BIOLOGICAL LEVERAGE IN HUMANS AND ANIMALS' SELF-MOVEMENT

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Abstract - In Newtonian mechanics a mass at rest is supposed to accelerate upwards if it undergoes force greater than its gravity force or greater than its weight. The forces acting are the weight W downwards and the force F upwards, F-W= positive, then the force F is greater than the weight W. The net force F-W acting on the mass will be a vector force upwards. A mass can be accelerated upwards with force less than its weight using the leverage concept. In a lever the force at the load arm is still bigger than the load weight however the force at the effort arm can be less than the load weight. In this paper I explain with experimental evidence that a human body uses force less than the human body weight to accelerate upwards by means of the biological leverage. The experiment measures the maximum force that a human muscle can exert and shows that this maximum force is less than the human weight but it lifts the human. I also apply this biological leverage concept to the human body joints including the human spine long-term functionality. This theory applies to other living organisms here I focus on the human body specifically.

Keywords - Biological Leverage, Muscles Force, Weight, Uplift, Self-Movement, Pressure

I. INTRODUCTION

A lever is a tool that consists of a rigid beam that rotates around a pivot called the fulcrum of the lever, levers use the leverage concept in which an input force is multiplied to provide a bigger output force and vice versa. The ratio of the output force to the input force is called the mechanical advantage.

For an ideal lever that does not cause energy loss due to friction or wear:

$$F_i a = F_o b$$

F_i The input force (The effort)

a The distance from the fulcurm to F_i

F_o The output force (The load)

b The distance from the fulcurum to F_o

The mechanical advantage is given by:

$$MA = \frac{F_o}{F_i}$$

For levers that have mechanical advantage greater than one, a smaller force can be multiplied to move and lift massive objects.

An average human of 60 kg can walk, run, dance, walk upside down on hands with relatively small force compared to the force needed for an object of the same mass 60 kg. An average human can run with average speed up to 12 km/h and walk an average distance up to 20 miles in one day. An average human of 60 kg can climb up to 300 meters height but if a mass like a rock of 20 kg fixed to his body the maximum height the human can climb reduces to several meters and the maximum distance he can walk reduces to tens meters even though we only add 20 kg. If the human is 60 kg then the total mass he climbs with the rock 20 kg is 80 kg but removing this 20 kg change the maximum height he can climb from several meters to 300 meters even though we only removed 20/80 or fourth the weight [1,2].

II. HYPOTHESIS

Theory: A human has a built-in biological leverage system in which relatively smaller muscles forces can move and lift massive human body:
The muscles forces that lifts a human body is always less than the body weight, after considering the mechanical levers of the human skeleton so a human can lift his body up short distance with calf and foot muscles pushing with foot toes with force smaller than his weight after considering the foot as a mechanical lever. Here we must distinguish between the foot as a mechanical lever and the new biological leverage that add forces reduction to the human self-movement.

III. METHODS

3.1 Experiment No.1:

3.1.1 A Human Lifts His Body With Force Less Than His Weight :

Each human muscle has an approximate maximum force that it can exert. If we measure the maximum force of calf and foot muscles for a single leg we will find that this maximum force is smaller than the human weight but it lifts the human. We measured the calf and foot muscles maximum force for a single leg for an individual by pressing as hard as he can on a scale by his toes which turned out to be approximately 32 kgf and the individual weight is 63.4 kgf. According to Newton's laws of motion for

the individual to lift his body up short height with his foot the individual minimum force of foot and calf muscles measured by the scale should at least equal to 63.4 kgf " The Achilles tendon will exert a bigger force but the force measured by the scale should at least equal to 63.4 kgf" However the maximum force of the individual's muscles was 32 kgf which is below the minimum force to lift the individual 63.4 kgf.

3.1.2 Measuring the Maximum Calf and Foot Muscles Force

A scale is fixed to a wall. A human is lying on the ground pressing the scale with his toes of a single foot. The human head is on another wall so that the body will not move when the human presses the scale. The pushing is only with foot and calf muscles other muscles of the leg are not involved. The push movement is equivalent to the human lifting his body up short height pressing the ground by his toes using a single foot; one movement is horizontal and the other is vertical both are equivalent done by the same group of muscles. The human presses with his toes as hard as he can, then the scale will measure the approximate maximum force by the calf and foot muscles.

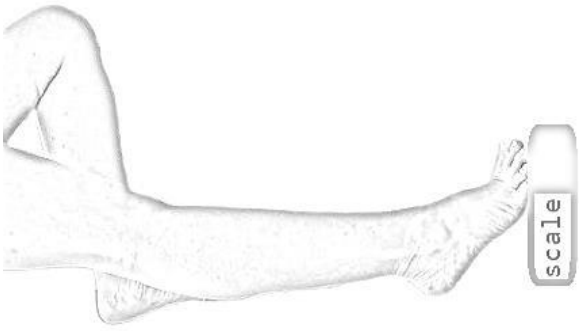

Figure 1: measuring the maximum muscles force for a single leg

Below figures are the calculations of the minimum tension by the Achilles tendon to lift the individual's body and the maximum force of the Achilles tendon.

Assume the individual's Achilles tendon pulls straight upwards on the heel bone while his tibia pushes straight downwards on the ankle joint.



Figure 2: Lifting the human body with a single foot

The tension on the Achilles tendon T when the individual lifts his body can be obtained by the free-body diagram:

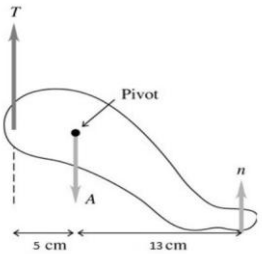

Figure 3: The free-body diagram of the foot

By putting the pivot at the ankle. The two upward forces T and n have to be in rotational equilibrium, so:

$T(5)=n(13)$

For the individual body mass 63.4 kg the minimum tension on the Achilles tendon T to lift his body up with a single foot is:

$T(5)=(63.4)(13)=164.84$ kgf. He needs tension by the Achilles tendon equals at least 164.84 kgf to lift his body.

