Balance Buttons

How Stimulating Specific Locations on the Bottom of Your Feet Can Improve Balance and Prevent Falls

By Tom Michaud, DC

Like it or not, as we age, most of our sensory systems begin to break down: our hearing worsens, our vision gets blurry, and our reflexes slow down. An underappreciated sensory system that also worsens with age is the ability of cutaneous receptors located along the bottom of our feet to accurately quantify pressure. This is a big deal because information supplied by these tiny receptors plays a huge role in keeping us upright and balanced, as they supply a rich source of sensory information that allows us to constantly track the location of our balance point (a.k.a. center of pressure). If the center of pressure veers off too far in one direction, a reflexive muscular response brings us back to a safer balance point (Fig. 1). These cutaneous receptors, which are illustrated in figure 2, are unlike other sensory receptors associated with balance in that they interact with a wide range of interneurons, allowing them to favorably modify activity in all limbs, not just the stimulated limb. This comes in handy for preventing falls, as it allows you to quickly move the opposite limb and/or adjust arm position in order to reestablish balance. Unfortunately, as we age, the receptors in the bottom of our feet become less sensitive.

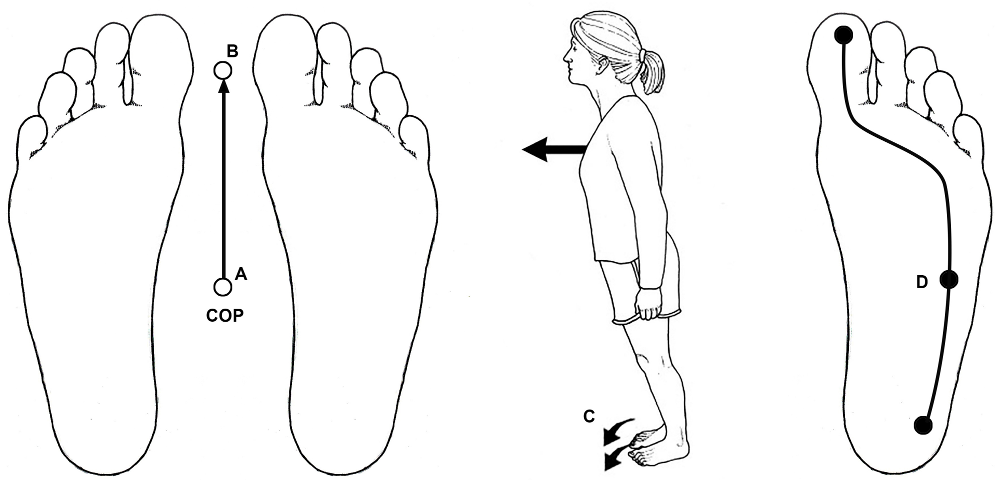

Fig. 1. The center of pressure (COP) refers to the precise point the body is balanced over while standing walking and/or running. When standing on both feet, the COP is located directly between our feet (**A**). If we inadvertently lean too far forward (**B**), cutaneous receptors in the soles of our feet sense this shift in pressure and reflexively force our toes to push down to help us regain balance (**C**). You can demonstrate this corrective response on yourself by keeping your arms at your side as you slowly lean forward. As your COP approaches your anterior fall envelope (the farthest distance you can lean safely forward without falling), you'll feel your toes push down to reposition the COP (**arrows in C**). While walking, your COP follows the path illustrated in (**D**).

