their periods of weightlessness. Glenn described normal sensations of bladder fullness and of urgency. According to records, just before reentry Glenn voided 800 cc of clear, straw-colored urine which had a specific gravity of 1.016 and a normal chemical analysis.

Gaume,¹⁵ formerly Chief of Life Support Systems, Martin Marietta Corporation, was of the opinion that gravity does play an important role in the mechanism of voiding by providing a stimulus to “weight sensors” in the floor of the bladder. Stretch reflex of the detrusor muscle contributes to the

References

1. Hodgkinson
2. Morton
3. R. H. Smith
4. Morton
5. Kelemen
6. Neuberschiger
7. Kelemen
8. Petrucci
9. Down
10. Laplace
11. Carr
pressure on the sensors, but is not the primary stimulus. He further thought that abdominal straining also contributes by increasing the pressure on the weight sensors. In order to void in the 90° head-down position, Gaume noted, forceful straining was absolutely necessary.

From Gaume’s personal experience on weightlessness, he stated that the sense of urgency diminishes in the ALI state. He also stated that the sensation to void was even more markedly lost if a subject with a full bladder was placed in the 90° head-down position.

The next, and final question, is pure speculation: Would stress urinary incontinence occur in the environment of zero gravity? If the thesis of this discussion is correct—that stress urinary incontinence is an example of inadequate adaptation of the human female to the augmented stress of gravity of erect posture—then one must conclude that stress urinary incontinence could not occur in the near-zero gravity of outer space. Such information, at this time, seems unlikely to be used to therapeutic advantage.

REFERENCES


