

Nível de desconforto para sensação de intensidade em indivíduos com audição normal***

Loudness discomfort level in normal hearing individuals

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Abstract

Background: Loudness Discomfort Level (LDL), a test used in the hearing aid fitting process, has also been recommended to evaluate patients with tinnitus and/or suspect of hyperacusis. **Aim:** to determine LDL reference values for normal hearing individuals and to correlate the LDL to the Acoustic Reflex Threshold (ART). **Method:** LDL was investigated in 64 normal hearing subjects, with ages between 18 and 25 years (53.1% female), in the frequency threshold of 0.5 to 8KHz and for speech (non-recorded, non-standardized connected discourse). Pulsate pure tones were presented for two seconds, with a one-second interval between each presentation. The initial stimulus intensity was at 50dB and was followed by ascending presentations, of 5dB each, until the subject referred initial discomfort with loudness. The testing procedure was performed separately in each ear, and was immediately repeated at the end of the test (test and retest situation). The choice of the ear that would start the testing procedure was alternated for each subject. After that contralateral acoustic reflexes ART were measured. The presence of the ART was indicated by a minimal needle deflection (larger than 0.05ml) on the emittance equipment. **Results:** median varied from 86 to 98dBHL, with no statistically significant differences between gender ($p > 0.11$), between ears ($p > 0.36$) and between the test-retest situation ($p > 0.34$). The determination coefficients (r^2) of the linear regression model revealed absence of correlation between $\log(\text{LDL})$ and $\log(\text{ART})$. **Conclusion:** normal hearing individuals have LDL between 86 and 98dBHL for all of the tested stimuli. Inter-subject differences and the good reproductivity suggest that the interpretation of the test should be cautious and analyzed considering the patient's history. The test can be an useful instrument go follow-up patients. No correlation was found between LDL and ART.

Resumo

Tema: o *Loudness Discomfort Level* (LDL), teste muito utilizado na adaptação de próteses auditivas, teve sua indicação ampliada e passou a ser recomendado para complementar a avaliação de pacientes com zumbido e/ou com suspeita de hiperacusia. **Objetivo:** determinar valores de referência do LDL para normo-ouvintes e sua correlação com o Limiar do Reflexo Acústico (LRA). **Método:** o LDL foi aplicado em 64 sujeitos normo-ouvintes de 18 a 25 anos (53,1% do sexo feminino) nas frequências de 0,5 a 8KHz e para sons da fala encadeada espontânea a viva-voz. Os tons puros pulsáteis foram apresentados por dois segundos, com intervalo de um segundo entre cada apresentação, a partir de 50dB de modo ascendente em passos de 5dB até que o sujeito referisse desconforto inicial com a sensação de intensidade. O procedimento foi realizado nas duas orelhas separadamente e repetido imediatamente (situações de teste e reteste), com alternância da orelha inicial a cada sujeito. O reflexo contralateral foi obtido em seguida. Foi considerado LRA a menor intensidade sonora capaz de provocar uma deflexão visível na agulha do imitanciómetro (maior que 0,05ml). **Resultados:** a mediana do LDL variou de 86 a 98dBNA, sem diferenças estatisticamente significativas entre homens e mulheres ($p > 0,11$), entre orelhas ($p > 0,36$) ou entre as situações de teste e reteste ($p > 0,34$). Os coeficientes de determinação (r^2) do modelo de regressão linear mostraram ausência de correlação entre $\log(\text{LDL})$ e $\log(\text{LRA})$. **Conclusão:** normo-ouvintes apresentam LDL de 86 a 98dBNA para todos os estímulos apresentados. Diferenças inter-sujeitos e boa reprodutibilidade sugerem que a interpretação do teste deve ser cuidadosa e aliada à anamnese e que o teste pode ser útil no acompanhamento de pacientes. Não houve correlação entre LDL e LRA.

Palavras-Chave: Percepção Sonora; Audição; Hiperacusia; Zumbido.

