
TREATMENT

EQUALIBRIUM

Hearing aids can be an important tool for regaining balance in those with hearing loss.

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Hearing Aids

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HOW DID WE GET HERE? WHAT CAUSES HEARING LOSS IN THE FIRST PLACE?

Hearing loss can be caused by a variety of risk factors. These most commonly include natural aging (degeneration of inner ear structures over time), exposure to loud sounds which includes both recreational (activities such as firearm usage and motorcycling) and occupational noise (some job types such as construction, farming, etc.), head trauma, genetics, medications, and many types of viruses and illnesses.¹⁸ There are three types of hearing loss. The first of these is called conductive hearing loss, wherein sound doesn't properly reach the hearing organ in the inner ear called the cochlea. The second type of hearing loss is called sensorineural hearing loss, which is damage to the inner ear system itself. The third type of hearing loss is mixed hearing loss, which is simply a combination of both conductive and sensorineural hearing loss. Whereas conductive hearing losses can often be treated by a medical professional, most types of sensorineural hearing loss are permanent. To date, the primary treatment for chronic hearing loss is hearing aids.

THE IMPACT OF HEARING LOSS AND WHY WE NEED A SOLUTION

Hearing loss is increasingly becoming one of the most prevalent chronic health conditions worldwide. According to a recent Global Burden of Disease Study, hearing loss is the third leading cause of "years lived with a disability," and affects individuals at all ages across the lifespan.⁴⁴ Though estimates vary, approximately 1.5 to 3 per 1,000 babies are born in the US with a hearing loss,¹³ and nearly 15% of American children aged 6-19 are reported have some degree of hearing loss.³¹ These numbers continue to grow with age over time. The National Institute on Deafness and Other Communication Disorders (NIDCD) estimates that hearing loss affects approximately 37.5 million adults in America.¹ When considering what this means for our national productivity, the implications are staggering.

Many of us have probably had a family member, friend, or colleague with hearing impairment that reported some difficulty in social settings, in school, or the workplace. Whether the difficulty is over the phone or in person, hearing loss can impact our ability to communicate successfully. Children with hearing loss are at risk for developing speech and language delays. Students with hearing loss typically perform less well than those with normal hearing in a traditional school setting, and this performance gap can increase over time. In some cases, students that don't receive additional services have fallen behind up to four grade levels.⁶ For working adults, according to an income study by Kochkin in 2010,²³ untreated



hearing loss is estimated to cause \$176 billion in lost potential earnings. Though the Americans with Disabilities Act (ADA) requires that businesses make reasonable accommodations for individuals with hearing loss, there was a reported difference of \$14,100 between those with mild and those with severe hearing loss. Depending on the type of job, hearing aids were estimated to mitigate the impact of income loss by 90-100% for mild hearing loss and 65-77% for moderate to severe hearing loss.²³ We know from several studies over the years that hearing loss affects more than just our ability to function at school and in the workplace, but has direct implications for our overall quality of life.

Untreated hearing loss has been linked to an increased risk for a variety of other medical problems. Some of these include social withdrawal,²⁸ loneliness,⁴⁶ depression,³⁵ anxiety,⁴ increased hospitalization,¹⁰ poor adherence to medical treatments,²⁷ falls,²⁰ and cardiovascular disease.⁴⁵ Hearing loss has also been strongly linked to tinnitus, or ringing in the ears.⁴² Our understanding of the human body as a remarkable set of interconnected systems is continuing to develop. The brain puts together information from multiple sensory modalities to give rise to our awareness of our environment. The advancement of hearing loss may be an indicator that signals progression of other chronic health problems. Recently there's been a wealth of studies that have looked at hearing as an important component of balance.

THE CONNECTION BETWEEN HEARING AND BALANCE

The triad of equilibrium maintenance classically includes successful integration of the visual, proprioceptive/somatosensory, and vestibular inputs.⁴⁰ The central nervous system takes all this information together and is suspected to weigh the dependence of which system it's relying on based on changes in our sensory input. As an illustration, imagine yourself simply standing still. In the maintenance of stance alone, the ability to remain upright and steady on a flat surface is largely dependent on information gathered from our proprioceptive and somatosensory inputs. The feeling of our feet on the ground, awareness of our steadiness, our understanding of our feet stacked beneath our hips, stacked beneath our shoulders, all comes from this system. If we were to remove this information from the brain, we would start to see that person's stance become less quiet, and they will start to sway as they struggle to use the

other inputs—vestibular and vision, to compensate for this lack of information.⁵ In the example above, it's relatively easy to separate these three inputs apart, but in a more dynamic situation, say jumping and turning around to catch a frisbee on sand while being mindful not to step near a patch of rocks, our brain has a much more difficult task and needs each of these systems to work harmoniously to allow us to coordinate our muscles effectively. The successful integration of these elements is critical for safety in the real world and allow us to interact seamlessly in our environment, but what if there is more to the equation? Is there anything else that we can use to supplement this information, especially when one part isn't working properly, say in the case of acute vestibular neuritis?

