Université Claude Bernard Lyon 1

INSTITUTE OF ADAPTATION SCIENCE AND TECHNOLOGY

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Impact OFS HELPS AUDITIVEOn PostURAL EQUILIBRE

MEMOIRE submitted for the

AUDIOPROTHESISTE ETAT DIPLOME

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Summary

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RESUME

Goals: The risk of falling is a major public health problem. Every year in France nearly 9,300 people over the age of 65 die as a result of a bad fall, according to INPES. The purpose of this brief is to demonstrate that the wearing ofso-called aids has an impact on the postural balance and would allow better management of patients over 65 years of age. We looked at what parameters were changed by the wearing of hearing aids.

Materials and method: 57 subjects were tested during this study on the space of one appointment per person. A setting to balance hearing aids was initially made. Patients were tested on a platform(MediBalance Pro) to calculate the swing, speed and range of movements of

the centre of gravity in the presence of noise in different situations; open-closed eyes and platform-platform and cushion.

Results: We noted that the balance score is significantly better when the patient is wearing hearing aids. Swinging, speed and range of motion are significantly better with hearing aids in dynamic situation: closed eye cushion. No correlation could be demonstrated between the wearing of hearing aids, gain, seniority of equipment and data logging.

Conclusion: We were able to validate our hypothesis without highlighting a potential correlation with the different parameters of hearing aids. With thisstudy, it is important to take these results into account in the management of patients by the audioprosthetist.

INTRODUCTION

Six million French people have hearing problems. Of these, 60% are over the age of 55. Hearing loss is a serious condition that can have serious consequences on a person'slife, both physiologically and psychologically.

It is often forgotten that the auditory system (cochlea) and the vestibular system (vestibule) are both part of the complex organ of the inner ear. Functionally, they process incoming signals and transmit them to the brain. The alteration in the number of hair cells obviously affects the hearing organ with aging, but also the balance organ. However, today hearing disorders are mostly treated to prevent social isolation and loss of autonomy.

The World Health Organization (WHO) has published in 2018 that falls are the world's second leading cause of accidentaldeath, with about 646,000 deaths eachyear, after road accidents. The majority of people affected by these accidents are over the age of 65, and each year there are more than 37.3 thousandfalls thatresult in medical care.

According to the National Institute for the Protection of Health Education (INPES), 9,300 people over the age of 65 die in France each year as a result of a fall.

This is a major public health issue. For severalyears, a lot of research has been put in place by health professionals (ORL, audioprosthetists)to establish the impact of hearing onbalance. But the treatments put in place are mainly focused on muscular and visual rehabilitation and do not take into account hearing disorders.

The purpose of this brief is to assess whether the wearing of hearing aids in a patient   improves his postural balance,and to determine what factors are altered by hearing aids related to balance. So it would be interesting to see if the improvement of the balance is to be taken care of by the audioprosthetist, and if the latter has a role to play among the multidisciplinary aids put in place by health professionals to reduce falls in a patient.

First we will do an anatomical reminder, then a reminder of the different binaural mechanisms of hearing allowing the location. We will summarize the studies related to our subject.

We will then see what protocol has been put in place in this brief to address our problem.

We will outline our findings to highlight which factors are significantlyof interest to our study.

Finally, we will be able to conclude and discuss the role to beplayed by the audioprosthetist, in relation to the risk of falls and hearing in the elderly.

I. Postural Balance

1. Posture

Posture is defined as the maintenance of everything or a party of the body in a position of reference. It is defined in relation to the disposition of the different corporate segments in correlation with the morphology of the individual. It precedes and accompanies body movement.

In humans, the fundamental posture is standing. Unlike young people with a centered centre of gravity, older people project their centre of gravity backwards.

2. Balance

Balance is the state of a resting body solicited by forces that compensate for or cancel each other out.

According to J. Jacquemard and M. Costille , "The balancing function is the set of reactions put into play by the central nervous system to keep a projection of the center of gravity in thesustenance polygon."

An individual's static balance will be conditioned by several factors; the weight of the individual (in a certain limit, the heavier one is the more stable one is), the height of the center of gravity (the higher it is and the less stable one), the ability to maintain a muscle tone large enough to maintain the force of the body on the ground, and finallythe projection to the ground of the center of mass which must be in the "sustenance polygon" and which is delimited by the differentpoints of support of the person(E. E. Please).

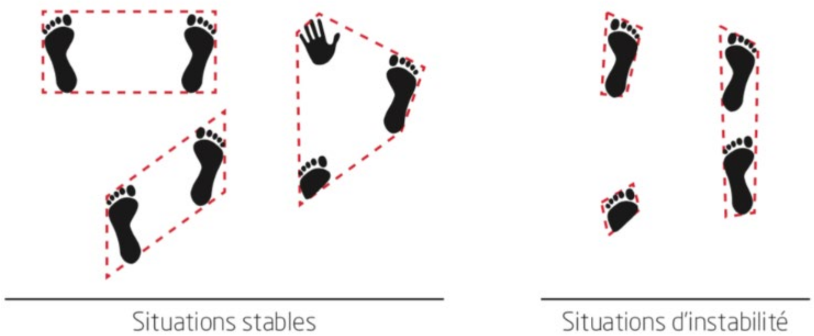


Figure 1 the sustenance polygon

(Source : https://www.broussal-derval.com/2019/02/27/lequilibrioception/)

3. Balance and posture

The ability to maintain a posture in the contrary is called balance. It allows us, among other things, to act against gravity.

The postural static balance refers to a motionless object. It is maintained by skeletal structure and the effectiveness of muscle tone. It is mostly managed involuntarily and automatically. Depending on the stability of the body, it diligently maintains its posture thanks to a set of sensory sensors that inform the real and desired postural gap.

Dynamic balance is when the shape or size of the sustenance polygon changes. The postural dynamicbalance allows us to adapt our posture to external events in order to stayupright and maintain balance during a movement. It refers to forces that cancel out in the presence of a movement of the body. Physiologically, the sensory sensors of balance still have great importance because it is indispensable to have information related to the actual and desired postural gap during movement. The body will set up mechanisms to accompany a change in posture by playing for example on the stiffness of the muscles, by widening the sustenance polygon, by modifying its supports, or even by preparing the damping of a fall.

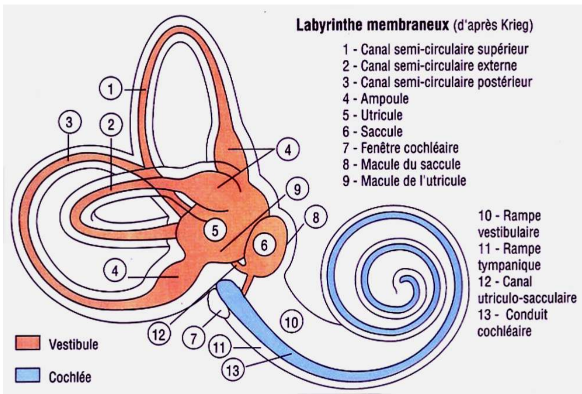
II. Proprioception, sensory sensors and cortical integration.

Proprioception can be defined as the set of unconscious neuromuscular means that can restore an imbalancein a short period of time. It combines the eyes, the inner ear, and all the neuromuscular information that can give immediate information about the body's position in space (P. Pilardeau). It therefore involves different sensory sensors:

a. *Labyrinthine* receptors: The vestibular system is located in the inner ear. The receivers are located in the posterior lateral position in relation to the cochlea. It has two systems:

- the ductal system which has three semi-circular channels (upper,external, and posterior) sensitive to the accelerationof the head and allows to determine its position inspace. These three channels are the so-called "ampullar" sensors.
- the otolithic system, composed of the utricule and the sacculus, whose receptors are sensitive to the linear and angular acceleration to which the body is subjected. These two sensors are called "macular".

At the root of each semi-circular channel is the "cup" which is a small hollow ball made up of a gelatinous substance in which the sensory cells connected to the vestibular nerve are located. During a movement, the endolymph (the liquid contained in the semi-circular channels) moves and enters the bulb, which produces pressure in the cup. The blinkcells are stimulated and transduction the fluid movements into electrical potentials which are then transmitted to the central system. Vestibular hair cells are innervated by primary related neurons that make up the vestibular nerve.



