The Elephant in the Room & the Lost Sense – Gravity & Balance

"In this world nothing can be said to be certain, except Death and Taxes" **Benjamin Franklin**

Benjamin Franklin made a fundamental error in not counting gravity among the true certainties in this world.

Rationally speaking, it should have been on the top of his list.

The gravitational force on our home planet has remained constant in direction and magnitude since the formation of our planet 4 billion years ago.

All living things including plants, animals and humans have evolved to cope with, and rely upon, gravity.

As life moved from water onto land, the need was felt to counteract gravity without the buoyancy of water. This directly led to the development of skeletal systems which allow us to withstand and move around in gravity.

It does not stop there.

Recent experiments with astronauts have shown that gravity influences us at an even more profound level. Gravity not only affects the way the heart pumps blood through our veins but also the way our body functions and builds itself at a cellular level.

Astronauts who spend a long time in space suffer bone and muscle loss as well as changes in their metabolism, immune function and cell division.

For you as an individual, gravity is the most persistent force of nature you have encountered. And that's including your mother.

You have been in gravity from the moment you were conceived. And unless you happen to be an astronaut, you have never spent a second without gravity being in attendance.

As a child, it was one of the constants which allowed your nervous system to learn and interact with the environment. Over the course of your first year of life, you learnt from it and got up on your two feet.

As you took your first wobbly steps, your nervous system desperately sought to keep you upright in gravity.

How you were in gravity over the years affected the way your muscles and bones developed along with your sense of balance. Scientists suggest that if children were to grow up in zero gravity, they will never develop their balance the way terrestrial kids do.

For gravity, posture and balance are intimately intertwined. The way we function while balanced in gravity determines our posture. In turn, good posture leads to improvements in balance and our ability to operate in gravity.

But the relationship is not quite as straightforward as one would think.

To see how we got here, let's rewind human history a few million years to the time our ancestors evolved to walk exclusively on two feet.

As a strategy to get around, humans are not the only ones who use two instead of four legs. Other apes occasionally walk on two feet and birds do it all the time. However, we are the only ones that can do it ergonomically. That is, in a way that is efficient and comfortable over long periods of time.

In order to achieve this easy bipedalism, our skeletons went through a series of evolutionary changes over hundreds of thousands of years. As a result, the bones and muscles of our feet, legs, pelvis, spine and skull differ significantly from those of our closest evolutionary cousins, the great apes.

Among other things, our spine developed its characteristic "S" shaped curve to keep us erect and to act as an effective shock absorber. Our hips also became wider to allow our hip muscles more leverage while keeping us balanced over one leg as we shift weight from one foot to the other in walking.

An erect stance also gives us the advantage of placing our tele-receptors (eyes, ears and nose) at a higher vantage point as well as freeing our hands.

This arrangement has obvious advantages and has been credited with the evolution of the hand and the brain, which in turn led to the development of tools, culture and even the society we live in today.

This design also places the head, which is a heavy object, balanced high over a narrow base of support, as we stand on two feet instead of four.

This is the opposite of a stable structure which requires a wide and heavy base.

The Center of Gravity (COG) of an object is the point at which its entire weight may considered to be concentrated so that if supported at this point, the body would remain in equilibrium.

For an object to be balanced in gravity, its COG must be directly above its base of support. The closer the COG to the floor and the wider the base of support, the more stable the body and vice versa.

With their relatively high COG and small base of support, humans are built for instability.

Consider for a minute, an ordinary pendulum. In its essence, it is a heavy ball hanging from a thin rod attached to a pivot from which it can swing freely.

At rest, the pendulum is balanced at its lowest point (Fig 1) where it is in a stable state and can stay without moving unless an external force is applied to it.

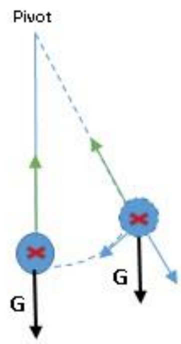

Fig1. Ordinary Pendulum.
Center of Gravity X is lower than Pivot Point

Once a pendulum is pulled away from its resting place and released, gravity works to swing the pendulum back towards the resting position. The pendulum passes through its resting point at maximum speed and then swings back and forth till it eventually comes back to its resting position in the center.