Introduction

The intolerance to sounds may be subdivided in hyperacusis, misophonia and phonophobia. The hyperacusis is characterized by a discomfort to mild or moderate sound intensity, independent on the environment or situation where it occurs (Jastreboff & Jastreboff, 2000; Santos, 2000; Jastreboff & Jastreboff, 2004). Its beginning may be gradual or subtle and suggests a disorder in the central or peripheral auditory pathway (Jastreboff & Jastreboff, 2000; Jastreboff & Jastreboff, 2002; Nelting, 2002; Jastreboff & Jastreboff, 2004; Knobel & Sanchez, 2004). Misophonia describes a strong dislike of certain sounds but, generally it depends on the context in which the sound is presented. Despite the auditory pathway conditions, a mild stimulation of the auditory system may provoke a great stimulation of the limbic system. Therefore, the situation in which the sound occurs is more relevant for determining the discomfort level than its acoustic characteristics. (Jastreboff & Jastreboff, 2000; Jastreboff & Jastreboff, 2002; Knobel & Sanchez, 2004; Jastreboff & Jastreboff, 2004). At last, the phonophobia describes fear of sound exposure by the belief that it may cause damages to the ear (Jastreboff & Jastreboff, 2000; Jastreboff & Jastreboff, 2002; Knobel & Sanchez, 2004; Jastreboff & Jastreboff, 2004).

The loudness discomfort level (LDL) is a commonly used test in the hearing aid fitting process (Bentler & Cooley, 2001) and, therefore it used to be indicated only for patients with a hearing loss. However, recent studies suggest that the indication of LDL should be broadened in order to complement the hearing evaluation of patients with possible intolerance to sounds, with or without tinnitus (Henry & Meikle, 2000; Santos, 2000; Valente et al., 2000; American Academy of Audiology, 2001; Jastreboff & Jastreboff, 2000; Jastreboff & Jastreboff, 2002; Gold et al., 2002; Jastreboff & Jastreboff, 2004), since there seems to be a strong correlation between the two symptoms (Jastreboff & Jastreboff, 2000; Breuel et al, 2001; Gold et al., 2002; Magalhães et al, 2003; Jastreboff & Jastreboff, 2004; Knobel & Sanchez, 2004). Thus, the LDL assumed an important role in the diagnosis and therapeutic follow up of patients who frequently do not present indication for a hearing aid.

The first study that evaluated the LDL in normal hearing subjects was conducted by Hood & Poole (1966), who tested the normal ear of 200 subjects with unilateral anacusia, using pulsed ascending

tones in the frequencies of 500, 1.000, 2.000 and 4.000 Hz until the individual referred beginning of discomfort. About 90% of the subjects referred discomfort for intensities between 90 and 105 dB NPS (averages of 98, 98,2, 98,9 e 95 dB for 500, 1000, 2000 e 4000 Hz, respectively). Since then, studies with normal hearing subjects were restricted to investigate the influence of the stimulus, of the instruction, and of the LDL procedures (Hawkins, 1980; Hawkins 1980a; Bentler & Pavlovic, 1989; Bornstein & Musiek, 1993).

Bentler & Colley (2001) performed a systematic review of five previous studies (totalizing 710 ears of 433 patients) in order to evaluate the relationship between the discomfort level (DL) and the maximum output of hearing aids. Although they didn't intend to determine the discomfort thresholds in normal hearing subjects, they used a control group composed by 79 subjects (103 ears) with normal hearing. The DL averages of the normal hearing group were 93,0, 92,8, 89,5, 89,1 and 87,4 dB HL in the frequencies of 500, 1.000, 2.000, 3.000 and 4.000 Hz, respectively.

