Speech audiometry in noise: SNR Loss per age-group in normal hearing subjects.

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Marine Decambron (1), François Leclercq (2), Christian Renard (2), Christophe Vincent (3)*

1 : Service ORL, Centre hospitalier de St Omer, 62505 Saint-Omer Cedex, France

2 : Laboratoire Renard, 50 Rue Nationale, 59000 Lille, France

3 : Service Otologie et Otoneurologie, CHU de Lille, Rue Michel Polonowski, 59037 Lille, France

* Corresponding author:

Email address: otologie@chru-lille.fr (C Vincent)

Abstract

Objectives

The present study aimed to determine normal SNR values per age group for the 50% speech reception threshold in noise (SNR Loss) on the VRB (*Vocale Rapide dans le Bruit*: rapid speech in noise) test.

Material and Methods

Two hundred patients underwent pure-tone threshold and VRB speech-in-noise audiometry. Six ages groups were distinguished: 20-30, 30-40, 40-50, 50-60, 60-70 and >70 years. All subjects had normal hearing for age according to ISO 7029. SNR Loss was measured according to age group.

Results

Mean SNR Loss ranged from -0.37 dB in the youngest age group (20-30 years) to +6.84 dB in the oldest (>70 years).

Range and interquartile range increased with age: 3.66 and 1.49 dB respectively for 20-30 year-olds; 6 and 3.5 dB for >70 year-olds. Linear regression between SNR Loss and age showed a coefficient R^2 of 0.83.

Conclusion

The present study reports SNR Loss values per age group in normal-hearing subjects (ISO 7029), confirming that SNR Loss increases with age. Scatter also increased with age, suggesting that other age-related factors combine with inner-ear aging to impair hearing in noise.

Key-words

Hearing in noise, presbycusis, aging, SNR Loss

Introduction

Presbycusis is often defined as age-related hearing loss. It is frequent, affecting some two-thirds of over-70 year-olds in the USA [1]. It is characterized by symmetric bilateral hearing loss predominating at high frequencies. Clinically, the main presenting symptom is impaired speech intelligibility in noise, yet diagnosis is usually founded exclusively on pure-tone threshold audiometry. Moreover, there are no precise consensual audiometric profiles according to age and gender to guide diagnosis. Audiograms can be difficult to interpret in middle-aged and elderly subjects, as not only age but also genetic and other factors such as acoustic trauma, associated pathologies, and drug-related iatrogenesis may be involved [2]. Even so, it is possible to speak of a "normal-for-age" audiogram, as this has been defined in an ISO (International Organization for Standardization) norm: an "otologically normal" person is in good health, without ear disease or symptoms, with free outer ear canals and no history of acoustic trauma. ISO 7029 defines variations in hearing level according to age and gender. It was drawn up on the basis of several publications compiling hearing levels in European and North American populations from the 1950s to 1970s. While describing the distribution of hearing levels according to age, it does not state how presbycusis is to be defined: is the threshold at the median (50^{th} percentile), between the 25^{th} and 75^{th} percentiles, or below the 10^{th} percentile?

Pathophysiologically, presbycusis results from lesions of the hair cells, vascular stria, spiral ganglion neurons and central auditory pathways. As early as 1955, Schuknecht distinguished sensory (hair-cell loss), neuronal (spiral ganglion loss) and metabolic (strial atrophy) forms [3].

For any given subject, it is tricky to attribute hearing loss simply to aging of the ear. Notably, for a given age, hearing levels differ between males and females. Thus there seem to be extrinsic and intrinsic factors modulating simple cochlear aging. Epidemiological studies revealed other factors such as noise exposure, genetics, atherosclerosis and smoking status [4].

Presbycusis can thus be defined by hearing loss according to age group and symmetry of hearing loss, but it remains difficult to identify the specific impact of aging among other factors. The present view of the pathophysiology of auditory aging implicates reduced mitochondrial activity by deletion and mutation and the toxic impact of oxidative stress [5]. There are no firm explanations for why hearing loss predominates on high frequencies.