Assume the force n is the maximum force measured by the scale previously which is 32 kgf:

$T(5)=(32)(13)$

$T=83.2$ kgf. A single leg Achilles tendon can exert a maximum of 83.2 kgf

So the individual maximum Achilles tendon tension of a single leg he could exert was 83.2 kgf but to lift his body 63.4 kgf he needs a minimum tension of the Achilles tendon of 164.84 kgf, despite this the individual can lift his body with a single foot with this maximum 83.2 kgf or less, Usually a human does not exert his maximum force to lift his body such way.

3.2 Experiment No.2:

3.2.1 The pressure on the human body by the body weight force is relatively small

A human is lying on the belly on a concrete block. The concrete block does not touch any bones, just the belly, and the rest of the body is free in air. The human body weight 60 kg will not damage the belly, however, the block of 20 kg put on the belly will damage it. The block of 20 kgf weight will give bigger pressure on the belly " damage it " than the pressure on the belly by the human weight 60 kgf even though the human weight is 60 kgf three times the concrete block weight 20 kgf. The areas of contact in both cases are equal. On the other hand if a

rock of 60 kgf weight put on the belly of an average human it will damage it severely compared to the human of weight 60 kgf lying on his belly on the rock which will not cause any damage to the average human (the 60 kg rock touches only the belly of the human so that the areas are equal in both cases) The individual of mass 63.4 kg was able to lie on his belly on the concrete block for one minute without any damage to his belly, we cannot put a 63.4 kg block on the individual's belly for his safety so this experiment can be conducted on an animal.

3.3 The Biological Leverage:

Below figure is a demonestration of how the human foot supports load less than the weight when the human stands on a scale, the force on the foot will be smaller than the weight, however the scale weighs the actual weight. The foot will lift the body via the biological leverage. The foot supports load less than the human weight, the belly in the experiment above as well and other parts of the body such as the spine.

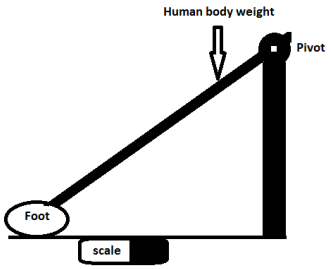

Figure 4: The concept of the biological leverage

IV. RESULTS

4.1 Observations Of Experiment 1:

a. The individual of 63.4 kg mass was able to lift his body up short height with a single foot , however when the individual was lying on the ground with his legs up, he could not lift a rock of 63.4 kg with an equivalent movement by pressing on the rock with his toes.

b. The individual of 63.4 kg could lift his body up holding a bar with his arms several times, but he hardly lift a rock of 63.4 kg with an equivalent movement by pulling a rope through a pulley.

4.2 Observations Of Experiment 2:

a. An average human of mass 60 kg can lie on a bar on his belly for several seconds without pain or damage, but the human cannot bear the same bar put on the belly with smaller weights than 60 kgf.

b. An average human body mass of the trunk, the arms and the head is approximately 40 kg. Even though the human's trunk, arms and the head are massive 40 kg, the human spine can bear it for years without spine cartilage damage, this is as a result of small pressure on the spine. A rock of mass 20 kg fixed equally on the human trunk for one week of everyday life will damage the spine cartilage severely. So it is one week vs 2571 weeks (50 years) and 40 kg vs 60 kg. Removing only third of the weight (the rock 20 kg) multiples the time the spine cartilage can bear by thousands.

V. DISCUSSIONS AND CONCLUSION

As in Experiment No.1 the human is able to lift his body with force less than his weigh, the tension on the Achilles tendon to lift the human with the minimum force which is equal to his weight must be a minimum of 164.84 kgf as in the previous free-body diagram, but the maximum tension by the Achilles tendon of a single leg was only 83.2 kgf and the human actually does not exert this maximum force to lift his body with a single foot.

And in experiment No.2 the individual could support his massive body weight 63.4 kgf on his belly without belly damage, so the pressure on the belly when the individual lies on it on a concrete block is relatively smaller than the pressure by a same-mass 63.4 kgf concrete block put on the belly, as experiment No.2 and the observations suggest, the belly can support relatively massive human weight and the spine cartilage as well, but the spine and the belly cannot support the same mass put on them as in experiment No.2 and the observations. If the individual of 63.4 kg is going to lift his body with the smallest force that is greater than his weight as current physics suggests then he should exert tension by the Achilles tendon greater than 164.84 kgf as was shown but the maximum Achilles tendon tension was 83.2 kgf so the individual was able to lift his body with force less than his weight by the biological leverage system.

The Achilles tendon in experiment No.1 and the human belly in experiment No.2 both support force smaller than the human weight due to the biological leverage. A human body uses this concept to move the massive body by walking, dancing, running, walking upside down, etc, with relatively smaller force, compared to an equal-mass object, a human can run with speed up to 12 km/h and climb up to 300 meters with this massive average human mass 60 kg.

The human uses a biological leverage in his self-movement, the force exerted is less than the human weight as in the experiments and the observations after considering the foot as a mechanical lever, this force is multiplied by this biological leverage so that it is equal to or greater than his weight. The work done is the energy consumed from the muscles. This theory applies to any other living being. Animals undergo the same concept. So an average horse of 400 kg mass can support this mass by its belly when

it lies on its belly on a concrete block but a rock of the same mass 400 kg put on its belly will damage its belly severely.

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