TRIAD OF EQUILIBRIUM MAINTENANCE	
Visual	What you see in your surroundings
Proprioceptive/ Somatosensory	The feeling of your feet on the ground
Vestibular	Your sense of balance

Some researchers are proposing that this model should also include hearing, and that our brain may be able to use auditory cues depending on the sensory demands of the task. The hearing and vestibular organs have a lot in common from an anatomical and physiological standpoint.²⁹ The two systems both send information to the temporal lobe of the brain via cranial nerve VIII. Both take advantage of mechanical receptors called hair cells to change the physical signal of head acceleration (in the vestibular system) and sound (in the cochlea) into an electrochemical signal. There are also several vestibular disorders that impact both hearing and balance. So the question we are now asking is whether hearing plays more of a role in balance as well than previously credited?

We know that the auditory system can help provide us with a representation of three-dimensional space surrounding us.⁴⁰ Having an external



sound source in the room such as a radio playing music, gives our brain an external reference point to focus on. Auditory cues subconsciously influence our postural alignment, and our posture automatically impacts our ability to localize cues in our environment. Our ability to tell where sounds are coming from helps us remain comfortable with our surroundings, and in many cases, is critical for safety. Being able to tell who's talking in a group setting will cue you into who to pay attention to at your lunch meeting, but being able to effectively localize, for example, a car horn in traffic, can be the difference between an accident and moving to safety. Our auditory system uses both the central nervous system and binaural hearing, or the interplay of both ears working together, to analyze our auditory scene around us. To accomplish this, we take advantage of interaural time differences (whether sound first reaches the right vs. left side) interaural level differences (subtle changes in the intensity of sound as it projects across the head in space), and spectral shape cues (differences in acoustic energy) as they travel into our ear canals that are acoustically optimized for sound.⁷ It is possible that these spectral cues give rise to a spatial reference, allowing us to determine the angle and distance relative to an external sound.⁴⁹



Though the evidence is still emergent, encouraging studies have shown a relationship between auditory cues and static balance,⁴⁰ balance during movement,⁴⁹ how we orient and stabilize,⁸ and depth assessment.¹¹ Moreover, in some patients with vestibular deficit, it was found that auditory biofeedback can partially compensate for the affected vestibular system.⁵ These findings suggest that optimizing spatial auditory cues may be a different approach to enhancing postural stability and ultimately, reducing fall risk. Several population studies have shown that hearing loss is associated with falling, and in a recent study Shayman et al. (2020) have suggested that the use of amplification

(i.e. hearing aids) might be an alternative approach for physical therapy programs and auditory rehabilitation techniques to improve balance in individuals with hearing loss.³⁷

BEYOND THE EAR—HEARING AND THE BRAIN

The human brain possesses an incredible capacity for neuroplasticity, the ability to reorganize connections between nerve cells, over our lifespan. This ability allows us to adapt to change during development and adulthood ranging from insult and injury to learning and experience. Recent research using imaging has demonstrated that in cases of sensory deprivation our brain can engage in a process called “crossmodal plasticity.” When this process occurs, cortical regions of the brain that are “unused” are repurposed and taken over by remaining sensory modalities. Studies have established that this occurs in individuals with congenital deafness where crossmodal plasticity favors the visual and somatosensory systems. This could be the result of increased reliance on visual cues to help in noisy environments. Recent literature, however, has found this effect to occur in individuals with mild to moderate hearing loss, including sensorineural hearing loss as a result of aging (see Glick & Sharma (2017) for a review on these above topics).¹¹ This is significant because many individuals who would benefit from hearing aids as demonstrated on an audiogram end up deferring treatment. One recent study showed that many potential hearing aid candidates wait an average of 8.9 years from the time of their initial diagnosis to being fit with their first pair of hearing aids.³⁸ While these individuals are delaying treatment, all the meanwhile their brain is slowly changing in response to the reduction of stimulation to the auditory cortex. Based on these findings, by the time of hearing aid treatment a candidate's auditory brain at a functional level can be very different from what they experienced when that person experienced no hearing problems.