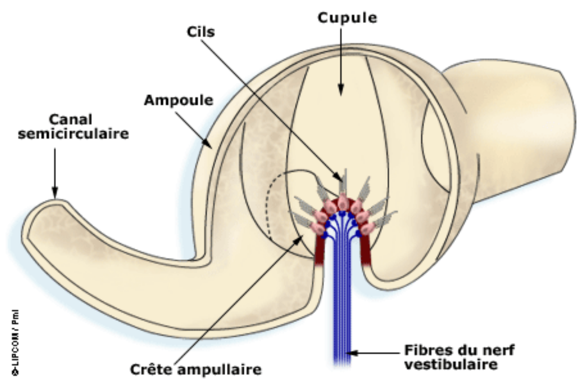


Figure 2 Labyrinthic Receptors

(Source : https://www.futura-sciences.com/sante/dossiers/corps-humain-oreille-numerique-avenir-audition-2031/page/2/ http://www.neuroreille.com/levestibule/chapb/f_parents-chapb.htm)

b. *Visual receivers:* are essentially an element of orientation and provide cues for space movements. Vision allows an individual to place his body in relation to the objects around him. The information provided by visual receivers is used for posture, balance and orientation.

c. *Somesthetic receptors: they are a fundamental entry route to* balance. The mechanoreceptors of the soles of the feet, joints and muscles play a major role in adapting the reflexes of balance. They provide information on the position and movements of different parts of the body, the pressure and the degree of tension.

d. *Summary:* The electrical potentials collected from the receptor cells of the various sensors are then transported to the vestibular nuclei; puis, to the spinal cord centers for rapid reflexes, or to the brainstem and brain for more complex integrations, possibly involving consciousness and will. Once the information is integrated and processed, the centres carry orders through so-called eerating fibers

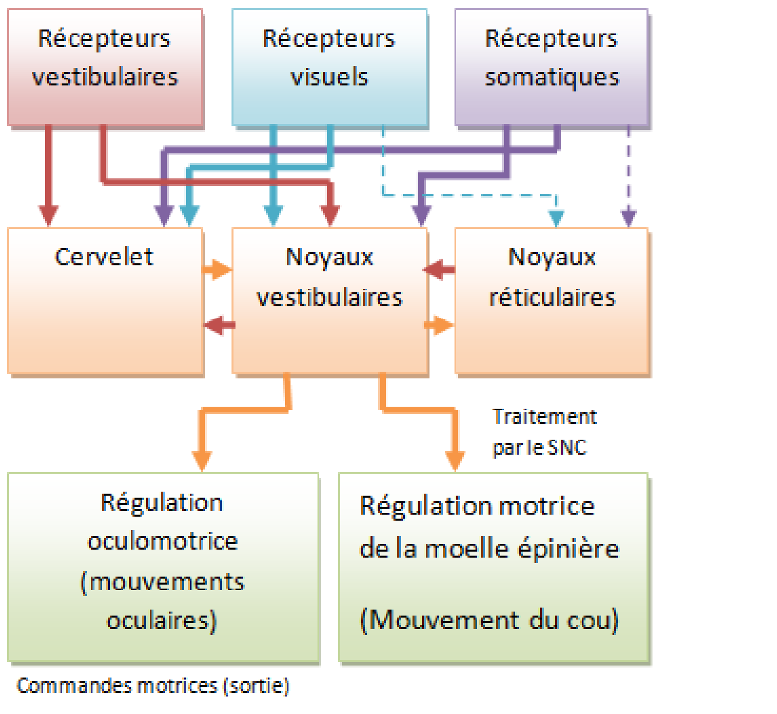
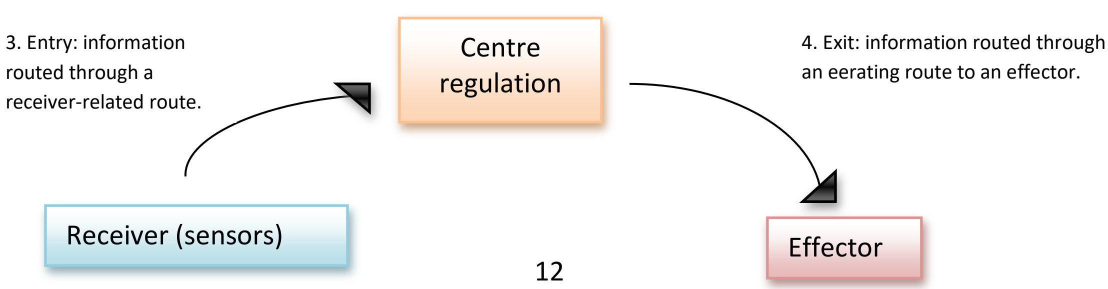


Figure 3 Ways to balance and orientation

(Source: Elaine N.MARIEB Human Anatomy and Physiology)

In the vestibular system, there are two essential targets: the eye musculature, which allows the movement of the eyes and thus allows the stabilization of the gaze, and the body musculature that helps to maintain the posture by moving segments Body.



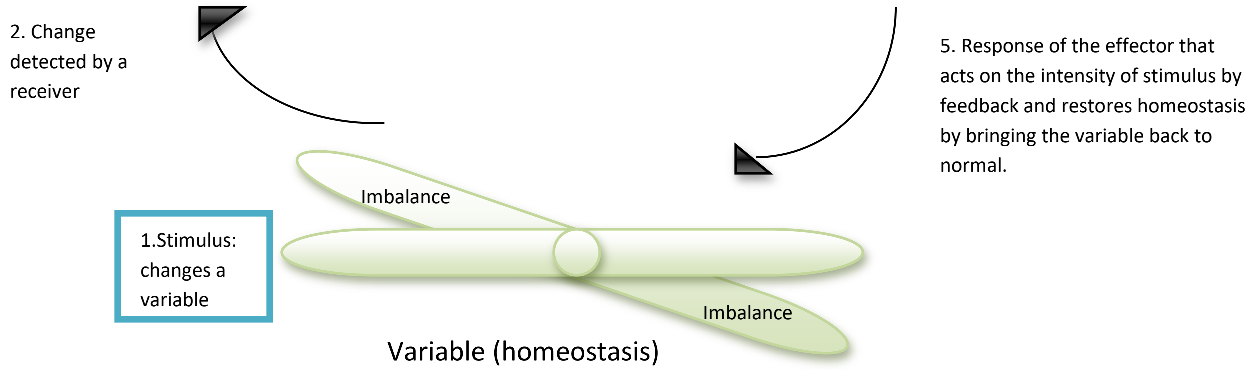


Figure 4 The elements of a regulatory mechanism

(Source: Elaine N.MARIEB, Human Anatomy and Physiology)

III. Audition binaurale

Our auditory system is composed of two ears arrangedon either side of our head. Thisfeature allows us to locate sounds in a complex sound environment. A binaural auditory balance is the condition of a good sound localization and a good understanding of speech in noise.

Spatialization is a person's ability to identify the origin of a sound source, its direction and its distance. In a horizontal plane, the main clues that allow the ear to locate an audible source are signal differences(see1. Sound spatialization) that reach both ears. In a vertical plane, monaural cues are mainly used, which result from changes in sound by being reverberated on the head and outer ear (flag).

1. Sound spatialization

Whena sound source is perceived by a subject,the acoustic fields reaching thex two ears aredifferent. Itsasymmetry is due to several physical phenomena: the attenuation of the sound beam reaching the opposite ear to the source, due to the shadow effect ofthe head, the diffraction of the sound beam, and the difference in the walking of the two waves. These physical phenomena introduce differences in levels, phases and time.

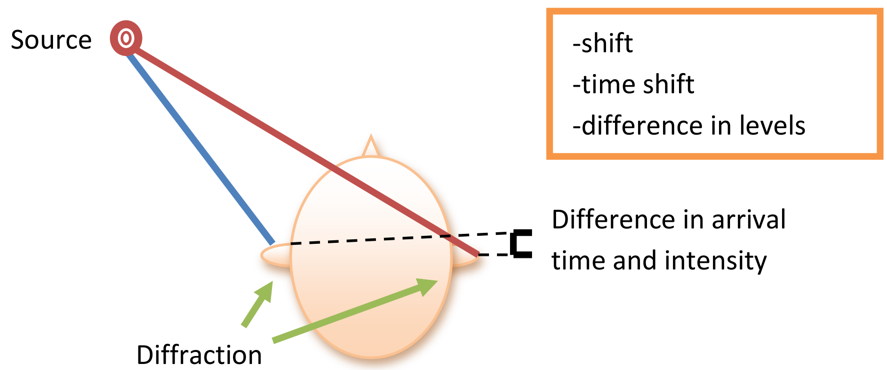


Figure 5 Acoustic pathways of the rays from a sound souce on the left of the subject

a. Level Differences*(ILD Interaural Level Difference)*

The interaural differences in intensity correspond to the differences in perceived sound levels between the two ears.

Several experimental and theoretical studies show that the differences in intensity between the acoustic fields measured at the entrance of the ear canals depend on the frequency of the sound, the morphology of the subject which can have an impact on the masking of the sound, and especially the azimut of the source. At low frequency, the interaural differences in intensity(ILD)arevery lowand not perceived. This phenomenon occurs if the wavelength of the sound is greater than the size of the head. The ILD is zero if the sound source is at equal distance from the two ears.

b. Différence de phases (*IPD Interaural Phase Difference*)

The phase interal difference(IPD)corresponds to the difference in the signal at the entrance of both ears. This index is mainly used for the location of low-frequency sounds.

c. Différence de temps (*ITD Interaural Time Difference*)

The time interaural difference(ITD)corresponds to the difference between the arrival of sound to both ears depending on the distance. The speed of the sound is 340 m/s, so the sound takes longer to travel a greater distance. This index cannot be used in cases where the sound source is at an azimut of 0 and 180 degrees because the distance between the source and the two ears is the same