Traditionally, the normal reference level for the LDL is considered 100 dBHL for the frequencies from 500 to 8000 Hz and for the speech (American Academy of Audiology, 2001; Katzenell & Segal, 2001; Gold et al., 2002). When there is a suggestive history of sound intolerance, the altered LDL stresses the hyperacusis suspicion. However, in accordance with other authors (Beattie et al., 1979; Anari et al., 1999. Jastreboff & Jastreboff, 2004), our experience suggests that there is a great variability in the LDL results. Therefore, it's important that the LDL is adapted for those individuals in order to assist the differentiation between misophonia and phonophobia, that may associated to hyperacusis (Jastreboff & Jastreboff, 2000; Jastreboff & Jastreboff, 2002; Gold et al., 2002; Jastreboff & Jastreboff, 2004). There are no reports in the literature about risks to the hearing resulting from the LDL application, but as patients with sound intolerance fear intense sounds exposure, they must be previously assured about the control of the sound intensity to which they will be exposed, so the test will be reliable.

Because the exam is subjective, some authors suggested that the acoustic reflex threshold (ART) could be used to predict the LDL (Al-Azazi & Othman, 2000; Araújo & Iório, 2003), which would be especially useful for small children evaluation or those mentally impaired (McLeod & Greenberg,

1979; Musiek & Rintelmann, 2001), or as a mean make the measure objective. However, this correlation between both results is denied by other authors (Goldstein & Shulman, 1996; Anari et al., 1999), characterizing a controversial subject.

Therefore, our purposes were:

1. to determine the loudness discomfort level (LDL) in normal hearing individuals, aiming at its future application in patients with tinnitus or with sound intolerance.
2. to study a possible correlation between the LDL and the ART values.

Method

The present study was approved by the Ethics Committee for Research Projects Analysis (CAPPesq) of the Medicine School of University of São Paulo (FMUSP) with protocol number 932/01 (annex III) and by the Research Ethics Committee (CEP) of the Medical Sciences School of University of Campinas (FCM-UNICAMP) with protocol number 369/02. There was no conflict of interest in the conduction of this research. Therefore, the protocol follows all the ethical principles for Researches with human beings determined by Resolutions 196/96 e 251/97 of the National Health Council.

All individuals were previously informed by the researcher and consented with the conduction of the research and the publication of its results (annex 1).

Subjects

In order to assure that the subjects had normal hearing and to avoid data contamination, 64 individuals (128 ears) ranging in age from 18 to 25 years, without complaints of hearing loss, tinnitus, hyperacusis, dizziness and history of high sound pressure levels (occupational or leisure) or ototoxic drugs exposures were evaluated.

Thirty four (34) female subjects (53,1%) and 30 male subjects (46,9%), with a mean age of 21,8 years (Sd=2,3), were evaluated. All of them had hearing thresholds equal or better than 25 dBHL in the frequencies of 250 to 8.000 Hz, tympanograms with peaks in 50 DaPa and presence of acoustic reflex in at least three frequencies between 500 and 4.000 Hz. The schooling level and socio-demographic data of the subjects were not considered.

Equipments

The tonal audiometry and the LDL were performed in acoustic cabins with the Interacoustics AC 30 audiometer with TDH 39 earphones. The immittance measures were obtained with a Interacoustics AZ7 middle ear analyzer, both calibrated according to the American National Standard Institute (ANSI) 3.6-1996.

Protocol

The LDL was obtained after the establishment of the hearing tonal thresholds of each subject. The procedures for the LDL application were adapted from different authors and according to our clinical evaluation experience of patients with sound intolerance.

The LDL was investigated with pulsed pure tones in the frequencies of 500, 1000, 2000, 3000, 4000, 6000 and .000 Hz, and with spontaneous speech sounds composed by simple questions. The peak of each syllable was 0 in the VU meter. The stimuli were presented from 50 dBHL, ascending in steps of 5 dB (Hawkins, 1980a). Each stimulus was presented during approximately two seconds with an interval of approximately one second between each presentation, until the subject referred initial discomfort with the intensity sensation. As the instruction is a determinant part in the type and the quality of response (Beattie et al., 1979; Bornstein & Musiek, 1993), the instruction proposed by Hawkins (1980a) was modified in order to guarantee its adequacy to the goals of this study. All volunteers of the research received the following instruction: "You will hear sounds that will become stronger. Please raise your hand when the sound reaches an intensity that you no longer want to hear it, and the sound will stop immediately. The aim of this test is to know which sound intensity provokes discomfort and not to know if the sound is strong or weak. The sound can be strong and not provoke any hearing discomfort, for example".

