



The Truth on Fitness:
BALANCE (Part 3)

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In our continuing series on balance, we've described equilibrium and stability as properties of the relationship between the position of the center of gravity and the boundaries of the base of support. In the last segment, we distinguished between static equilibrium, whereby the center of gravity remains relatively motionless, and dynamic equilibrium, during which the center of gravity moves, sometimes at a considerable velocity.

Whether equilibrium arises from subtle control of the center of gravity, or a dynamic repositioning of the base of support in front of a moving center of gravity, the eventual outcome is the product of information gathering and the ensuing motor response. To put it plainly, one must first recognize that their stability is being, or is about to be challenged, and then, they have to produce some action intended to maintain equilibrium. In this installment, we'll explore the sensory side of this equation.

The human system has available a multitude of sensory inputs that allow for the accurate and effective detection of changes in stability. No one sensory system, by itself, can provide the necessary information to correct for minor or major deviations of the center of gravity. Instead, we use a combination of information from our eyes, muscles, joints, ears, and other tissues, to detect changes in position that may lead to decreased stability, or ultimately, a loss of balance.

Let's examine a static balance task, standing on one foot, to see how this process might work. Although balancing on one foot is a static challenge, it is compounded by the fact that it is nearly impossible to keep the center of gravity absolutely motionless, and given the fairly small base of support, there is little room for the center of gravity to move before it transcends the base. Consequently, subtle deviations in the center of gravity must be detected in order to remain in a balanced position.

In single leg stance, one might first sense a shift in the center of gravity as a change in the location of pressure on the bottom of the foot. In many cases, that may be sufficient to trigger an appropriate corrective response. If the center of gravity shifts enough, it may alter the point of force application in the joints, in which case, joint pressure receptors may provide additional information about the direction and extent of displacement of the center of gravity.

If displacement is significant enough to cause joint motion, perhaps at the ankle, or at the hip, then the muscles spanning those joints will be tensioned as well, sending signals to the brain about their change in

length and how quickly that length is changing. A rapid change in muscle length may indicate a sudden, and significant, change in position that could precede a fall.

Any movement of the body will be detected by the eyes and vestibular system of the inner ear. Visual information provides us with a reference point in space against which we can compare our position. Any deviation around that reference point will be detected, even the most subtle changes. To understand just how valuable visual information is to equilibrium maintenance, try standing on one foot with your eyes closed. If you can keep your balance for ten seconds, you're doing extremely well.

The vestibular system consists of unique sensors in the inner ear that detect movement and acceleration. Changes in head position will trigger these sensory cells, which alert the brain about the direction of movement, the extent of motion, and the rate of acceleration (one might notice the redundancy between the vestibular system and muscle sensory functions). With small, discrete movements of the center of gravity, these sensors will contribute little to ongoing balance control. But in the event of highly dynamic movements, their input to the control system is crucial.

During conditions of dynamic equilibrium, the human body uses the same sensory mechanisms as it employs during static tasks, although the relative importance of those senses may change. In quiet standing, for example, pressure receptors and muscle sensory organs may play a more prominent role, while visual and vestibular inputs, while still important, may have a secondary role. In tasks where there is a dynamic repositioning of the center of gravity, the relative contribution of these elements may reverse.

Consider a situation in which one has to leap over a puddle, for example. This is truly a dynamic condition which will introduce a significant challenge to the performer the moment the lead foot hits the ground. At that moment, the base of support has been established, well in front of the center of gravity, which will be rapidly moving towards, and potentially beyond, the base. As discussed in an earlier segment of this series, the challenge to the performer is to recognize how fast the center of gravity will be moving towards the base, so that on foot contact, enough force can be exerted to effectively bring it to a stop over the base. Too much force and the center of gravity will stop in front of the base, while too little force will allow it to continue moving beyond the boundaries of the base. In either case, the result will be a loss of equilibrium.

This is where a combination of visual and vestibular inputs is so critical to the successful completion of the task. Information gathering actually begins while the performer is in the air. Through vision, the leaper will identify the landing spot on the ground and can quickly calculate how rapidly they are moving towards that spot. The landing foot can also be readily seen out in front of the body, providing information about how far in front of the body the foot will hit the ground.

The sensors in the vestibular system also contribute to this input by detecting the rate of acceleration towards the ground. Together, these senses alert the performer about how fast they are moving, where their foot will contact the ground, how much force can be expected on impact, and where the center of gravity will be positioned in relation to the lead foot.

At the moment of contact, the previously mentioned pressure, joint, and muscle sensors will relay information about the distribution of weight, joint loading, and muscle length properties. Taken together with visual and vestibular information, this sensory array helps the performer to recognize how their equilibrium is being challenged so that they can plan the appropriate response.

The truth is that balance control is a very complex process involving multiple sensory systems. In many cases, even the most acute sensory input fails to result in an effective solution, especially if the motor response is inadequate. In our next segment, we'll examine how the body creates motor solutions to balance problems, and discuss the basic requirements for enacting these responses.

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