With age, many patients with varying hearing levels complain of difficulty in understanding speech in noisy settings. This decline compared to younger people may, according to some authors, involve peripheral, central and cognitive factors [6–11]. Despite these complaints, auditory testing in noise is rarely performed. The main index in speech audiometry in noise is the SNR for the 50% Speech Reception Threshold in noise (SNR Loss), which can be compared between different tests in noise if the normal value is known. For example, SNR Loss for a normal-hearing subject is 0 dB on the VRB test, and -6 dB on the FraMatrix test. While absolute SNR Loss values vary according to test, difference from normal values is comparable whatever the test. In subjects experiencing difficulties in noise, SNR Loss will be 8 dB on VRB and 2 dB on FraMatrix, but the difference from normal values is 8 dB on both: 0 dB normal value versus 8 dB for the patient on VRB and -6 dB versus 2 dB on FraMatrix.

The aim of the present study was to provide normal SNR Loss values on VRB according to age group in normal-hearing subjects as defined by ISO 7029.

Patients and methods

Two hundred caucasian patients were included. Pure-tone threshold audiometry was first performed in a soundproof booth to check normal hearing according to ISO7029. Thresholds were considered normal when lower than the ISO7029 median for the subject's age group. Additional environmental factors were screened for in interview. Otoscopy was required to be normal.

Speech audiometry in noise used the VRB test, as previously described [12]. Briefly, it is conducted in a soundproof booth with 5 loudspeakers delivering a frontal speech signal (azimuth 0°) and masking noise at 0°, +60°, +120°, -60° and -120°. The subject is positioned at the center, 120 cm from the sources, and should repeat four 9-sentence lists with masking cocktail-party noise at varying signal-to-noise ratio (SNR). The speech material consists of sentences with 3 key-words as the basis for scoring. The cocktail-party background noise was developed from the global speech wave described by Dodelé. The speech signals were delivered at 65 dB SPL and noise was increased by 3 dB increments. SNR thus ranged from +18 dB to -3 dB. SNR Loss was calculated automatically, using the Spearman-Kärber equation [12], by the HuBsound software (Biotone), which includes the VRB test.

Subjects were grouped by age: 20-30, 30-40, 40-50, 50-60, 60-70 and >70 years. SNR Loss was analyzed according to age group.

Statistical analyses used Prism software, with ANOVA followed by Bonferroni post-hoc tests for multiple comparison.

Correlations between SNR Loss and age were assessed by R^2 coefficient on linear regression. SNR Loss cannot be rounded off to the nearest unit as, given the performance/intensity curve, a variation of 1 dB SNR induces a 20% variation in intelligibility.

Results

Table 1 shows distribution by age group. The population was 51% male and 49% female. Mean SNR Loss ranged between -0.37 dB in the youngest age group (20-30 years) and +6.84 dB in the oldest (>70 years).

Table 2 shows SNR Loss values in dB according to age group; figure 1 presents the distribution.

One-way ANOVA followed by Bonferroni post-hoc tests for multiple comparison showed suggestive differences between all age groups ($p < 0.05$) except between the 30-40 and 40-50 year-olds ($p = 0.0616$).

SNR loss differed non-significantly according to gender (Table 3).

Linear regression assessing the correlation between SNR loss (dB) and age (years) found $R^2 = 0.83$.

Figure 2 shows the curve for the equation $Y = 0.1353*X – 4.22$, where Y is SNR loss in dB and X is age in years.

Discussion

For audiometry in noise, calibration of speech and noise levels must be precise, as moderate variations of 3 dB in SNR may induce large differences in intelligibility. Given the mean intensity-performance curve of the VRB test, intelligibility increases by about 40% when SNR increases from 0 to +3 dB in normal-hearing subjects.

Calibration is firstly acoustic, according to each test's procedure, but then needs checking clinically. For example, the VRB tests was designed so that normal-hearing SNR Loss would be 0 dB. The 20-30 year-old age group represents the "otologically normal" population. Mean SNR Loss on the VRB test was -0.37 dB for an expected normal value of 0 dB, thus clinically validating the acoustic calibration.

SNR Loss notably increased with age, with more than 6 dB difference between the youngest (20-30 years) and oldest (>70 years) groups. This is in agreement with other reports, with no relevant geographical factors [13]. However, few studies used balanced 10-year age groups.