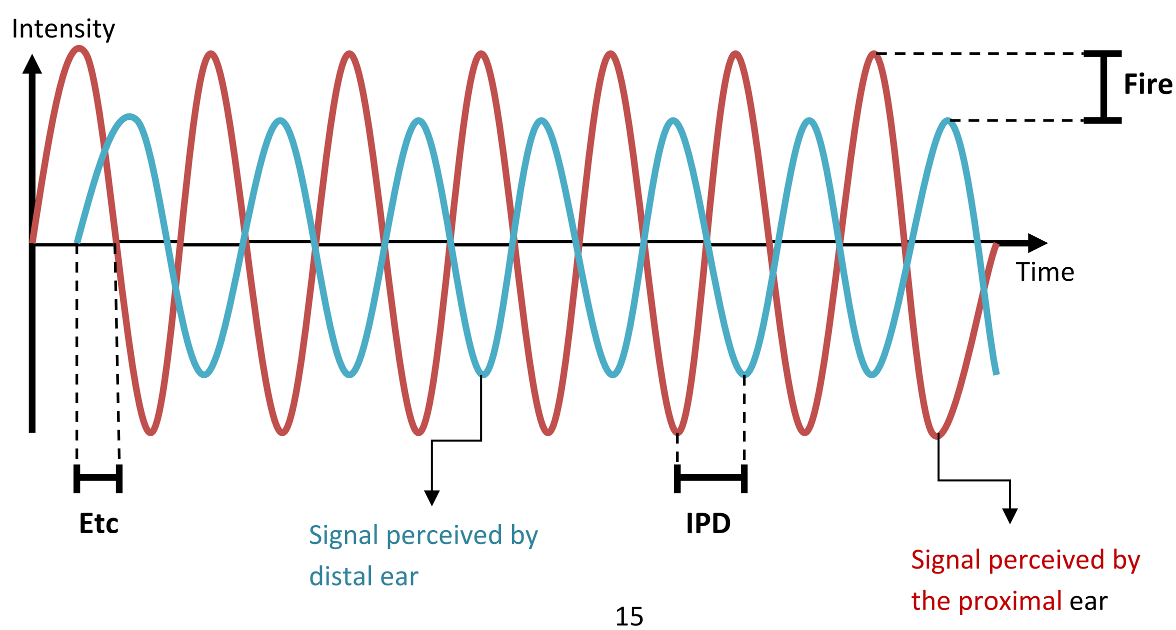


Figure 6 6: A difference in the perception of a sound source in a horizontal plane and characterization of interal differences for a sine signal (pure sound). According to (Hoen, 2014).

d. Spectral information

Spectral cues are used forlocalization in the vertical plane. They mainly involve the anatomy of the subject, for example the shape of the ear pavilion, the shape of the bust, the shape of the skull,etc. The sound waves that reach the patient are modified by reverberating. The angle of impact of the acoustic wave also changes the spectrum of the acoustic wave.

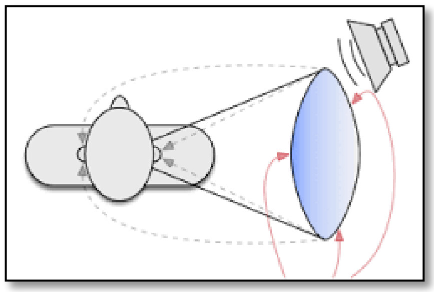
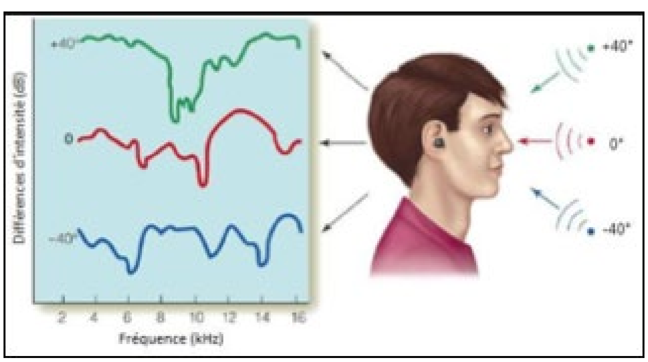


Figure 7 Influence of the vertical location of the sound source on the intensity of the signal measured at the duct according to the frequency.

e. Special case: Cone of confusion

Area that does not allow a precise location. The confounding cone represents all the points in space that communicate the same interaural differences (phase, time, intensity). This cone brings together all the points that are at the same distance from each of the two ears.



Equal interlacing difference

Figure 8 Confusion Cone (Source: https://science-of-sound.net)

2. Binauraux Mechanisms

The Squelcheffect, the binaural summons and the head screen are the various binaural mechanisms that come into play in the location.

a. Squelch Effect

It is a phenomenon that allows you to focus on a particular sound in a noisy environment. The information of both ears reaches the brain that analyzes them by making comparisons of the flow of sound elements. It is based on the interal difference indices of intensity and time seen previously because they can discriminate two distinct sounds. Too much hearing loss mitigates this phenomenon. The patient is then unable to concentrate on a specific source. According to a study by Peissig (1997), a separation of noise and source of 105 degrees is favourable to signal/noise unmasking.

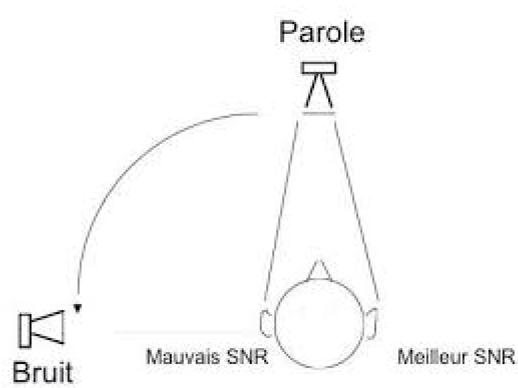


Figure 9 Squelch Effect

b. Binaural summons

When a subject has two healthy ears, the perceived information from both ears is amplified by the auditorybrain, which gives an impression of increased intensity. This phenomenon leads to an increase of 3 dB of perceived sound compared to a single ear.

c. Shadow effect of the head

The physical presence of the head in asound environment acts as an acoust-visual insulatorbetween the two ears and generates a difference in signal-noise ratio. To help with location and understanding, a listener relies on his ear which has the best signal/noise ratio.

3. Hearing location

The location of a sound source, based on the difference in the auditory fields at the pavilion level, requires taking into account three parameters: the azimut or position of the source in relation to a horizontal plane passing through the line of the ears, the distance of the source and its height (vertical plane)

a. Determining the azimut

Azimut determination is mainly due to phase-out for frequencies below 1500Hz, while conversely, for frequency waves above 4000Hz, it is the inter-intensity difference that plays an important role. In the area from 2000 to 3000Hz, itismore difficult for a patient to determine theazimut. This inaccuracy stems from an interaural difference of too little intensity and an inefficiency of the phase shift. This makes it difficult to pinpoint the exact source of the sound source.

In the case of a sound pulse, the time-intertwining difference between the rays that reach both ears also plays a role in determining the azimut.

b. Source height

The height of a source of pure sounds is difficult to determine and it seems that the pavilion associated with the movements of the head plays a role. In the case of complex sound, the spectral composition and pitch of the source significantlyaffect the location of a sound source.

c. Distance appreciation

The binaural function does not seem to intervene in determining distance.

In open field conditions, the intensity dependson the distance. It results that when a source moves away or approaches a listener, the level variations give accurate information and allow accurate detection of the movements of the source. On the other hand, when the source is perfectly still, for lack of references, the assessment of the distance by the ear israther blurred.

The spectral content of a source can also be used to determine the distance of the source, for example, in the context of an already known and identified sound source, such as the sound of anambulancesiren. We know that the further away the vehicle goes, the louder the siren noise; it's the Dopplereffect. When sound spreads in the air environment, the highs are more heavily absorbed than the bass, resulting in an alteration of proportions. By comparing it with the known sound, one is able to identify the distance of the sound source.

IV. Deafness and posture

1. Physiological ageing

Aging leads to a decline in the physiological systems responsible forbalance. At the level of the nervous system, proprioceptive sensitivity decreases and decreases in functional fibers as well as an increase in information conduction time in peripheral nerves promotes postural instability with aging (National College of Geriatric Teachers (2014).

For the aging of the visual system, it is the clouding of the lens and the decline in the ability to accommodate closely that are responsible for a decline in visual information that can lead to postural instabilities (French College of ORL and cervico-facial surgery (2008). Studies have shown that vision deprivation involves increasing the amplitude of body oscillations in the standing position by about 30%(Perunou,2012).

Finally, for vestibular function, aging can lead to vestibularomissions. Itremains normal but it is no longer requested. This corresponds to a non-use of vestibular function linked to a gradual decrease in mobility of the body but especially of the head. These vestibular omissions then become the cause of imbalances (French College of ORL and cervico-facial surgery (2008). Aging also causes a decrease and degradation of vestibular hair cells.

At the auditory system level, there may be a decrease in discrimination in ITDs, with an aging of the ear that results in a longer period of sound conduction between the eardrum and the inner ear as well as a longer conduction of the action potentials of hair cells. A reduction in discrimination of the ILD is alsopossible. It is due to the pinching of auditory dynamics that alters the sensation of sound level, which can lead to a poor analysis of the spectr cues.

2. Perception deafness and postural impact

Hearing loss is also characteristic of aging and it impacts all the location systems stated above. In a healthy subject, 70% of the information used for good stability comes from muscles,20% from the vestibular system,and 10% from the visual system. In a situation of instability (soft/unstable soil) the impact of the different systems on the balance is reassessed, the vestibular and visual information are then more important (A. Berthoz). In addition, older adults are very sensitive to the reduction or suppression of certain sensory channels which can be detrimental in maintaining their posture(Teasdale et al. 2001).

In 2009, a study conducted by A. Viljanen et al., on more than 400 twin subjects,showed that hearing loss causes a deterioration of postural balance because it is poorer in sensory information, and the risk of falling can be three or four times higher than for a normal-hearing person. No genetic link has been demonstrated between auditory acuity and postural balance.

A more recent study (Lopez, 2011) of approximately 5,000 Australian subjects looked at whether the sex of the patients predisposed them to a higher risk of falls depending on their visual and hearing impairments. As a result, the risk of falls, death and depression was increased with visual and/or auditory impairment. However, this risk is not greater in men or women, although men are mainly affected by hearing loss and women are affected by a decrease in visual acuity. In this study, visual impairment was also shown to have a greater impact on postural balance than hearing loss.

Zhong X et al. demonstrated in 2013 a link between spatial hearingand balance. These tests showed an improvement in postural control in the presence of auditory cues from a single speaker. The presence of auditory spatial cues allows an average swing reduction of 9% for the Tandem Romberg test, and a 76% reduction for the Fukudatest. However, the importance of the clearing effect that the vestibular system receives from auditory signals is lower than that of visual signals.