When the patient demonstrated to fear a hearing lesion due to an intense sound stimulus, another information was added:

"This test does not offer risk to your hearing even if you hear a sound in the maximum intensity of this equipment".

The initial ear was alternated and the contralateral ear was tested next. The retest was

performed right after, with the repetition of the procedure in the same order established in the test.

The tympanometric measures and the contralateral ARTs were obtained next. The minimal sound intensity capable of provoking a visible deflection of the needle of the equipment was considered an acoustic reflex threshold

Results

All LDL and ART data were adjusted in a log-normal distribution. A survival analysis considering the data statistically censored (that could not be measured because of the maximum output of the audiometer and of the middle ear analyzer) was performed in order to reduce the risks of underestimating the LDL values.

The Chi-square test did not show significant statistical differences between the ears, nor between the test and retest. Table I shows the average, median, Standard deviation, upper and lower limits of the LDL in four situations (right and left ears, test and retest), with an confidence interval of 95% for each studied stimulus.

Graph 1 shows a box-and-whisker plot of the medians, the first and third quartiles and the minimum and maximum values of LDL for the right ear test situation. Graphs 2, 3 and 4 present the same information regarding the left ear test, right ear retest and left ear retest, respectively.

The percentiles were obtained by dividing the sample, organized in a crescent order, in 100 equal parts. The first quartile (or percentile 25) includes 25% of the sample's lowest values, the second quartile (or percentile 50) corresponds to the average and the third quartile (or percentile 75) aggregates 25% of the sample's highest values. The distance between the first and the third quartiles indicates the results concentration with no influence of the extreme values.

The lower and upper horizontal lines represent, respectively, the minimum and maximum values. The asterisks evidence aberrant values that, although being part of the distribution, have a minimum chance of occurring again.

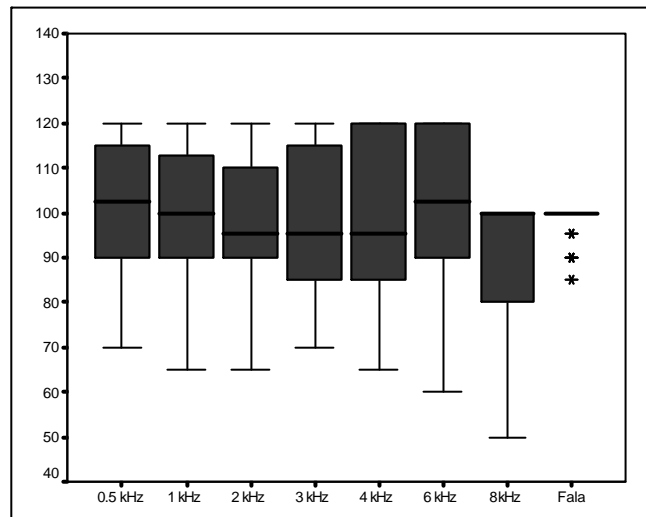
Table II shows the average and the Standard deviation of LDL for the right ear test situation and the significance level (p-value) of the comparison between female and male. Tables III, IV and V present the same data concerning the right ear retest, left ear test and left ear retest situations, respectively. Significant statistical differences were found between female and male for the frequencies of 500 and 1000 Hz in the right ear test and retest

TABLE I. Average, median, Standard deviation (Sd), upper limits (UL) and lower limits (LL) of the LDL results.