In the present series, ranges and interquartile ranges per age group were wide and comparable, except after 60 years of age, when scatter became even greater (figure 2). The reasons for this variability of intelligibility in noise in elderly subjects for a given pure-tone loss in silence are unclear. Animal models suggest that moderate noise exposure induces synaptopathy and degeneration in the spiral ganglia, exacerbating strial dysfunction [14]. These peripheral mechanisms are accompanied by central age-related mechanisms: impaired use of temporal indices of speech, and spatial index processing deficit [8–11, 15,16]. There may moreover also be cognitive disorder and impairment of working memory, information processing speed and/or inhibitory control [6,7]. Some authors even highlighted neuroanatomic factors, such as left superior frontal gyrus cortex thickness, associated with declining intelligibility in noise [17]. And finally, deterioration in the peripheral auditory system strongly impacts central auditory system structure [18]. Thus, multiple causes are involved in SNR Loss variation for a given age group and level of hearing loss [19]. The only precise means of assessment of speech reception in noise is thus performing speech audiometry in noise, rather than making estimates based on other tests.

Sex difference in hearing level is well known for pure-tone thresholds in silence, although the mechanisms are not clearly understood; difference in acoustic exposure is often claimed to be the main factor [20,21]. SNR Loss variation according to age group found non-significant differences, varying according to age group. In over-70 year-olds, the difference was most strongly in favor of females. Although no significant association emerged in the present study, similar findings were reported elsewhere [13] and should doubtless be taken into account. Subjectively, on the other hand, it is (surprisingly) females who report the greater difficulty in hearing [22].

It should be borne in mind that the linear regression model, although satisfactory from a statistical point of view, failed to fully account for increased scatter with age, especially after the age of 60.

Conclusion

The VRB test provides rapid objective assessment of intelligibility in noise. The main endpoint in the present study, SNR Loss, has the advantage of being comparable across tests in noise [23]. The present results showed that variations in SNR Loss according to age and gender could be as great as 6 or 7 dB. These SNR Loss values per age group could provide a basis for interpreting the test according to patient age. Finally, SNR Loss scatter increased with age, likely due to additional central factors exacerbating peripheral inner-ear aging.

Conflicts of interest : none

References

1. Lin FR, Niparko JK, Ferrucci L. Hearing Loss Prevalence in the United States. Arch Intern Med. 14 nov 2011;171(20):1851-2.

2. Vaden KI, Matthews LJ, Eckert MA, Dubno JR. Longitudinal Changes in Audiometric Phenotypes of Age-Related Hearing Loss. JARO J Assoc Res Otolaryngol. avr 2017;18(2):371-85.

3. Schuknecht HF. Presbycusis. The Laryngoscope. juin 1955;65(6):402-19.

4. Yamasoba T, Lin FR, Someya S, Kashio A, Sakamoto T, Kondo K. Current concepts in age-related hearing loss: Epidemiology and mechanistic pathways. Hear Res. sept 2013;303:30-8.

5. Tavanai E, Mohammadkhani G. Role of antioxidants in prevention of age-related hearing loss: a review of literature. Eur Arch Oto-Rhino-Laryngol Off J Eur Fed Oto-Rhino-Laryngol Soc EUFOS Affil Ger Soc Oto-Rhino-Laryngol - Head Neck Surg. avr 2017;274(4):1821-34.

6. Gordon-Salant S, Cole SS. Effects of Age and Working Memory Capacity on Speech Recognition Performance in Noise Among Listeners With Normal Hearing. Ear Hear. oct 2016;37(5):593-602.

7. Roque L, Karawani H, Gordon-Salant S, Anderson S. Effects of Age, Cognition, and Neural Encoding on the Perception of Temporal Speech Cues. Front Neurosci. 19 juill 2019;13:749.

8. Goupell MJ, Gaskins CR, Shader MJ, Walter EP, Anderson S, Gordon-Salant S. Age-Related Differences in the Processing of Temporal Envelope and Spectral Cues in a Speech Segment. Ear Hear. déc 2017;38(6):e335-42.

9. Glyde H, Cameron S, Dillon H, Hickson L, Seeto M. The effects of hearing impairment and aging on spatial processing. Ear Hear. févr 2013;34(1):15-28.

10. Glyde H, Hickson L, Cameron S, Dillon H. Problems hearing in noise in older adults: a review of spatial processing disorder. Trends Amplif. sept 2011;15(3):116-26.

11. Hall JW, Buss E, Grose JH, Roush PA. Effects of age and hearing impairment on the ability to benefit from temporal and spectral modulation. Ear Hear. juin 2012;33(3):340-8.