Both studies tend to show a link between hearing loss and fall. Because of the anatomical proximity of the organs to hearing and balance one wonders whether the hearing aid can have an impact on these two functions.

However, not all studies have demonstrated an improvement in postural control with external auditorysignals. The study by Raper SA and Soames RW shows that an external sound source producing pure sound or a pre-recorded conversation leads to more postural swings compared to a situation in silence.

3. Hearing aid and posture

We have seen previously that hearing loss has a negative impact on postural balance and therefore leads to a higher risk of falling.

It is therefore possible to think that with the help of a hearing aid, the provision of a more precise spatial representationallows the patient to better position himself and avoid imbalances. Several studies have shown a positive shift in balance in relation to the wearing of hearing aids.

A 2014 study(Rumalla, K., Karim, A. M., And Hullar, T. E.) published in the journal "The Laryngoscope" tested 14 patients over 65 years of age who had been wearing hearing aids for 3 months (ormore) with 25 dB gain for each ear and able to move. In the Romberg foam test, 10 out of 14 patients performed better in assisted condition. The results of this test are statistically significant. The results of the tandem test also showed an improvement in the balance with hearing aid compared to the unassisted situation. The results of the ABC test, evaluation of the overall level of physical functionality, showed no correlation with the results of both tests and patient performance. This study did not demonstrate a significant correlation between hearing aid gain and average improvement in patient performance on both tests. However, it is clearthat that wearing your hearing aids significantly improves balance results and decreases the risk of falling.

A study using a Nintendo Wii platform to assess center of gravity pressure also showed a slight improvement in balance in the presence of larger external sounds in normal subjects, but the results are inconsistent (Kanegaonkar RG).

In the study of Negahban.H et al. the results initially show an improvement in static balance with hearing aids, but they also show that the speed of movements of the centre of gravity is significantly reduced in assisted situations. However, during this study, patients are always tested inunassisted situation first. Theresults could therefore be explained by the postural fatigue of the patients.

Vitkovic et al. studied the effects of sound on postural swinging by observing the pressure center in 50 normo-hearing subjects,28 with hearing loss and 19 subjects with vestibular dysfunction.

In this study, it was shown that the normo-hearing used auditory signals to improve their postural control. Subjects with hearing loss had reduced ability to use sound cues, but this difficulty is apparently offset by the wearing of hearing aids.

Patients with additional vestibular deficits use more auditory signals, suggesting that sensory weighting to increase the use of auditory signals may be put in place to compensate for a vestibular deficit.

A dissertation on the same subject by Dal Yves (2017) demonstrated a non-significant improvement in balance. The frequenciesimplicated in this improvement appear to be 250 to 750Hz, especially the 750Hz. A frequency importance from 2000 to 6000Hz was also shown. An imbalance of these frequencies is not sufficient to explain a variation in spatialization performance, but the perception of these frequencies is very important.

Wearing hearing aids would also have an impact on the fear of falling in the elderly. A study (CF Lacerda), testing 56 elderly people with sensorineural hearing loss and using hearing aids, showed that wearing their devices increased self-confidence and in the long run reduced the risk of falling. Seniors responded to quality of life questionnaires, the health survey, the international fall effectiveness(FES-I) and the Berg Balance (BBS) scale test.

CLINICAL STUDY

I. Introduction

The purpose of this brief is to demonstrate that wearing hearing aids can help patients better control their postural balance and reduce their risk of falling. Returning to the patient laboratory on several appointments was difficult to set up. So we found a way to test patients in one appointment, this system allowed us to test more subjects.

During this appointment, audiometric tests are carried out at first, followed by a setting of the devices. Inthe year a second time will be carried out a two-phase balance test thanks to the MediBalance Pro scale.

II. Population studied

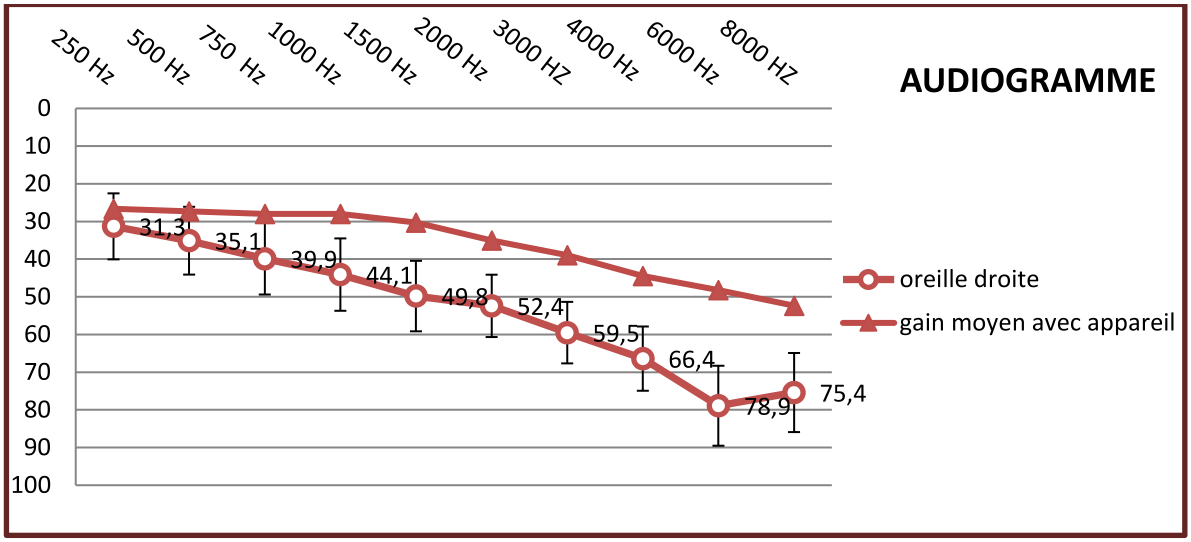
The recruitment of patients was done on a voluntarybasis. Tests were conducted on a total of 57 people, but only 50 cases were selected.

The exclusion criteria were:

- 4 subjects were unable to do the entire test due to too much postural instability, fear of testing or physical painin the legs.
- 2 topics for which a technical problem occurred when the results were displayed on the software.
- 1 subject who caught up in the middle of the test at the walker placed in front of him, thus distorting the results.

Of the study, 19 women and 31 men were tested. Patients in the study have an average age of 69.58 between 40 and 90 years.

The average audiograms (dB HL) of patients right and left ear are presented below:



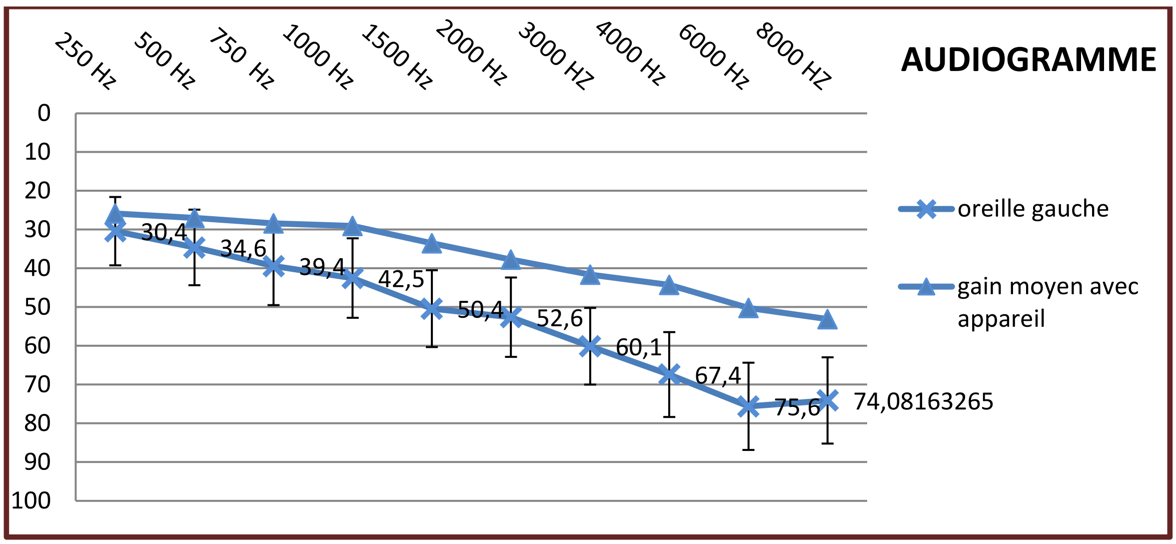


Figure 10 Average audiogram of patients tested right and left ear.