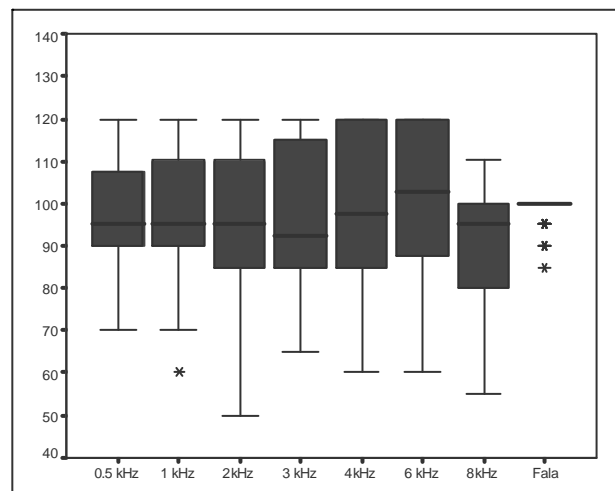
	N	Média (dB)	Mediana (dB)	DP (dB)	LI (dB)	LS (dB)
0,5kHz	256	98,8	100,0	14,4	97,0	100,6
1kHz	256	98,3	95,0	15,0	96,4	100,1
2kHz	256	98,4	95,0	16,0	96,4	100,3
3kHz	256	97,8	95,0	17,4	95,7	99,9
4kHz	256	99,4	95,0	17,7	97,3	101,6
6kHz	256	101,9	105,0	18,1	99,7	104,1
8kHz	256	88,9	100,0	14,1	87,2	90,6
fala	256	98,2	100,0	3,9	97,7	98,6

Legend: N= sample number, Sd= Standard deviation, LL=lower limit, UL=upper limit

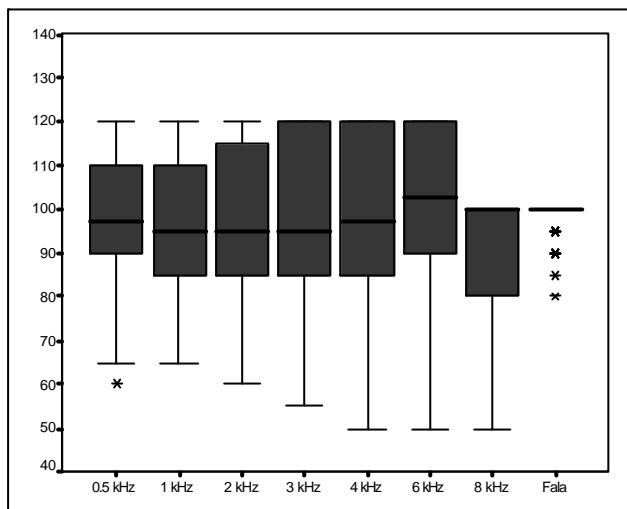
GRAPH 1. Medians, first and third quartiles and minimum and maximum values of LDL for the right ear test situation.



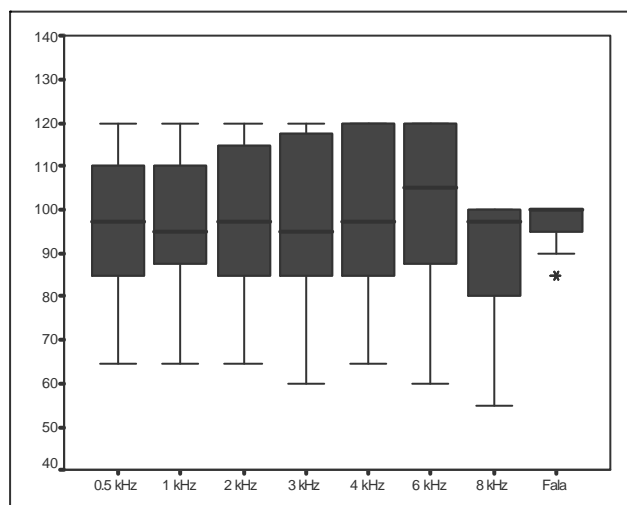
GRAPH 2. Medians, first and third quartiles and minimum and maximum values of LDL for the left ear test situation.