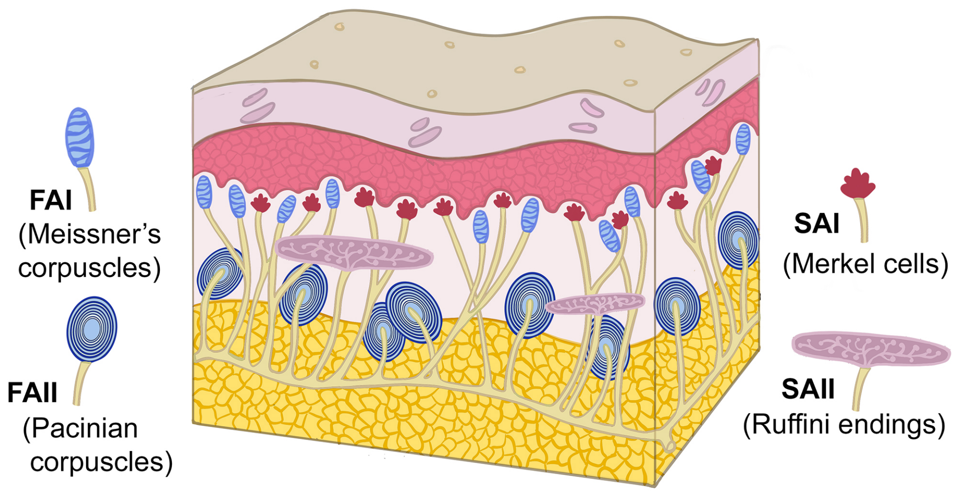

Fig. 2. Cutaneous receptors located in the soles of our feet. Notice there are 4 types of receptors, which are categorized by the size of their receptor fields (**type I or type II**) and by the speed in which they adapt to a given stimulus: fast adapting (**FA**) or slow adapting (**SA**). Type **I** receptors possess numerous branches that terminate in the epidermis. Type **II** receptors are supplied by a single nerve and are positioned deeper in the dermis. Fast adapting receptors essentially function as on-off switches: they fire immediately when a stimulus is applied, stop firing, and then fire again once the stimulus is discontinued. In contrast, the type **II** receptors fire constantly when stimulated but have slightly higher thresholds for stimulation. All 4 receptors are more frequently referred to by their eponyms, which are listed above. Because of their multiple branches, the superficial type **I** receptors are by far the most common cutaneous receptors in the soles of our feet, representing more than 60% of all cutaneous receptors.

Even without underlying neuropathy, it takes 20% more pressure to stimulate cutaneous receptors in the soles of the feet by age 50, and 75% more pressure to stimulate the same receptors by age 80 (1). The reduced sensory input from the soles of our feet makes it extremely difficult to maintain balance and adds to the high fall rate present in senior citizens. In any given year, nearly 40% of seniors aged 70 and over will fall at least once (2), and the resultant injuries often begin a downward spiral of weakness and frailty.

For more than 50 years, researchers have attempted to improve balance and prevent falls by incorporating textured insoles with specific elevations designed to stimulate cutaneous receptors. These textures range from small triangles and pyramids, to round tubes and/or circular nodules. Some are made from hard plastics, and others from soft foams. In theory, textured insoles improve balance by increasing output from cutaneous receptors that are becoming increasingly insensitive with age. The problem with textured insoles is that the research regarding efficacy has never been that impressive. Some research shows these insoles reduce fall risk (3,4), while other studies show these insoles produce little change (5,6), or worse, they can impair balance making you more vulnerable to a fall (7,8).

In my opinion, the problem with textured insoles is that the irritating textures are applied uniformly over the entire foot. Almost 30 years ago, Robbins et al. (9) showed that this can have negative consequences as they convincingly prove that the muscular response to pressure along the bottom of the foot varies depending upon the location of the stimuli. For example, stimulating the skin under the inner forefoot produces a reflex downward contraction of the toe muscles, which distributes force away from the metatarsal heads into the toes. In contrast, stimulating the skin beneath the arch has the opposite effect in that it causes the toes to move upward, shifting pressure away from the toes and onto the metatarsal heads. The inability of the toes to push downward greatly increases our risk of falling forward (10) (refer back to figure 1).

New research supports the concept of site-specific cutaneous specificity along the bottom of our feet. Using advanced EMG technologies to stimulate specific cutaneous receptors in different locations along the bottom of the foot, Zehr et al. (11) note that when cutaneous receptors beneath the heel are stimulated, there is an immediate increase in activity of the soleus and gastroc muscles (Fig. 3A), with inhibition of tibialis anterior. Stimulating the lateral midfoot increased activity in peroneus brevis (Fig. 3B), while stimulating the lateral forefoot (Fig. 3C) increased activity in tibialis anterior. The authors specifically state that stimulating the lateral side of the midfoot is an important location of transition that provides "greater resolution in the fine sculpting of motor output." The authors make the interesting statement that site-specific stimulation provides "a kind of guided tuning" that the authors refer to as "sensory steering."