As we see in Fig 1, the COG of the pendulum is lower than the Pivot point.

With the heavy skull placed on top of the spine, the human body may be considered to be an inverted pendulum.

An inverted pendulum is just what it sounds like: an upside down pendulum. The heavy ball now rests on top of a thin rod which is attached to floor via a pivot or hinge (Fig 2)

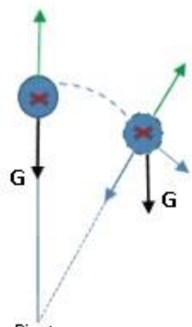

Fig2. Inverted Pendulum.
Center of Gravity X is Higher than Pivot Point

For an inverted pendulum, the COG is above the pivot point and it has a very small balance point.

Whereas a normal pendulum is stable in its resting place, an inverted pendulum is inherently unstable, and must be actively balanced in order to remain upright.

While gravity brings the normal pendulum back to rest, even a small disturbance can tip over an inverted pendulum, unless a corrective force is applied in the opposite direction.

In the human body, the postural “anti-gravity” muscles provide this corrective force to keep it erect.

While standing still, postural muscles distributed throughout the body continuously make small, corrective contractions to keep us from falling. That is how we stay balanced in gravity.

These muscles are controlled by a more ancient part of the brain. They are automatically adjusted in response to gravity. We neither consciously control, nor feel the effort in these muscles.

As Dr. Feldenkrais writes in **“Awareness Through Movement” (**Pg 70), “T*he upright position and all that it involves is organized by a special section of the nervous system, which performs a great deal of complicated work of which no more than a hint penetrates our conscious mind.*

This section is one of the oldest in the evolution of the human species; it is certainly older than the voluntary system, and it is also physically placed below it.”

We only have to slip, or lose our balance, to see this part of the brain in action. Before we even realize what is happening, this system takes instantaneous action to help us regain our balance.

As the bones and the muscles underwent an evolution to allow us to be upright, the human nervous system evolved in lockstep to control their movements.

So in order to be balanced over two feet, we developed an exquisite sense of balance.

In his book “**Balance – In Search Of The Lost Sense**,” Scott McCredie makes a strong case for including balance, “*that intricate orchestration of nerve impulses that allows us to dance with gravity,”* as one of our most important primary senses.

In order to maintain this sense of balance, the nervous system relies on information from the visual, vestibular as well as the proprioceptive systems on a continuous basis.

We are all familiar with how vision impacts balance. One needs only to close the eyes and try to stand on one foot to feel its effect.

The other 2 are more difficult to detect in ourselves.

Located primarily in the inner ear, the vestibular system senses if we are moving or not, and how fast we are moving. It also detects in which direction we are moving, if we are upright, upside down, or at a tilt.

Proprioception is the system by which the body senses its own movement. Proprioceptive receptors are located in the joints, muscles, and tendons all over the body. They sense the position, force, direction and movement of our own body parts.

Together, these 3 systems work with the nervous system to keep us upright. According to McCredie, “*No other sense has this sort of built-in redundancy, perhaps because no other sense is as critical for survival.*”

For keeping us upright is one of the primary directives for the nervous system. And it is a tough ask.

McCredie reasons that “*Maintaining equilibrium requires three sensory inputs because the act of balancing a mass as large as a human body over a base as small as two human feet is exceptionally demanding*.”

Not only are we unstable like an inverted pendulum, we have a lot more complexity built into our bodies as compared to an inverted pendulum.

Unlike the unbending rod of an inverted pendulum, the skeleton has several hinges at the ankles, knees, the hip joints, and each of the vertebral joints in the spine.

These hinges or joints, allow for movement in one or several planes of motion. In addition, the skeleton also allows for rotational movement around the axis of the spine.

All these degrees of freedom to move add immense complexity to controlling the movements of the body while balanced in gravity.

The obvious question is: why add instability and variance to an already complex equation?

What do we “stand” to gain from this?

Dr. Feldenkrais proposed that with the head held at the highest position, we can start moving in any direction with the minimum of effort and no prior preparation or adjustment.