12. Leclercq F, Renard C, Vincent C. Speech audiometry in noise: Development of the French-language VRB (vocale rapide dans le bruit) test. Eur Ann Otorhinolaryngol Head Neck Dis. oct 2018;135(5):315-9.

13. Gordon-Salant S. Hearing loss and aging: New research findings and clinical implications. J Rehabil Res Dev. 2005;42(4s):9.

14. Heeringa AN, Köppl C. The aging cochlea: Towards unraveling the functional contributions of strial dysfunction and synaptopathy. Hear Res. 2019;376:111-24.

15. Gaskins C, Jaekel BN, Gordon-Salant S, Goupell MJ, Anderson S. Effects of Aging on Perceptual and Electrophysiological Responses to Acoustic Pulse Trains as a Function of Rate. J Speech Lang Hear Res JSLHR. avr 2019;62(4 Suppl):1087-98.

16. Roque L, Gaskins C, Gordon-Salant S, Goupell MJ, Anderson S. Age Effects on Neural Representation and Perception of Silence Duration Cues in Speech. J Speech Lang Hear Res JSLHR. 26 avr 2019;62(4S):1099-116.

17. Wong PCM, Ettlinger M, Sheppard JP, Gunasekera GM, Dhar S. Neuroanatomical characteristics and speech perception in noise in older adults. Ear Hear. août 2010;31(4):471-9.

18. Eckert MA, Cute SL, Vaden KI, Kuchinsky SE, Dubno JR. Auditory Cortex Signs of Age-Related Hearing Loss. JARO J Assoc Res Otolaryngol. oct 2012;13(5):703-13.

19. Phatak SA, Brungart DS, Zion DJ, Grant KW. Clinical Assessment of Functional Hearing Deficits: Speech-in-Noise Performance. Ear Hear. avr 2019;40(2):426-36.

20. Blanchet C, Pommie C, Mondain M, Berr C, Hillaire D, Puel J-L. Pure-tone threshold description of an elderly French screened population. Otol Neurotol Off Publ Am Otol Soc Am Neurotol Soc Eur Acad Otol Neurotol. juin 2008;29(4):432-40.

21. Bahng J, Lee J. Hearing Thresholds for a Geriatric Population Composed of Korean Males and Females. J Audiol Otol. sept 2015;19(2):91-6.

22. Uchida Y, Nakashima T, Ando F, Niino N, Shimokata H. Prevalence of self-perceived auditory problems and their relation to audiometric thresholds in a middle-aged to elderly population. Acta Otolaryngol (Stockh). juin 2003;123(5):618-26.

23. Joly CA, Reynard P, Mezzi K, et al. Recommendations from the French Society of Audiology (SFA) and the French Society of Otorhinolaryngology-Head and Neck Surgery (SFORL) for Speech-in-Noise Testing in Adults. Eur Ann Otorhinolaryngol Head Neck Dis. 2021 (in press)

Table 1: Age-group distribution

Age group	Total	Male	Female
20-30 years	30	16	14
30-40 years	32	18	14
40-50 years	29	17	12
50-60 years	33	16	17
60-70 years	39	16	23
>70 years	37	19	18