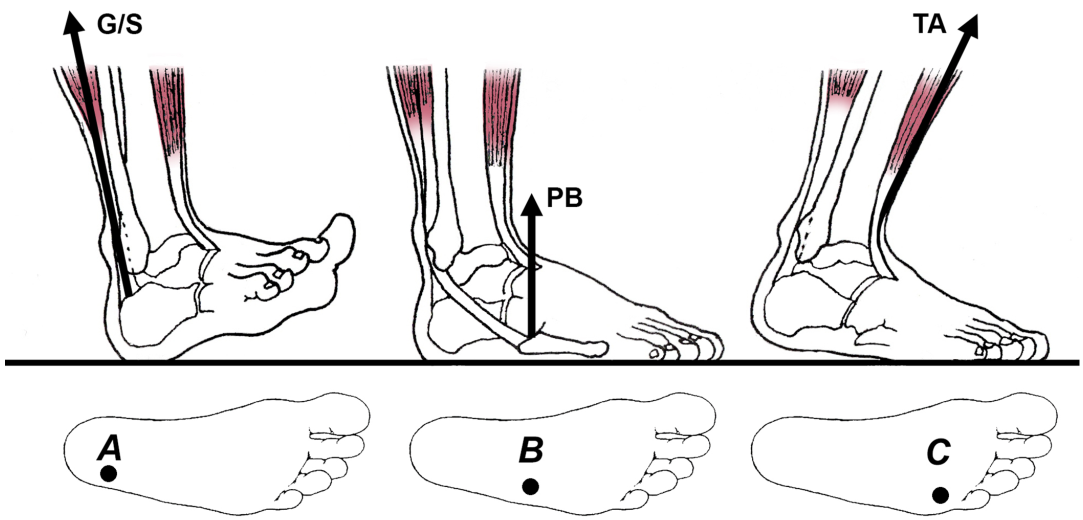

Fig. 3. Site-specific muscular response to cutaneous stimulation to the sole of the foot. Notice how stimulating cutaneous receptors in the heel increase activity in the gastroc/soleus muscles (**G/S**), while stimulating the lateral midfoot and forefoot increase activity in peroneus brevis (**PB**) and tibialis anterior (**TA**), respectively. Stimulating the peroneal muscles is extremely important for fall prevention because it can prevent lateral displacement of the center of mass while balancing over one foot.

In the most detailed study of cutaneous receptors to date, researchers from Canada used microneurography to determine the exact location of each type of receptor in the bottom of the foot (12). Figure 4 illustrates the results of their research, which for the first time ever proves that there is a gradual increase in sensory receptors when moving from the back of the heel to the forefoot, and when moving from the medial to the lateral side of the foot. The outer side of the midfoot is especially well innervated, possessing both slow and fast adapting cutaneous receptors.

The abundance of sensory receptors along the lateral foot makes perfect sense when you look at the progression of the center of mass while walking (refer back to Fig. 1). Because we spend so much time with our weight distributed over a small section of our foot, it is important that that section have the ability to provide the greatest amount of information in order to allow us to respond immediately to even minor perturbations that may affect balance. The plethora of cutaneous receptors located along the lateral foot is also key for preventing the most dangerous type of falls: lateral falls. While forward falls can be prevented by firmly pressing down with your toes, and medial falls are rarely a problem as the opposite leg is there for support, lateral falls require a complex cross-over movement from the opposite leg, which is difficult to perform and nearly impossible to recover from once initiated. In fact, a recent paper published in the *Journal of Biomechanics* demonstrated that seniors who are most likely to fall have greater lateral displacement of their center of mass while initiating their first step while walking (13). Lateral falls have also been proven to result in greater fracture rates (14,15).