Audiometric imbalances after the right-left ear setting are shown below in absolute values:

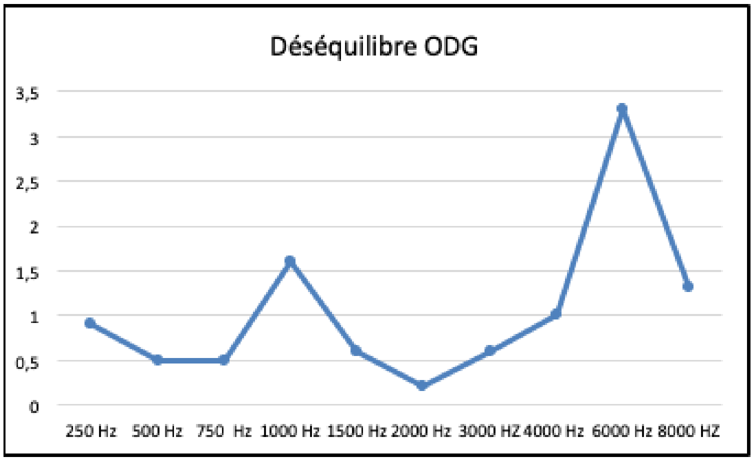


Figure 11 imbalance between right-left ear after setting in absolute values (dB HL)

Of the 50 patients tested, four are machine-fitted. No cross/bicross system was entered into the study. Hearingaides are described below,as well as the physical characteristics of the patients tested:

Type of hearing aids	
RITE	43
BTE	4
CIC	2
Lyric	1
TOTAL	50

Patient weight	
Average weight (kg)	74.46
Minimum weight (kg)	46
Maximum weight (kg)	112
Ecart-Type (kg)	13,98

Patient size	
Medium height (cm)	168.78
Minimum size (cm)	154
Maximum size (cm)	185
Ecart-Type (cm)	7,67

Only four people tested wear Class 1 devices, the other patients wear Class 2 devices. On average, thepatients have been fitted for 5,8 years, the most recently fitted patient being adapted for 15 days, and the oldest being adapted for 16 years.

III. Material

The tests were carried out in the same soundproof cabin with the same equipment being set up.

The material used is as follows:

- 7 SIARE speakers, MODEL DELTA 60, calibrated.
- Speaker distribution box.
- The MediBalance Pro testplatform, provided with a walker allowing the patient to catch up in case of excessive imbalances.
- A cushion (sizes 38 x 47.5 cm, thickness 6.5 cm)
- Otometrics Software

Figure 12 MediBalance pro platform presentation

This platform was created by a German company "MediTECH" for all health professionals who can study symptoms such as dizziness, coordination problems, problems of daily stability. This platform has the function of re-educating patients through numerous postural exercises. It is composed of a foam part locatedunder the rigid platform. Thispart contains sensors that can represent the center of gravity in real time according to the patient's movements. We will only use the balance performance analysis mode. The patient stands on the test platform barefoot in front of the red visual marker at eye level. Two loudspeakers are located in front of the patient, and five others are located on the ceiling behind him, and spaced 45 degrees each. The walker is in front of the patient in case of imbalance.

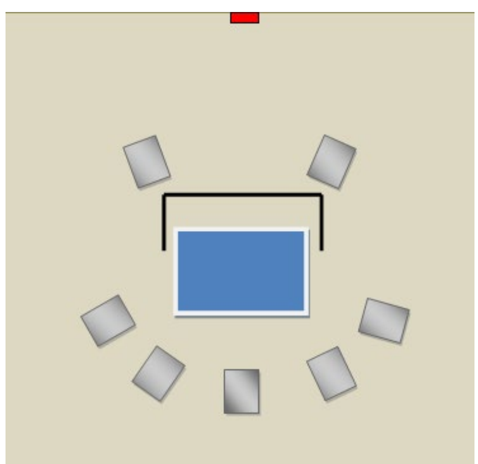


Figure 13 Cabin in balance test configuration

IV. Procedure

1. Protocol

At first, tonal audiometry on the headset is performed,as well as an ear-toned audiometry fitted in open field. A device adjustment is then made to balance the two ears as much as possible in order to best reproduce the binaural mechanisms stated above. Werely on ear-equipped tonal audiometry.

Atfirst, the patient is asked to remove his shoes, as well as getheavy clothes(coat, jacket, etc.). During the balance test the subject was asked to stand in four different positions; (1) motionless with eyes open on the rigid platform, (2) motionless with eyes closed on the rigid platform, (3) motionless with eyes open on the platform with the cushion, and (4) motionless with eyes closed on the platform with the cushion. During the step with the cushion, it is added over the rigid platform. The feet should be positioned on the platform markers, slightly apart, and the arms should be along the body. In front of the patient, at eye level, is a red marker that the patient must stare at when his eyes are open. Tests (1,2,3,4) are performed twice each sequentially, with and without hearing aids. Each step is completed over a 30-second period. We perform the first sequence with or without the hearing aids randomly so as not to influence the results.

Between each test sequence the patient is asked to sit down to avoid the fatigue factor. The speakers around the patient deliver the "Cocktail Party" noise at an intensity of 60 dB. This noise was chosen because it was more representative of patients' daily lives.

	Items calculated at each stage
Step 1: Rigid platform with open eyes	Swinging
	Speed
	Air
Step 2: Rigid platform with eyes closed	Swinging
	Speed
	Air
Step 3: Platform with open eye cushion	Swinging
	Speed
	Air
Step 4: Platform with closed eye cushion	Swinging
	Speed
	Air

Table 1 calculated foreachtest

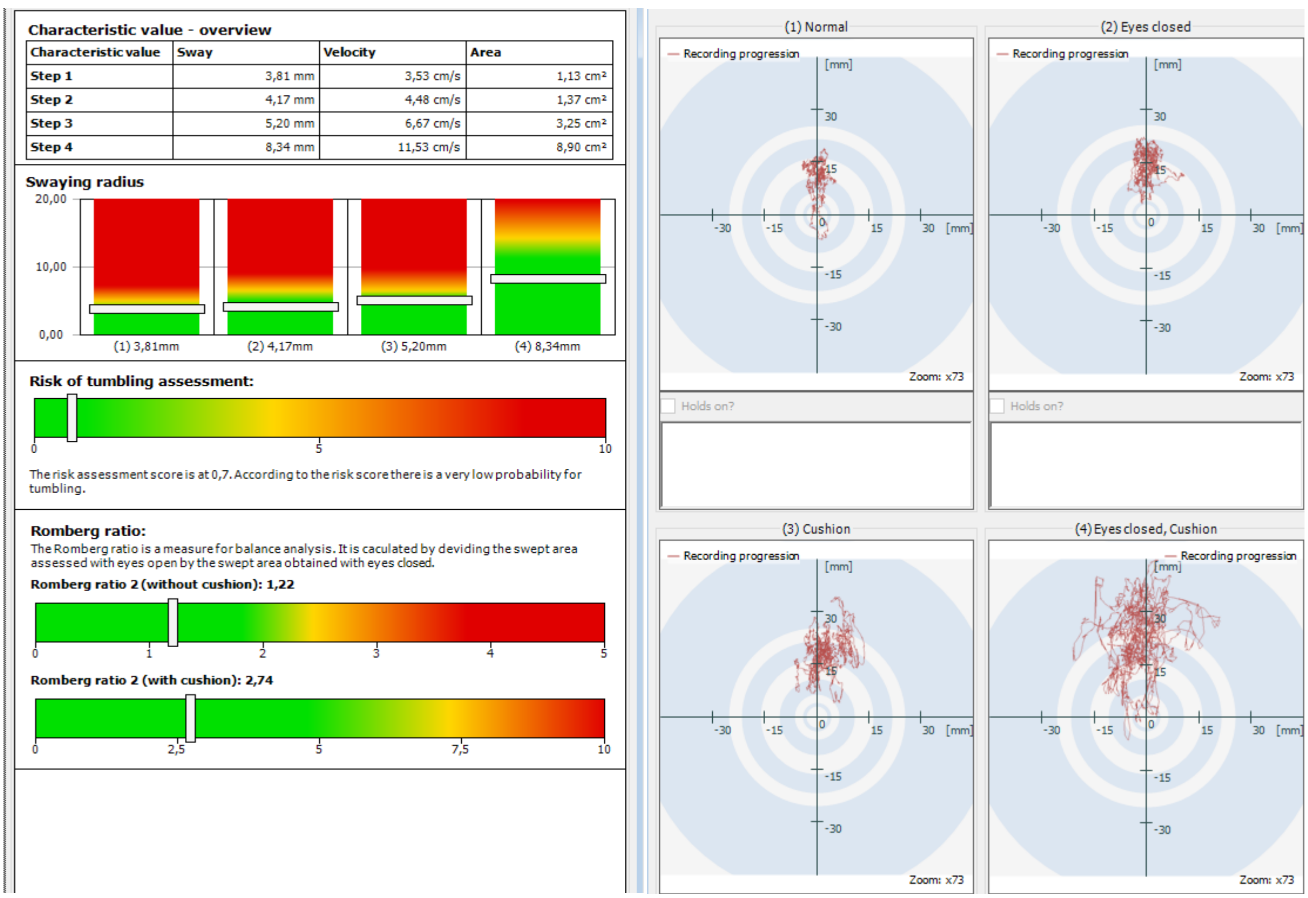
2. Platform result

The results of the scale is presented as below.

Figure 14 presentation of platform results for a patient.

The pressure center is raised in real time and allows a direct analysis of the patient's movements. Thanks to the evolution of this pressure center, different data are calculated: the sway, the speed,and the range of movements according to the different stages.

Iscalculated ensu ite, thanks to these three characteristics, the risk of <u>falling patients.</u> It is



established with an algorithm that takes into account age, height, weight and postural variations between the different stages of the test.

The Romberg Ratio is also determined. The Romberg test is very often used in posturography. Postural control is evaluated fortwo different conditions years; eyes open, and eyes closed. Romberg's quotient is determined by dividing the recorded area corresponding to the postural swing in the closed-eye position and the recorded area corresponding to the open-eye swing (MediBalance Pro Instruction, MediTech). This test is an indicator of the vestibular and proprioceptive contribution of postural control when performed standing and on a firm surface(A. Shumway-Cook, F.B. Horak).

For each patient, a comparison is made between the paired and unpaired results.

RESULTATS

In this section, we explain the results of the various tests carried out: the characteristic values of the different stages (1, 2, 3, 4), the risk of falling, the results of the Romberg Ratio and the self-assessment of patients on their own balance with and without hearing aids.