Anecdotally, the longer a hearing loss is left untreated, the harder the rehabilitation process is generally with hearing aids. Individuals who have untreated hearing loss for many years may have poorer outcomes when they decide to finally pursue hearing aids. These crossmodal changes in the central nervous system might offer a visual explanation of why speech understanding in individuals with longstanding hearing loss is limited even with optimally fit hearing aids. Speech understanding is also exacerbated by competing background noise or other distracting stimuli-



the brain has to do extra work to try to make sense of the incoming auditory signal. This has been demonstrated in research that measures pupillometry, or measurement of pupil dilation to difficult auditory stimuli.⁴⁷⁻⁴⁸ Hearing loss is now being shown to have direct effects on how our brain functions.

Several recent studies have described an association between hearing loss, cognitive decline, and dementia.^{9, 14, 24, 26, 41} Hearing loss prevention has been deemed the largest modifiable risk factor for development of dementia, ranking above other common risk factors such as smoking, high blood pressure, lack of exercise, and social isolation.¹⁹ It is estimated that hearing loss accounts for up to 9.1% of the modifiable risk for dementia.²⁵ A recent longitudinal study by Sarant et al. (2020) found that hearing aid performance resulted in significantly improved cognition for participants 18 months following hearing aid usage.³⁶ Though results are still preliminary in establishing a direct causal link, results are encouraging and may suggest that in order to preserve our brain, we may need to more strongly consider preserving our hearing. In light of the abundance of research suggesting the beneficial usage of hearing aids, one pattern that needs addressing is why those who could benefit from hearing aids elect often not to.



HEARING AID ACCEPTANCE—AN ELEPHANT IN THE ROOM

Hearing loss for most individuals is a marathon—not a sprint, and hearing aids aren't a “one-time fix.” It can be a lifelong journey that requires consistent reinvestment in one's health. For

hearing aids to work properly, they require both routine maintenance and follow-up care. Despite the documented benefits, discussing hearing aids for many individuals with hearing loss can be a frustrating topic. In the United States, it is estimated that upwards of 28.8 million adults could benefit from hearing aids.³⁰ According to one survey of American adults, only about 30% of those with hearing aid difficulties pursue treatment.¹⁵ Reasons behind poor acceptance and tolerance of hearing aids can vary for each person, but one of these reasons is often the high cost of amplification.^{2, 15, 21, 22, 32} Though some financial assistance programs are available and some insurance policies are now starting to include hearing aid benefits, today's modern hearing aids can end up costing patients several thousand dollars out of pocket. Other often cited reasons for deferring treatment include: difficulty with care and maintenance, discomfort while wearing the devices,³ difficulty in noise,¹⁷ lack of perceived benefit, the perceived stigma of wearing the devices,²² the presence of other more pressing health problems or comorbidities,³⁴ relying on other's bad experience with hearing aids,⁴³ and a lack of perceived hearing problem.³² Whatever the reason may be, it is important to understand that hearing aids are incredible medical devices. They are tools that can change a life and help individuals with hearing loss reconnect with the world around them. Our ability to hear is not just an important part of communication with friends, family, and loved ones, but it can also be critically important for safety. For safe interaction with our surroundings we need to be able to hear things like alarm systems, knocking on the door, and footsteps of someone approaching you. Many individuals with hearing loss will need to become assertive advocates for themselves. Examples include seeking preferential seating at a gathering or restaurant, asking communication partners to rephrase instead of repeat, and acknowledging a hearing loss prior to conversation starting so that if things are missed in conversation, frustration can be avoided.

A fundamental part of hearing aid success is putting forth realistic expectations for hearing aid usage, in that even with the best hearing aid technology it's highly unlikely that hearing aids will perfectly overcome every communication barrier or prevent all communication problems. Hearing aids do not restore normal hearing sensitivity, and with each person having upwards of ten thousand hair cells in their ear, everyone has their own “auditory fingerprint” in that no two hearing losses are going to be the same even if scores are identical on a hearing test. Even more to consider, there are

many amplification companies that offer a variety of products and services. With the addition of the signing of the Over the Counter Hearing Aid Act of 2017, to date this market space has expanded further when considering the widely unregulated direct to consumer marketplace. Many of us have received numerous mailed flyers or seen commercials or advertisements for these products. Navigating this space can and making these large investments be extremely confusing for someone pursuing treatment.



This is why it is highly recommended that you consult an ENT physician to rule-out medical involvement related to hearing loss and seek out a hearing healthcare provider to partner with you and help navigate your own personal hearing health journey. A hearing healthcare professional will be able to work within your unique situation, resources, and support network to help you make the most out of your amplification treatment options. Many clinics work with state assistance programs or other organizations that work with those with limited budget for hearing aids such as the Starkey Hear Now program, Hearstrong organization, and other services such as the Lion's Club hearing aid recycling program (HARP). Hearing healthcare professionals will be able to connect you with these local resources and formulate a plan to help ensure that your treatment plan is optimized for your lifestyle.