GRAPH 3. Medians, first and third quartiles and minimum and maximum values of LDL for the right ear retest situation.



Graph 4. Medians, first and third quartiles and minimum and maximum values of LDL for the left ear retest situation.



situations. For the left ear there were differences in 1000Hz in the test and retest situations and in 2000Hz in the retest situation. For the other frequencies the difference was not significant.

The estimate log-normal distribution function of the LDL lowest values averages per individual for the frequencies of 500 to 3000 Hz and for the frequencies of 4000 to 8000 Hz and for the speech stimuli are in Tables VI e VII, respectively.

Graph 5 illustrates the medians and the standard-error of the lowest LDL values per subject, for all tested stimuli. It can be observed that the LDL medians are stable in all frequencies, except the 8000 Hz.

The ART averages for 500, 1000, 2000 and 4000 were, respectively, 98.6, 97.4, 95.9 and 95.0 dBHL. The coefficients of determination (r^2) of the linear regression model used to study the correlation between $\log(\text{LDL})$ and $\log(\text{ART})$ showed absence of correlation between the studied variables (Table VIII).

Discussion

As the data distribution was asymmetrical, we considered more appropriate to study the LDL distribution for each frequency and not the average between them. As the Chi-square test did not show any statistical difference between the ears or between the test-retest situations, only the lowest response of each individual was considered. The lowest values were considered because in real situations and with a binaural hearing it is expected that the individual shows his discomfort when the sound intensity reaches the ear with the lowest discomfort threshold.

There were no statistical significant differences between the LDL of men and women ($p > 0.11$), which agrees with our clinical routine. Also, there were no statistical significant differences between the ears ($p > 0.36$) or between the test and retest situations ($p > 0.34$), which confirmed a good internal consistency of the test (Bornstein & Musiek, 1993).

As there isn't a consensus on which would be the best method to evaluate the loudness discomfort level, the few studies that evaluate the LDL in normal hearing subjects used different stimulus, instructions and procedures, making difficult the comparison of the results. Furthermore, most of the authors used dB SPL as a measure and not dB HL, since they intended to use the LDL to assist the adaptation of hearing aids (Beattie et al., 1979; Hawkins, 1980a; Bornstein & Musiek, 1993; Bentler & Cooley, 2001). Even though, we can infer that our results are similar to those reported by Bentler and Cooley (2001), from 500 to 4.000 Hz in dB HL, once the differences found for each frequency were lower than the standard deviation of both studies.

Just in order to enable the comparison between ours and other researchers' results, we presented the averages of LDL of both ears in the test and retest situations converted to decibel sound pressure level (dB SPL). We stress that this is a limited comparison once there was no methodological replication between the mentioned studies. The LDL averages for 0,5, 1, 2, 3, 4, 6, 8 kHz and speech were 107.8, 102.8, 105.1, 95.8, 107.7, 116.2, 100.8 and 97.5 dB SPL, respectively, and therefore above the ones presented by Hawkins (1980a). Our results were closer to Beattie's et al. (1979) results for speech sounds.

TABLE II. Average and Standard deviation (Sd) of LDL for the right ear (RE) test situation and the significance level (p-value) of the comparison between female (F) and male (M).

Teste - OD		Média (dB)	Mediana (dB)	DP (dB)	p-valor
0,5kHz	feminino	99,0	100,0	12,6	0,05*
	masculino	104,7	107,5	14,8	
1kHz	feminino	96,0	95,0	12,1	0,01*
	masculino	103,5	107,5	15,6	
2kHz	feminino	96,9	92,5	14,0	0,29
	masculino	101,8	105,0	15,3	
3kHz	feminino	93,7	85,0	16,3	0,06
	masculino	101,5	105,0	16,6	
4kHz	feminino	96,3	90,0	17,4	0,38
	masculino	102,3	105,0	16,4	
6kHz	feminino	100,2	100,0	17,0	0,54
	masculino	103,2	110,0	17,0	
8kHz	feminino	87,8	100,0	15,4	0,52
	masculino	89,8	100,0	13,6	
Fala	feminino	98,2	100,0	3,9	0,75
	masculino	98,8	100,0	3,6	

* = significant p values

TABLE III. Average and Standard deviation (Sd) of LDL for the right ear (RE) retest situation and the significance level (p-value) of the comparison between female (F) and male (M).