The data "age," "size," "weight" and "sex" are already integrated into the results of the MediTechplatform, so this data has not been processed in this memory.

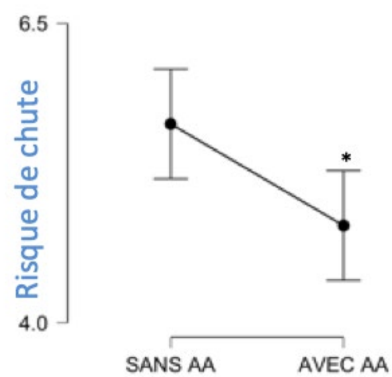
I. Risk of falling with and without hearing aid

The table below (see Figure 14)shows the scores obtained by patients. The risk of falling is estimated on a scale of 0 to 10, with 0 being the highest score and 10 representing the maximum fall risk. This data is calculated based on the patient's age, height, weight and various postural characteristics captured during the test. Beloware the results of the fall risk test. The first column represents the score of patients in the test without hearing aids, the second column represents the score of those same patients tested this time with their assistants, and the last column represents the difference in score between the two. Theupgrade is shown in green while a degradatioof performance isshown in red. Only one patient had an equivalent result in both situations.

To find out if the evolution of the balance score is significant we used a Ztest. For the difference between the two tests to be significant, "p-value" must be less than 0.05. Indeed: "If an event has less than a 5% chance of occurring due to the fluctuation of sampling, it will be considered that this is not due to chance and that the difference observed is significant" (Colin, statistics course, first year of audioprosthesis,Lyon).

	risque de chute						
	sans aa	avec aa	écart		sans aa	avec aa	écart
1	8	8,8	-0,8	26	6,2	4,7	1,5
2	9,7	2,3	7,4	27	2,2	4,5	-2,3
3	10	10	0	28	4,7	1,9	2,8
4	7	5,9	1,1	29	3,5	1,7	1,8
5	4,5	4,2	0,3	30	10	6,9	3,1
6	7,1	5,7	1,4	31	3,6	8,5	-4,9
7	2,7	4,8	-2,1	32	3,9	4,2	-0,3
8	2,6	1,2	1,4	33	3,4	4	-0,6
9	6,7	7	-0,3	34	8,3	4,2	4,1
10	5,4	3,7	1,7	35	5,3	5,9	-0,6
11	4,9	7,2	-2,3	36	1,5	1	0,5
12	8	7,9	0,1	37	1,1	5,2	-4,1
13	8,5	6,7	1,8	38	8	2,8	5,2
14	6,4	4,4	2	39	1,7	3,4	-1,7
15	7,9	7,1	0,8	40	4,3	1,1	3,2
16	10	9,2	0,8	41	0,7	0,2	0,5
17	7,2	6,8	0,4	42	7,8	7,7	0,1
18	2	1,1	0,9	43	5	4,9	0,1
19	7,7	6,9	0,8	44	3,3	0,4	2,9
20	5	0,5	4,5	45	10	5,8	4,2
21	9,3	10	-0,7	46	6,5	2,9	3,6
22	4,7	2,5	2,2	47	4,4	4,8	-0,4
23	9,7	9,3	0,4	48	2,1	4,4	-2,3
24	3,4	0,8	2,6	49	4,1	3,7	0,4
25	3	3,1	-0,1	50	10	8,7	1,3

Table 2 Evolution of the balance score achieved between Test 1 without aa and Test 2 with aa



moyenne d'amélioration =		0,848
Test Z	p-value =	0,01
	significatif =	OUI

Figure 15 evolution of the balance score

In this test, 34 participants achieved a better result in assisted situations. This table shows us that the balance score is significantly better when patients wear their hearing aids ("p-value" 0.05). The average improvement in the balance test score is 1.93.

II. Improved balance variations with hearing aids.

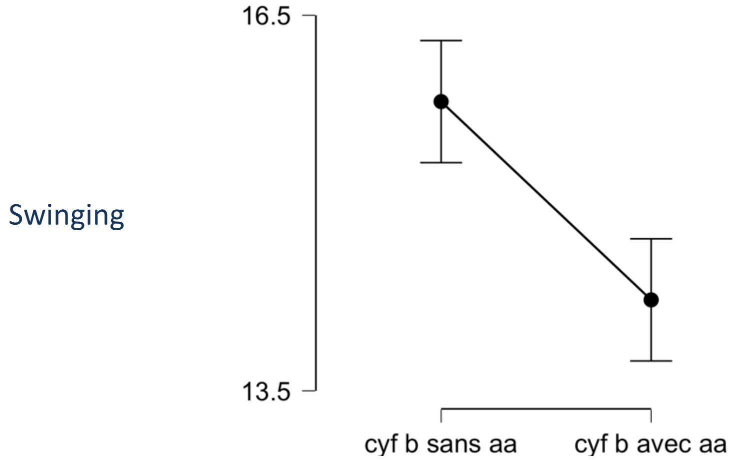
We have shown above that the balance is improved when the patient wears his hearing aids, so we canaskourselves on what characteristics of the balance the devices have an impact. For each of the steps mentioned above (1, 2, 3, 4) are evaluated the swing, the speed of movement, and the travel area of the patient's center of gravity. Using the Ztest, we test what characteristics have been modified by the wearing of hearing aids to allow a significant difference in the risk of falling.

	« P-value »
Swing - Open Eyes Platform - "AA-free" vs. "with AA"	0.670
Speed - Open-eyed platform - "AA-free" vs. "with AA"	0.119
Aire - Open-eyed platform - "aA-free" vs. "with AA"	0.679
Swing - Closed-eye platform - "aA-free" vs. "with AA"	0.618
Speed - Closed-eye detain - "AA-free" vs. "with AA"	0.249
Aire - Closed-eye detain - "aA-free" vs. "with AA"	0.207
Swinging - Open-eyed cushion - "aA-free" vs. "with AA"	0.375
Speed - Open-eye cushion - "AA-free" vs. "with AA"	0.324
Aire - Open-eye cushion - "AA-free" vs. "with AA"	0.503
Swinging - Closed-eye cushion - "aA-free" vs. "with AA"	<.001
Speed - Closed-eye cushion - "aA-free" vs. "with AA"	0.006
Area - Closed-eye cushion - "aA-free" vs. "with AA"	0.016

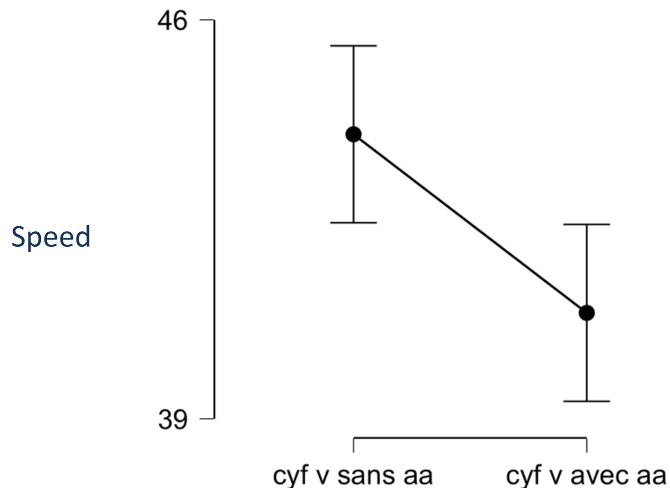
Table 3 Evolution of the different characteristics of the balance between Test 1 without AA and Test 2 with AA

On "closed-eye cushions" we notice that the difference between the "no a" and "aa" situation is significantly different for swinging, speed and area because "p-value" is less than 0.05.

Closed-eye dislikecushion, Blaunch without and with hearing aid



Closed-eyedislike cushion, Speed without and with hearing aids



Closed-eyedcushion, Aire sans and with areils auditive s

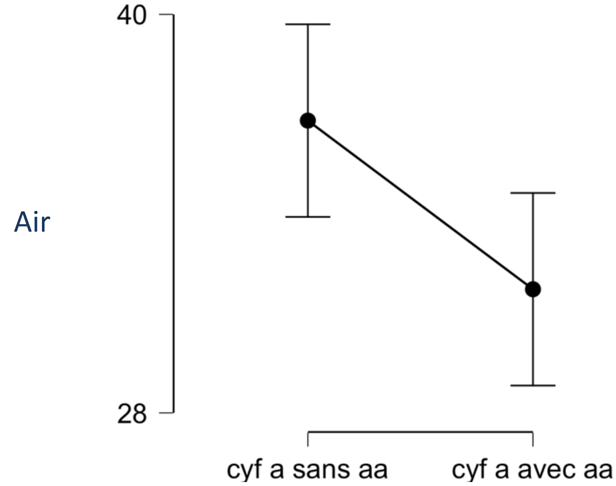


Figure 16 Changes in the risk of falling according to swing, speed and area, with and without hearing aids

However, in situations of "plateform eyes open without AA" and "plateform eyes open with AA" it is observed that thes score of speed and area are better s in the unassisted situation. The "Open Eyes Cushion" situation also shows a better score for speed in the unassisted configuration.

Below is a diagram highlighting the variation between the assisted situation and the percentage unassisted situation for each situation and characteristics tested.

In red are highlighted the significant data. It can be inferred that it is these values that contribute to the significant difference in the risk of fall seen above.