Table 2: Descriptive statistics for SNR Loss per age group

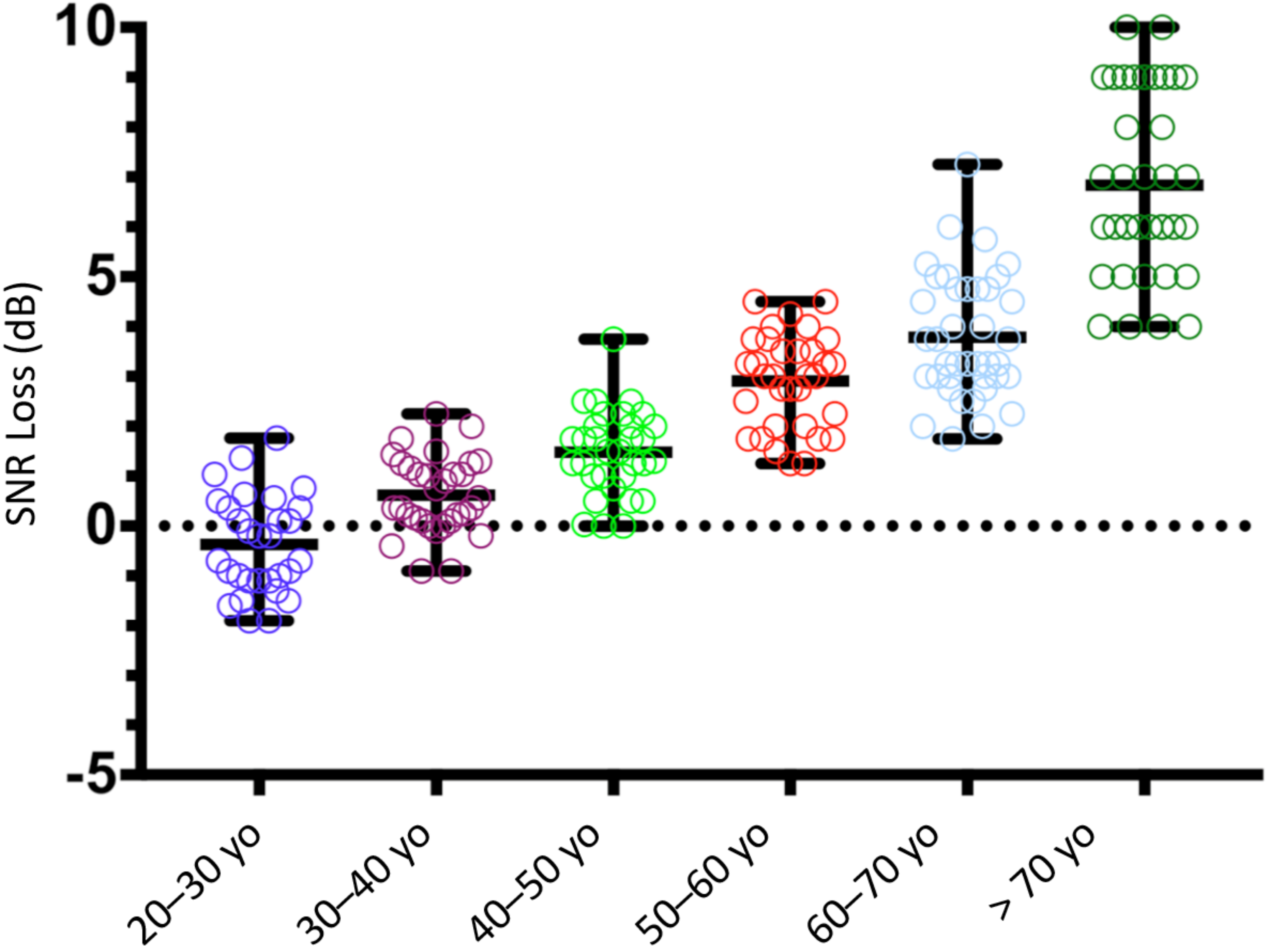
	20-30 years	30-40 years	40-50 years	50-60 years	60-70 years	>70 years
mean	-0.37	0.62	1.48	2.91	3.79	6.84
median	-0.45	0.46	1.5	3	3.25	6
min	-1.9	-0.9	0	1.25	1.75	4
max	1.76	2.25	3.75	4.5	7.25	10
25th percentile	-1.1	0.1	1	2	3	5.5
75th percentile	0.39	1.23	2	3.63	4.75	9
standard deviation	0.98	0.77	0.84	0.94	1.24	1.83
inf 95% CI	-0.74	0.34	1.17	2.58	3.39	6.23
sup 95% CI	-0.002	0.90	1.78	3.24	4.19	7.45