Oftentimes hearing aids themselves are not enough to fully address all concerns. Hearing aid wearers may need to consider other hearing assistive technology (HAT) such as telephone amplifiers, caption assistance, telecoil/FM technology, remote microphones, and other alerting devices such as vibrating alarm systems or smoke detectors with strobe lighting. An individualized treatment plan might also include aural rehabilitation classes to help minimize the impact of hearing loss on daily

activities and participation. These professionals also can connect candidates with national and local support groups such as the Hearing Loss Association of America (HLAA) and online support forums. These can be great resources to pick up tips and tricks from peers who have overcome similar issues. It is the author's opinion that you should seek out a clinician who offers an evidenced based practice that uses both validation and verification measures (through "real-ear" measurement) to ensure that the devices are working properly. It is also important that candidates be sure to ask which (if any) services are included in the cost of hearing aids, and whether subsequent follow-up care are a part of the pricing model. There are also several YouTube videos that delve into these topics more in detail. Most hearing aid companies also have a lot of information, white papers, and research online that outlines their various features. It's important for everyone considering hearing aids to be an informed consumer and voice their concerns to their hearing healthcare professional.

TYING IT ALL TOGETHER—HEARING AIDS, BALANCE, AND NEW HORIZONS

Hearing aid technology has greatly improved even over the last few years. Going into detail about every hearing aid feature and company is beyond the scope of this article, though some general trends are evidenced across all manufacturers. Hearing aids have become exceptional at taking in information and applying changes automatically based on what environment you're in, with most devices scanning your surroundings and looking for changes in acoustic information thousands of times each second. This has led to vast improvements when it comes to speech understanding in the presence of background noise, and overall user comfort in challenging listening environments. Form factors, or the shape of the hearing aid shell, has reduced considerably to make hearing aids more cosmetic and low-profile. Rechargeable and lithium ion batteries have been introduced which eliminate the added expense of disposable batteries and the need to change them weekly. Moreover, hearing aids are increasingly user-friendly. Many hearing aids are able to connect directly with smartphones to stream phone calls and media wirelessly. There are several companies that offer free to install apps that allow hearing aid wearers to adjust device volume, create their own soundscapes for various environments, make small programming changes, and help locate the devices if they are lost. Companies also have invested in making their hearing aids durable so they need to be repaired



less frequently, with most manufacturers using a nano-coating to make hearing aids more resistant to dust, debris and water. Each manufacturer has a different fitting philosophy and approach toward treating hearing loss, and these should be discussed in more detail with your hearing healthcare professional.

One company, Starkey Hearing Technologies, however, has recently pioneered technology that draws an important connection between hearing and balance—fall detection. In their latest flagship product, the Starkey Livio AI, the hearing aid wearer can select up to three contacts in their Thrive Hearing app who are notified when there is a fall event. When a fall is detected, an audio prompt allows the user to validate whether a reported fall has occurred for 60 seconds before sending an alert with a GPS location to their selected contacts. The contacts can then reach out to the wearer to check in on them. Starkey CTO Anchin Bhowmik detailed this capability at the 2018 Starkey Expo and was featured in The Hearing Review for his description of how this technology could help those with dizziness.³⁹

"MAYBE YOU DIDN'T FALL, BUT INSTEAD JUST FELT DIZZY OR WERE OTHERWISE FORCED TO SIT DOWN ON THE FLOOR," EXPLAINS BHOWMIK. "OBVIOUSLY, THIS IS NOT A FALL. BUT YOU CAN STILL USE THE MANUAL ALERT TO GET HELP WHEN YOU NEED IT. BY TAPPING A BUTTON, YOU CAN SEND AN AUTOMATIC ALERT TO YOUR CONTACTS, TELLING THEM YOU NEED ASSISTANCE."

-ANCHIN BHOWMIK, STARKEY CTO

Starkey reports that since their devices work with the vestibular system in the inner ear that work to help stabilize the head and neck, this system is more accurate and less prone to mistakes than other fall detection devices worn on other parts of the body. This is especially true for bilateral users, as these individuals have two fall detection sensors (one in each device) compared to a single unit, which gives rise to better detection and performance. This is just one way that hearing aids are pushing the boundaries of what these devices can do and how they have multiple functions.

Our understanding of the hearing and balance organs continues to increase and will likely see

that these systems are even more connected than we previously knew. As several organizations are now working with Congress to raise awareness and educate policy makers on the effects of hearing loss and the struggles of those seeking treatment, perhaps soon we will see these products become more widely accessible for those that need them.

*This article is intended for informational purposes only. No endorsement is implied.

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