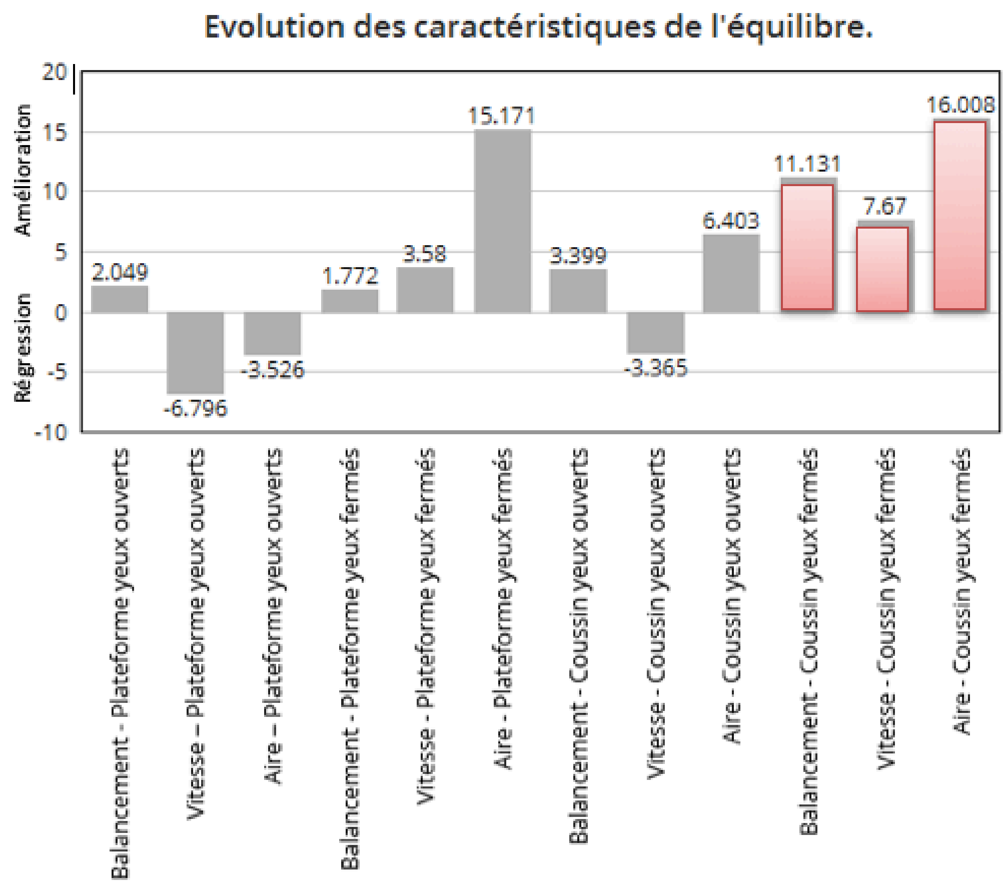


Figure 17 Changes in the characteristics of the percentage balance between unassisted and assisted.

These data are consistent with the results of the study (Negahban.Het et al) which showed that with the wearing of hearing aids the static balance was significantly improved but also that the speed of movements of the centre of gravity is significantly reducedin anassisted situation.

III. Romberg Ratio Analysis

The Romberg test is frequently used in posturography by comparing postural swinging in closed-eye and open-eye conditions.

	PAS COUSSIN			COUSSIN		
	SANS AA	AVEC AA		SANS AA	AVEC AA	
1	2,56	1,62	0,94	4,23	3,33	0,9
2	0,46	1,57	-1,1	3,4	6,2	-2,8
3	5,98	3,95	2,03	4,12	6,69	-2,6
4	1,29	3	-1,7	10,84	8,73	2,11
5	1,79	1,13	0,66	3,33	5,43	-2,1
6	1,52	4,19	-2,7	4,51	5,12	-0,6
7	1,32	0,28	1,04	4,45	10,3	-5,9
8	1,94	1,2	0,74	3,97	2,18	1,79
9	2,06	1,73	0,33	2,27	2,99	-0,7
10	0,88	1,59	-0,7	8,02	1,96	6,06
11	0,98	0,77	0,21	2,04	2,54	-0,5
12	2,25	2,14	0,11	4,98	6	-1
13	1,61	1,79	-0,2	5,14	3,89	1,25
14	3,21	3,69	-0,5	2,69	2,25	0,44
15	3,15	2,71	0,44	4,77	3,87	0,9
16	1,19	2,31	-1,12	3,21	1,46	1,75
17	1,94	0,57	1,37	9,08	1,19	7,89
18	1,53	1,51	0,02	3,07	1,46	1,61
19	2,51	1,91	0,6	7,14	2,95	4,19
20	0,75	2,09	-1,34	1,65	1,34	0,31
21	3,19	0,75	2,44	0,83	2,06	-1,2
22	3,11	0,97	2,14	8,93	5,9	3,03
23	1,92	3,95	-2,03	4,58	2,03	2,55
24	2,72	2,26	0,46	4,35	2,84	1,51
25	1,21	1,3	-0,09	4,92	1,45	3,47
26	3,8	1,72	2,08	4,04	2,54	1,5
27	1,68	0,78	0,9	2,86	3,32	-0,5
28	1,88	1,93	-0,05	5,1	5,2	-0,1
29	2,71	1,9	0,81	3,48	7,13	-3,7
30	6,76	2,88	3,88	6,64	7,23	-0,6
31	1,41	0,69	0,72	2,16	3,25	-1,1
32	1,61	2,21	-0,6	1,34	1,11	0,23
33	1,21	0,96	0,25	2,86	3,82	-1
34	1,38	0,88	0,5	9,41	3,99	5,42
35	1,56	1,3	0,26	2,67	1,93	0,74
36	2,21	1,22	0,99	4,88	2,05	2,83
37	2,61	3,17	-0,6	5,8	2,22	3,58
38	0,47	2,07	-1,6	1,61	1,92	-0,31
39	1,09	1,52	-0,4	3,84	3,92	-0,08
40	0,83	1,11	-0,3	6,77	3,74	3,03
41	1,22	2,67	-1,5	2,74	3,83	-1,09
42	1,84	1,62	0,22	5,59	5,52	0,07
43	1,14	2	-0,9	3,83	3,04	0,79
44	0,94	1,8	-0,9	3,01	4,49	-1,48
45	5	3,73	1,27	5,04	2,65	2,39
46	2,59	2,51	0,08	7,34	6,17	1,17
47	5,93	3,59	2,34	2,25	6,87	-4,62
48	3,84	0,62	3,22	2,55	1,86	0,69
49	1,75	1,07	0,68	6,07	5,2	0,87
50	12,81	4,38	8,43	7,25	10,34	-3,09

Table 4 Romberg Ratio's score changes in "aa-free" and "aa" situation

This quotient represents the integration of visual aferences into postural control. The purpose of this test in the context of this memory is to realize if auditory aferences, thanks to the devices, take a greater part in the postural control, and therefore improveit. In Table 3 above, in green are annotated the improved results between the two situations with and without hearing aids, in red are annotated degraded results.

To compare whether the balance ratio is improved with hearing aids we use the Z test.

	P-value
"Romberg Ratio platform without aa" vs. "Romberg Ratio platform with aa"	0,080
"Romberg Ratio Coussin without aa" vs. "Romberg Ratio Coussin with aa"	0,129

Table 5 Figure 18: Test Z result of the evolution between romberg unpaired ears and paired ears test

Bothresults were above 0.05. Hearing aids do not significantly alter postural control aferences.

IV. Impact of different factors on the benefit of the hearing aid on balance

1. Influence of gain on the benefits of hearing aids.

We tested the links between device gain and the balance score benefitsof hearing aids for the 35 patients whose scores were improved. For this we used a Correlation test to highlight a link between these two variables.

	P-value
"Earnings" vs. "250-750 Hz Gain"	0,662
"Earnings" vs. "1000-2000 Hz Gain"	0,693
"Earnings" vs. "3000-4000 Hz Gain"	0,222
"Earnings" vs. "6000-8000 Hz Gain"	0,166

Table 6 Results in the Correlation test between gain on different frequencies and the benefit of hearing aids.

These resultsshow us that there is no correlation between the gain of hearing aids and the benefits of hearing aids in the fall risk test (p-value 0.05).

As in the study (Rumalla, K., Karim, A. M., and Hullar, T. E.) published in the journal "The Laryngoscope" in 2014, there is no evidence of the gain of hearing aids and improvement in the patient balance test.

2. Influence span time of hearing aids and seniority of equipment on improved performance on the balance test.

We also tested the correlation between the wear time of hearing aids and the benefits of the balance scoreprovided by hearing aids. The hypothesis being that if a patient has been fitted forlonger, then his results will be better with hearing aids, and the difference between the situation "with aa" and "without aa" will be greater. On average, the time ittakes to wearhearing aids per day is 10.15 hours. Patients tested for this study have been fitted for an average of 5.8 years.

For this we also made a correlation:

	P-value
"Benefit" vs. "Equipment Seniority"	0,076
« Bénéfice » vs « data logging »	0,905

Table 7 Result of the correlation between equipment age and data logging with the benefits of wearingdevices.

There is no significant link between these two variables (P-value-0.05). The age of the equipment and the data logging do not seem to be related to the lower risk of falling.

DISCUSSION

The goal of our brief is to demonstrate that wearing hearing aids improves postural balance. We have previously demonstrated in a balance assessment test that the presence of hearing aids significantly reduces the risk of patients falling.

We hypothesize that the mechanism for improving certain characteristics of postural balance (speed, swinging, area) is probably due to increased stimulation of external auditory inputs resulting from the wearing of hearing aids,thus allowing a better spatial representation of the environment. However, we cannot rule out, for lack of correlation, that the wearing of hearing aids was simply the source of a greater alert and concentration mechanism rather than providing spatial auditory cues for better postural stability.