Table 3: Sex differences in SNR Loss per age group

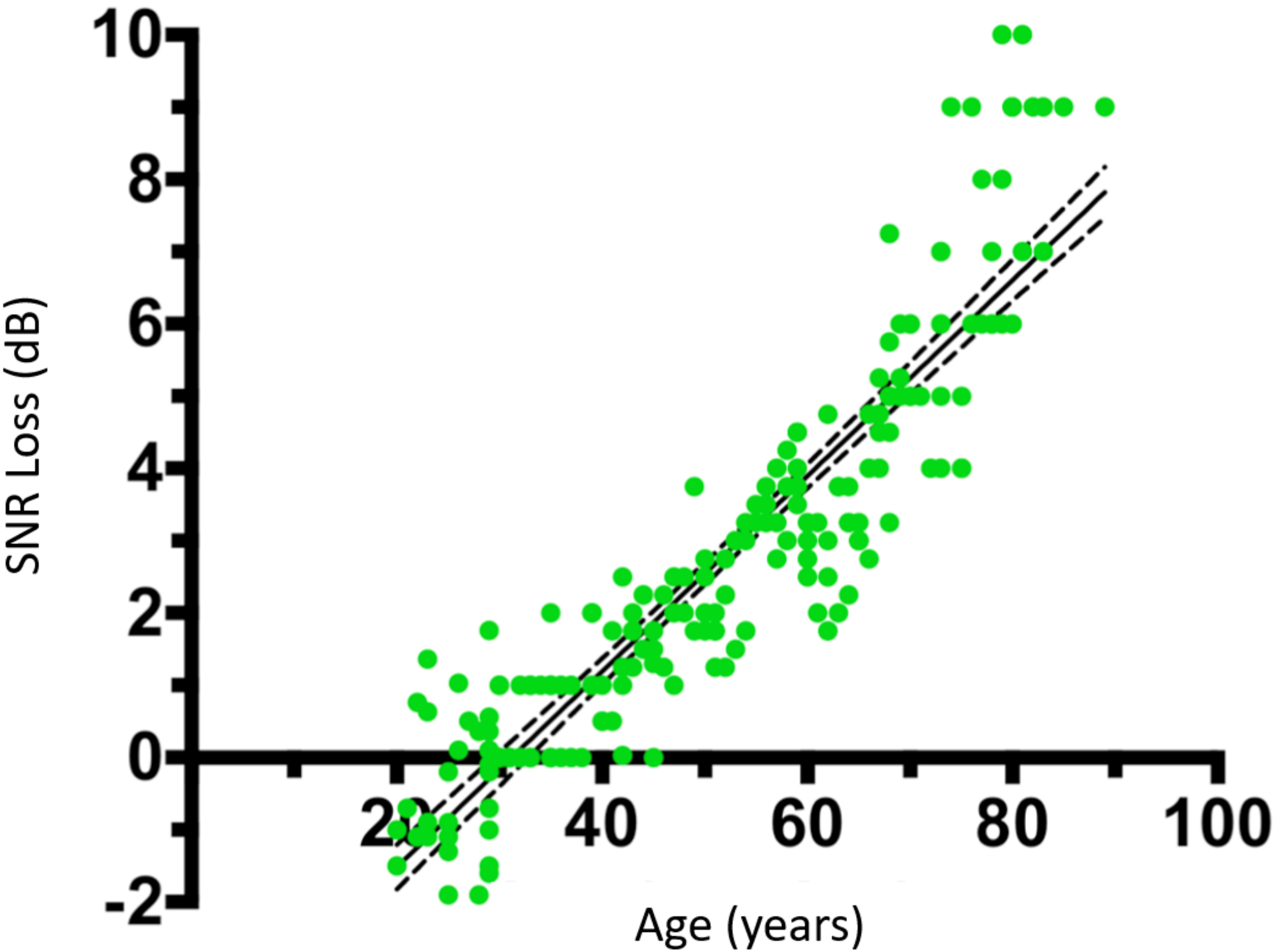
	Male	**Female**
20-30 years	-0.21 dB (95%CI = [-0.72 ; 0.29])	-0.54 dB (95%CI = [-1.14 ; 0.05])
30-40 years	0.54 dB (95%CI = [0.11 ; 0.96])	0.72 dB (95%CI = [0.34 ; 1.11])
40-50 years	1.37 dB (95%CI = [0.99 ; 1.67])	1.9 dB (95%CI = [1.3 ; 2.5])
50-60 years	3.24 dB (95%CI = [2.77 ; 3.7])	2.6 dB (95%CI = [2.13 ; 3.07])
60-70 years	4.38 dB (95%CI = [3.64 ; 5.11])	3.38 dB (95%CI = [2.97 ; 3.8])
>70 years	7.27 dB (95%CI = [6.34 ; 8.19])	6.39 dB (95%CI = [5.6 ; 7.23])

Figure 1: SNR Loss according to age group

Figure 2: Linear regression of SNR Loss with age



10
5
0
-5
SNR Loss (dB)
20–30 yo
30–40 yo
40–50 yo
50–60 yo
60–70 yo
> 70 yo



10
8
6
4
2
0
-2
20
40
60
80
100
SNR Loss (dB)
Age (years)