Letter to The Editor

MATHEMATICAL-REVIEW: THE ROLE OF MATHEMATICS ON HUMAN STRUCTURE*

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Human body is a machine and a machine has mathematical precision. Swapan Kumar Adhikari has looked into the human machine from a mathematician's view point. He believes that everything under the sky is mathematically formulated.

This is nothing new. His research is not original; the beauty of his book lies in its approach. Now-a-days the joint structures are being replaced by prostheses. This requires mathematical vision. The kinetics of the component body structures - especially at the big joints, have been studied from extensive literature and put together under two covers.

Nature is a very good scientist with a foundation of mathematics. Her engineering skill has been expressed in a review style in this book. The author is a mathematician. He has taken the pains of studying physiology and matched it with mechanics. Human body is designed to move. We will eagerly wait to see another book from Dr. Adhikari which will depict kinesiology in details. The static description of the lines of description of forces through the mathematically modeled joint structure can be a very interesting reading material for the advanced students of anatomy. This part is usually ignored in the graduate level curriculum in the Medical Universities.

Dr. Adhikari has shown how the body structures have taken up the present shape due to interaction of various forces. He has taken the example of *pineal gland* from **Descartes'** study. Pineal gland in the lower order animals was like an 'eye' outside the skull box. Through ages it has taken a deep position in the brain as per lows of mathematics. In this connection Dr. Adhikari has discussed *Poinsot's Spiral*: $r.\mathrm{Sinh}\theta = 1$. In early stage of evolution, thalamus of brain was in the form of an ellipsoid containing pineal gland and was transformed to Poinsot's Spiral as a result of different forms of motion. Mathematically speaking, *polhode* in the form of circle or ellipse turns into *herpolhode* and lastly to spiral with advancement of time. This does not require application of any external force.

In the next chapter, the flow mechanics of circulation has been evaluated mathematically. Haemodynamically the ventricles are muscular pumps with conical spiral appearance of muscle fibres. They raise vortices in the flow during ejection. Usually, the skeletal muscles are in *catenary* distribution which has distinct mathematical advantages during contraction. But heart muscle is a syncytium and its arrangement is in spirals. This can open up the cavity in one twist and close the cavity in the next twist. Thus the circulation is maintained.

The oxygenation of haemoglobin is also a mathematical phenomenon. The haemoglobin molecules undergo structural changes during oxygen uptake and release. Upon deoxygenation the β-chains rotate apart by about 0.7 mm. This conformational change is responsible for many of the functional properties of haemoglobin. De-oxyhaemoglobin is in taut (T) form, stabilized by salt bonds. The addition of ligand is such that full liganded haemoglobin is in the relaxed (L) configuration. Dr. Adhikari has given a figure showing the rotation of β-chain of haemoglobin.

The oxygen saturation curve of myoglobin is hyperbolic but the oxygen saturation curve of haemoglobin is sigmoid. Generally the Medical practitioners do not bother for all these mathematical details but after all Dr. Adhikari is a mathematician! He has peeped into the thermodynamics of heart. Oxygenation of blood is endothermic and deoxygenation is exothermic. Human body can be compared with a heat-engine that transforms food-energy and oxygen. About 55% of the input of food-energy is released to the environment as heat. The remaining 45% is in ATP to supply energy to body cells. The energy is used in muscular contraction, blood circulation, metabolic demands etc. In muscles and nerves, the potential chemical energy is transformed into kinetic and electrical energies.

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Next few chapters of the book deal with the human skeletal forms, stressing on the functions of big joints. Vertebrae in the spinal column are discrete but they form 'motion segments' in accordance with kinematics. Cervical vertebrae allow flexion which is hyperbolic and extension is parabolic. The translation at occipito-atlanto-axial complex is small. Dr. Adhikari has analysed the effects of load on head. Carrying load on head is very common in the developing countries. The mathematical deduction in this respect is also interesting. In nutshell, no weight bearing should distort the normal vertebral curvatures. This is followed in ergonomics. The vertebral column develops secondary curvatures in conformity with the extra corporeal forces. It remains weak anteriorly which often becomes troublesome with bad body postures.

It is interesting to note when Dr. Adhikari points out the fact that the grains on the shaft of long bones are helical. Geodesics on circular cylinder are helices. So, these are capable of transforming forces through the shortest path. Dr. Adhikari has not taken into consideration of the histopathological structure of Haversian Canals of bone which makes it the toughest light weight structure. Dr. Adhikari has rightly pointed out that the head of humerus is a compound solid body of different curvatures and the ball and socket joint (ovoid) moves in a series of short segments of circles of different radii and a line joining their centres form evolute. The mathematical formulation of evolute and the motion of ovoid have been considered in some details. These may be important for the orthopaedic surgeons to find out the optimum arm position in relation to shoulder movement. The mathematical deductions on abduction - adduction and circumduction in shoulder movement in relation to thorax and shoulder girdle make interesting reading material. The ribs can resist pressure due to expansion of air in the lungs due to spiral appearance of the ribs which are in the form of spiral twist.

The pelvic bones behave differently in sitting, standing or on lying. In standing posture the acetabula and the side walls of the pelvis tend to close together but the pubic bones acting as a strut prevents it to happen. The components of forces along the hip bone is symmetrically transmitted to upper part of acetabulum and then to femur. In sitting condition the pressure is transmitted from pubis to the lower part of acetabulum. Mathematically it can be deducted that the ratio of curvature and torsion is constant.

The neck of femur is like a truncated cone with the base supported by flattened concave trochanteric surface. Any force applied to the head of femur is transmitted directly to the central wedge and then to the junction of the neck and shaft. Weight of the body is transmitted through the femur shaft at an angle of 55° then at an angle of 125°, thus it becomes a total angular displacement of $125^\circ + 55^\circ = 180^\circ$. The head of femur is ellipsoidal (Spheroid + ellipticity), the neck of femur has bone distributions in the form of gothic arch. All these facts become very relevant in cases of fracture neck of femur in the old people. The femur absorbs the forces through the helicoids whose equations are considered to be same as that of conoid due to geometrical similarity. On the basis of mathematical equations it is clear that all the forces (weights) at the upper part of the body can be transmitted smoothly to the feet. The ligaments play a great role in transmission of forces at rest and during movements. Dr. Adhikari has considered necessary mathematical formulae in this connection.

The stresses experienced at the spherical dome of the head of femur can be meridional thrust and hoop stress. The acetabulum contains a ring like acetabular labrum; it holds the femoral head within the ball and socket hip-joint. Ligament teres connects the acetabular fossa to fovea femoris capitis. It is in the form of truncated cone to absorb pressure as well as tension of the head.

Human bone is three times lighter and ten times more flexible than cast iron having its equal tensile strength. However it can exhibit plastic behaviour before going to breaking point. Unfortunately doctors have no cilinical or imaging tool to assess it before failure. Measurement of bone density is a preliminary tool. Forces acting on bone have internal and external effects. Internal effect is distribution of forces through the grain structure and external effect is accompanied by activities of ligaments, muscles and cartilages. Internal forces may be either normal stress or at times the shearing stress. Normal stress act perpendicular to surface and shear acts parallel to the surface of application.

Nothing humane is out of the domain of mathematics.

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Review of Mathematical concepts have only been considered as per request of Prof. Naci Bor.