The results presented in this brief are still to be nuanced. En effect some biases are to be taken into account, as well as some factors not studied and included in this study.

I. Material

First of all, we must take intoaccount the variations due to the MediBalance Pro platform, and thevariations in the implementation of the hardware. Because the equipment is large, it was necessary to store and put the test system between each patient in place. Despite the marked cues placed, there were variations in the distances of the platform and the speakers. Also, between the step without the cushion and the step with the cushion, the patient had to get off the platform to be able to add it, so the location ofhis feet could bemodified and have an impact on the results. No blindfold stuns for patients' eyes had been provided, some could have opened their eyes without us noticing.

II. Time for testing

The tests were carried out in one go on the space of a singleappointment. Thestate of fatigue, physical or fitness may have been different for each subject and thus skew the comparisons of results made. Familiarization of test instructions may also have led to changes in performance. Indeed, the patients were much more at the eduring the second phase of thetests. It is also necessary to take into account the emotional state of patients which can affect their general condition and thus their performance.

The processes involved in acclimatizinghearing aids is long. Itmight be interesting to study the improvement of balance over a longer period of analysis.

III. Patient selection

Patient selection wasdone on a voluntary basis, and patient diversity may also have skewed performance comparison. In addition, no limits have been placed on patients' hearing aids: the age of the devices and the brand that can change the technology of the machines, as well as the diversity of settings applied to patients (frequent compression, different gain ...) that could have impacts on hearing and therefore postural performance. We chose to perform the tests randomly to preventan influence of the results. Some patients started testing without the devices, and others with their hearing aids. However, this decision may create some biases. Indeed, a study by Vitkovic et al (2016) showed that patients accustomed to wearing their hearing aids are more destabilized in the presence of sound when they are not wearing them, but they regain a good performance of their balance once their hearing aids are found.

IV. Cognitive aspect

No tests that could rule out a pathology such as "senility, lossof alertness or memory" were carried out. Thus the cognitive aspect could have hadan impact onour results. A study by Bernard-Demanze (2009) showed that attentional resources decreased with age and thus increased the risk of falling. In this study, double tasks are studied, which involves comparing postural performance by combining cognitive tasks. As in our brief, s analyzed the movements of the pressure center using statistical tests in three different age groups. As a result, older adults have been shown to have a recoveration ofdegraded postural balance compared to the performance of younger age groups. It can be concluded that in everyday life, postural stability is more difficult foranelderly person to achieve by performing another task simultaneously or for lack of concentration.

A cognitive evaluation test might have been interesting for the analysis of our results.

V. Additional test

It would have been interesting to test the impact of patients' hearing aids on the location aspect by highlighting the phenomena of DII and DIT. This point was evaluatedin DAL Yves's brief (2017). Ithas been shown that there is a significant difference not related to chance for DIT and DII on the sound lateralization in the center. This improvement is linked to a better piercingof certainfrequencies due to the wearing of hearing aids. The treble is very important to complete the location information especially around 3kHz, in addition to the frequencies 250-750Hz.

It is important for the audioprosthetist to minimize the frequency imbalances between the two ears in order to first allow better localization and lateralization but therefore also improve the postural balance. patients.

VI. Risk of falling

The risk of falling has been shown to increase by 1.4 to10 dB of hearing loss (National Health and Nutrition Survey 2001-2004). Inour study, the average gain of our patients is 15.97. On can infer that wearing hearing aids divides the risk of falling by 2.23. However, we did not observe a correlation between aircraft gain and balance performance for fall risk.

However, it is important to take into account that wearing hearing aids does not completely reduce the risk of hearing-related falls. Indeed, with aging, the auditory system loses acuity as a result of the breakdown of hair cells, but the vestibular system is also affected by this phenomenon.

As we have seenbefore, the ability to double-task is more complicatedin an olderperson. Thus, it will have more difficulty in keeping a stable postural balance, despite hearing aids,this being due to a greater concentration for the understanding of sound information.

CONCLUSION

The study of this dissertation was to study the postural balance of patients by doing tests without a device at the ditifs and with hearing aids and to see if wearing them improves stability and reduces the risk of falling.

We have shown that wearing hearing aids significantly reducesthe risk of falling. This reduction is due to the decrease in swing, speed and range of movements in a dynamic situation (foot on a cushion with eyes closed).

No correlation could be established between "the benefits of hearing aids," "gain," "equipment seniority" and "data logging."

These results are consistent with the studies and reference lists cited in this dissertation. However, the results need to be nuanced according to the different biases encountered.

The time spent on the study did not allow us to investigate further, but it would have been interesting to correlate the type ofhearing aids tested, because the lack of homogeneity of the various devices tested does not allow us to deepen this angle. Assessing balance using a frequent compression adjustment couldbe an axis of deepening. The orientation of the microphones and deer ofhearing aids would be tobe studied.

Andfinally, using the data already collected in this brief and in that of DAL Yves (2017), it would be interesting to study a standard of postural balance to be achieved with the wearing of hearing aids over a given period of time in correlation with the age of patients.

It is important to remember from this study and all the references cited that they highlight another aspect of the device that is important to consider in the patient's follow-up. It is important to minimize the risk of falling by preventing the impairmentof patient balance due to age, by providing as much information as possible to stimulatebrain aferences.

Bibliography

- A. Shumway-Cook, F.B. Horak (1986) Assessing the influence of sensory interaction of balance.
- A. Viljanen , J. Kaprio , I. Pyykko , M. Sorri , S. Pajala , M. Kauppinen (2009) The hearing as a predictor of falls and postural balance in older twins.
- Bernard-Demanze (2009). Age-related changes in posture control are differentially affected by postural and cognitive tasks complexity
- Berthoz A (1988) The sense of movement. Paris: Odile Jacob
- CF Lacerda , LO Silva , RS by Tavares Canto , NC Sheik (2012) Effects of hearing aids on balance, quality of life and fear of falling in elderly people with int sensorineural hearing loss. Cambre. Otorhinolaryngol. , 16, 156-162
- National College of Geriatric Teachers (2014) Walking and Balance Disorders. In Geriatrics. 3rd ed. Elsevier Masson SAS131-42 32.
- French College of ORL and Cervicofacial Surgery (2008). Sensory deficit in the elderly: deafness and dizziness. In ENT. Elsevier Masson SAS 28-33
- DAL Yves (2017). Postural balance and equipment. Audioprosthesis State Diploma Memoir. Lyon: ISTR. Claude Bernard Lyon University 1.
- David Colin. Statistics First-year course of the State Diploma of Audioprosthetist. Lyon: ISTR University Claude Bernard Lyon 1.
- Elaine N. MARIEB (2005), Human Anatomy and Physiology (p599-614)

- Evci ED, Ergin F, Beser E. Home accidents in the elderly in turkey. Tohoku J Exp Med. (2006) ; 209: 291 – 301.

- Henriot N., The postgraduate dissertation presented for the State Diploma of Audioprosthetist in 2017, School of Audioprosthesis of Lyon, Université Lyon 1 - Methods of equipment, binaural balance.

- HG Palm , J. Strobel , G. Achatz , F. von Luebken , B. Friemert (2009) The role and interaction of visual and auditory aferences in postural stability Gait Posture ,30, p. 328 - 333

- Hoen, M. (2014). Hearing Physiology Course. First year Audioprosthesis course. ISTR. Claude Bernard Lyon University 1. Lyon.

- INPES. (2014). Accidents of everyday life: falls. INPES, themes/accidents/falls.

- Jacquemard J, Costille M. (2008) Contribution of vestibular rehabilitation for multisensory management of balance disorders.

- Kanegaonkar, R. G., Amin, K., & Clarke, M. (2012). The contribution of hearing to normal balance. The Journal of Laryngology & Otology (126), 984-988.

- Lin FR, Ferrucci L. Hearing loss and falls among older adults in the United States. Arch Intern Med (2012); 172:369–371.

- Lopez D, McCaul KA, Hankey GJ, Norman PE, Almeida OP, Dobson AJ, Byles JE, Yeap BB, Flicker L. (2011) Falls, injuries from falls, health related quality of life and mortality in older adults with vision and hearing impairment--is there a gender difference? Aug;69(4):359-64.

- MediTech Electronic GmbH (2013) Instructions for use MediBalance Pro, p-15

- Negahban H, Bavarsad Cheshmeh Ali M, Nassadj G (2017) Effect of hearing aids on static balance function in elderly with hearing loss.

- Who. (2016). Memory Aid No. 344. Media Centre - WHO Online.

- P. Pilardeau. Postural tonus balance and proprioception.

- Peissig, J., and Kollmeier, B. (1997) Directivity of binaural noise reduction in spatial multiple noise-source arrangements for normal and impaired listeners.

- Pérennou, D. (2012). Physiology and pathophysiology of postural control. In Summary Article in Letter of Physiological Medicine of Rehabilitation (pp. 120-132).

- Raper SA, Soames RW. (1991) Influence of stationary auditory fields on postural swinging behaviour in humans; 63 ; 363-367

- Rumalla, K., Karim, A. M., & Hullar, T. E. (2014). The Effect of Hearing Aids on Postural Stability. The Laryngoscope (125), 720-723.

- Teasdale N, Simoneau M. (2001) Attentional demands for postural control: the effects of aging and sensory reintegration. Gait Posture. Dec ;14(3) :203-10.

- Please, E. (2014). Balance. First-year course of the State Diploma of Audioprosthetist. Lyon: ISTR University Claude Bernard Lyon 1.

- Vitkovic J, Le C, Lee SL, Clark RA (2016) The Contribution of Hearing and Hearing Loss to Balance Con

- Zhong X, Wa Yost. (2013) Relationship between postural stability and spatial hearing