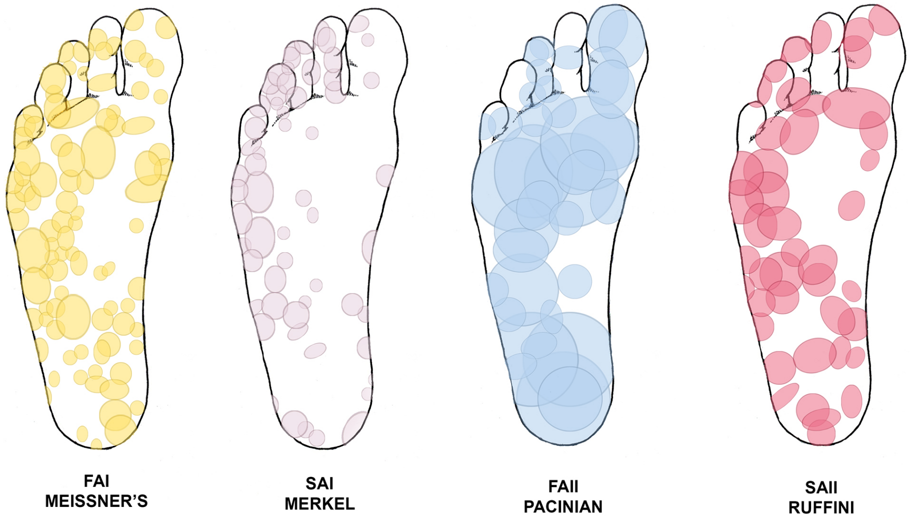

Fig. 4. Cutaneous receptor locations along the soles of our feet. Notice the greater concentration of receptors located along the lateral side of the foot and the toes. When it comes to fall prevention, the high prevalence of Meissner's corpuscles and Merkel receptors is important, as they are low-threshold receptors that "preferentially respond to dynamic skin deformation, with a particular sensitivity to skin indentation" (20).

After seeing research by Strzalkowski et al. (12), I looked at every paper ever published on textured insoles and made a series of prototypes, each possessing a different pattern of ridges and elevations. The final version was made with a series of rounded elevations that get progressively larger when moving laterally (Fig. 5). I deliberately placed the smaller elevations on the inner side of the *Balance Buttons* to stimulate slow adapting receptors, which provide constant information regarding the location of the center of mass. I then placed the larger elevations far enough laterally that the individual could avoid stimulating them by walking with a slightly wider base of gait. Walking with your feet farther apart greatly diminishes the risk of lateral falls as your center pressure is maintained in a more central position. Should the individual accidentally shift his or her weight so far to the side that they press on the larger nodules, it is likely to initiate an immediate response from the fast-adapting Meissner's corpuscles, which have extensive branches to specific muscles in the lower extremity responsible for fall prevention (16). Last but not least, the entire pad acts as a wedge lifting the outer side of the foot, which shifts the center of pressure to a safer midline position.

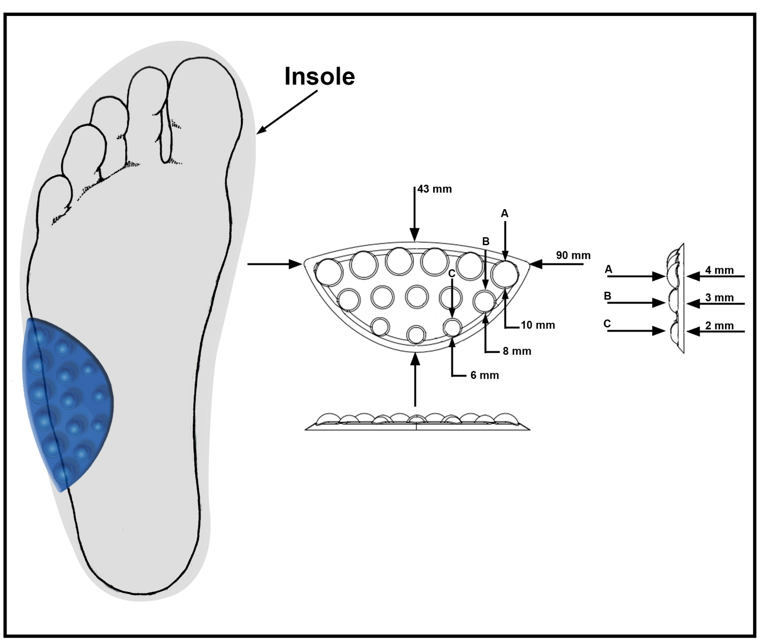

Fig. 5. *Balance Buttons* are positioned on top of the insole with the outer edge hanging slightly off the side of the insole. Notice how the elevations on the *Balance Buttons* get progressively larger as you move laterally, which are designed to increase feedback from cutaneous receptors as the center of pressure moves too far to the outer side of the midfoot. Stimulating this precise location is key for improving balance and preventing lateral falls.