From a mechanical point of view, lifting the head high above the ground stores potential energy. Being balanced on two legs allows us to pivot and move in any direction. Just as water stored in an elevated tank flows down freely in any direction as the stored potential energy is converted into kinetic energy.

We are not only built to be unstable, we are built for motion. We have traded-in stability in return for an ability to move quickly and efficiently in any direction.

A stable object by definition is hard to move. On the other hand, the inherent instability of the inverted pendulum acts as a source of energy.

This makes it very energy efficient.

For instance, walking can be considered as “controlled falling”. Every time you take a step, you actually lean and fall forward a little bit, throwing your body out of balance and advancing it ahead.

When you “catch” your weight with your outstretched foot, the body moves back into balance. If you failed to put your foot forward, you would fall flat on your face.

In fact, as a result of our unstable design, it is easier for one to walk than it is to stand still. It has been shown that even while standing still, the head continuously moves ever so slightly in space in what is called “Postural sway.”

Walking on two feet is actually a very complex process. It involves a staggeringly large number of bones (600), bones (200) and joints (230).

Further, as the weight shifts from one foot to the other, all the vertebrae in the spine must continuously adjust their position in a very precise, sinuous pattern to prevent the head from moving from side to side as we walk.

This allows us to keep the head (and hence the eyes) stable as we walk or run.

This ability has to be learnt and every child masters it around the age of five.

If you observe toddlers, you will find that their head moves side-to-side as they walk. For their nervous system is yet to learn how to make these delicate adjustments of the spine in order to allow the head to stay balanced in the center.

We also observe the same in many older people. They sway side to side as they walk, like a stick – and as a result, they have a compromised sense of balance.

Our ability to stay balanced on two feet does get affected by the passage of time.

Per McCredie, "*All three primary sensory inputs for balance begin to atrophy in middle age*." Vision loses its acuity requiring us to use reading glasses. The proprioceptive receptors at the bottom of the feet lose sensitivity with age even as the vestibular canals in the ears start to lose the tiny hairs which measure and track motion.

He continues, "*The hands, for instance, retain most of their sensitivity late into old age, while the feet are particularly vulnerable. Their sensory alertness holds steady until about age forty, then goes down 20 percent in the next decade, and by a staggering 75 percent by age eighty*."

He reports an astounding statistic, that "*According to the Centers for Disease Control and Prevention (CDC), one in three Americans sixty-five and older falls each year, which today translates to about 10 million falls annually*."

This decline and loss of balance is not inevitable as exemplified by Karl Wallenda in the 1970's when he walked across a wire stretched 750 feet above Tallulah Falls in northeastern Georgia (in the US), despite a vicious wind that threatened to topple him. "*He even did two headstands in mid-span to demonstrate his mastery*."

He was in his 70's at the time!

When the ability of humans to start moving quickly and effortlessly in any direction united with the capacity of their nervous system to adapt and learn, a remarkable new combination was born.

I grew up thinking of humans as cerebrally-gifted, but physically-limited, animals.

We cannot run as fast as a horse, swim as fast as a dolphin, or jump as high as a cat, or climb as quickly as any of the great apes.

But, we can do some of everything that other animals can do.

We can crawl, walk, run, climb, swim AND jump.

Being erect, we can pivot swiftly around the axis of our spine as compared to 4 legged animals that must turn around like a four wheeled vehicle.

Our ability to sweat in order to regulate our body temperature allows us to run extremely long distances in hot conditions. As reported in the delightful book "**Born To Run**" by Christopher McDougall, early humans used this ability to chase down prey to exhaustion.

Our sense of balance which originally evolved to keep us balanced in gravity on two feet can be trained to achieve amazing feats.

From learning to ski at incredible speeds, to spinning incredibly fast as figure skaters do on ice, to being balanced upside down on just one hand as some dancers, yoga practitioners or gymnasts are able to do.

And in some activities, humans are in a league of their own.

We can ride a unicycle, or don a wingsuit and learn to "fly" and maneuver in the air.

Through the combination of a body built for motion and a brain made to learn, we can all improve our skills at *dancing with gravity*.