Keep in mind that *Balance Buttons*, like all textured insoles, only work while you are wearing them as there is an almost immediate return to baseline poor balance when discontinued (17). As a result, it is extremely important to strengthen your feet and legs, especially your toes, as foot strength plays a huge role in fall prevention. Research from Australia shows that every 1% increase in toe strength decreases a seniors' risk of falling by 7% (10).

It is easy to measure toe strength using a toe strength dynamometer and ideally individuals will be able to generate 10% of their body weight beneath their big toe, and 7% beneath the lesser toes (Fig. 6). My favorite way to strengthen the legs and feet is with the ToePro exercise platform, which is easy to do and extremely effective. A pilot study at Temple University showed that in addition to increasing toe strength by more than 20%, using the ToePro for just 6 weeks appreciably improved balance, as measured with the Y-excursion balance test (18).

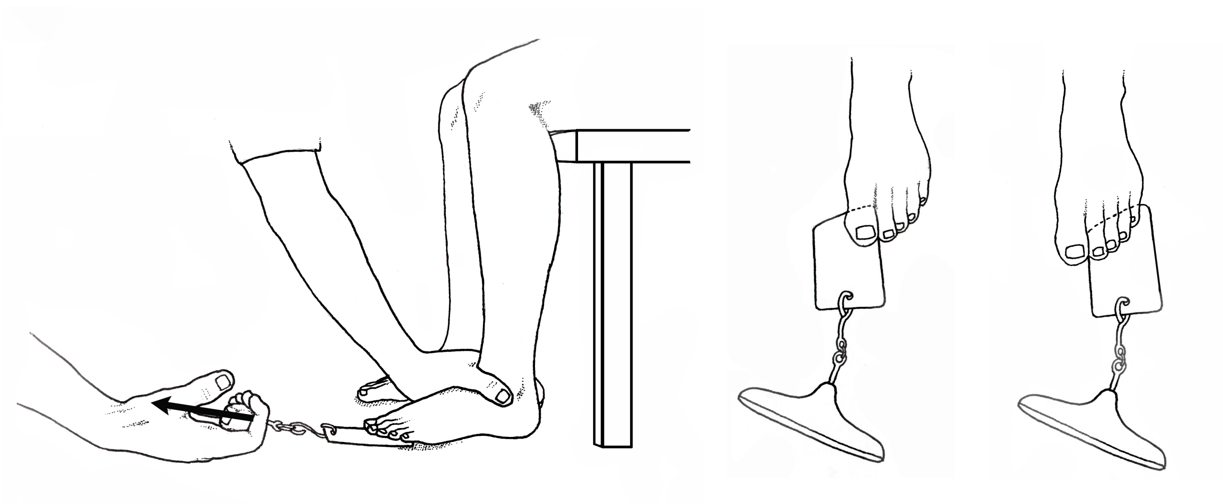

Fig. 6. Toe strength is easily measured with the toe strength dynamometer. The subject is instructed to push down with the tips of their toes as hard as they can as the examiner pulls the card out from beneath either the big toe, or the second through fifth toes. Toe weakness is a proven predictor of falls in the elderly (10).

The easiest way to determine if you might benefit from using *Balance Buttons* is to get into a safe location and stand on one foot with your eyes open and try to balance for a full 10 seconds. In a 12-year study of more than 1,700 older adults, the ability to successfully balance on one foot with eyes open was strongly correlated with longevity (19). In fact, individuals who were unable to balance for 10 seconds after 3 tries had an 84% higher risk of all-cause mortality, even when adjusting for other risk factors, such as heart disease, hypertension, and obesity. This study emphasizes the disastrous consequences associated with impaired balance. It also proves that it is imperative that people have their balance evaluated regularly, just like they have their cholesterol, blood pressure, and eyes examined annually. If impairment is found, preventive measures should be initiated as soon as possible, and inexpensive *Balance Buttons* coupled with a few simple home exercises can make a tremendous difference.

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