Reteste - OD		Média (dB)	Mediana (dB)	DP (dB)	p-valor
0,5kHz	feminino	94,3	95,0	13,6	0,03*
	masculino	102,5	110,0	15,5	
1kHz	feminino	92,5	90,0	15,4	0,02*
	masculino	103,0	107,5	15,7	
2kHz	feminino	94,7	90,0	16,2	0,06
	masculino	102,5	107,5	17,1	
3kHz	feminino	93,8	85,0	18,6	0,12
	masculino	102,8	102,5	16,7	
4kHz	feminino	95,9	90,0	20,2	0,15
	masculino	103,8	102,5	15,2	
6kHz	feminino	99,7	95,0	18,8	0,39
	masculino	104,5	107,5	16,4	
8kHz	feminino	86,5	87,5	15,0	0,12
	masculino	91,7	100,0	12,6	
Fala	feminino	97,5	100,0	4,3	0,33
	masculino	98,5	100,0	4,2	

* = significant p values

TABLE IV. Average and Standard deviation (Sd) of LDL for the left ear (LE) test situation and the significance level (p-value) of the comparison between female (F) and male (M).

Teste - OE		Média (dB)	Mediana (dB)	DP (dB)	p-valor
0,5kHz	feminino	96,2	95,0	12,6	0,18
	masculino	100,7	105,0	14,5	
1kHz	feminino	94,7	90,0	13,9	0,05*
	masculino	101,5	105,0	13,9	
2kHz	feminino	94,3	90,0	15,7	0,23
	masculino	100,3	105,0	16,5	
3kHz	feminino	93,8	90,0	17,3	0,15
	masculino	101,3	100,0	16,6	
4kHz	feminino	96,2	90,0	18,4	0,41
	masculino	102,3	100,0	16,8	
6kHz	feminino	100,4	95,0	18,7	0,33
	masculino	103,5	110,0	18,6	
8kHz	feminino	88,1	92,5	13,7	0,65
	masculino	90,2	100,0	14,5	
Fala	feminino	98,2	100,0	3,5	0,88
	masculino	98,8	100,0	3,1	

* = significant p values

TABLE V. Average and Standard deviation (Sd) of LDL for the left ear (LE) retest situation and the significance level (p-value) of the comparison between female (F) and male (M).

Reteste - OE		Média (dB)	Mediana (dB)	DP (dB)	p-valor
0,5kHz	feminino	94,1	92,5	14,3	0,07
	masculino	100,7	105,0	15,4	
1kHz	feminino	94,0	90,0	14,6	0,02*
	masculino	103,0	105,0	15,4	
2kHz	feminino	95,3	90,0	15,4	0,04*
	masculino	102,7	105,0	16,4	
3kHz	feminino	95,3	90,0	18,0	0,09
	masculino	102,2	107,5	17,2	
4kHz	feminino	97,4	92,5	19,5	0,51
	masculino	102,8	102,5	16,3	
6kHz	feminino	99,3	100,0	20,2	0,44
	masculino	105,3	117,5	18,2	
8kHz	feminino	87,4	90,0	14,4	0,54
	masculino	90,3	100,0	14,0	
Fala	feminino	97,5	100,0	4,7	0,76
	masculino	97,8	100,0	3,9	

* = significant p values

TABLE VI. Estimate log-normal distribution function for the frequencies between 500 and 3000 Hz.

x dB	500Hz			1.000Hz			2.000Hz			3.000Hz		
	Pr < x	LI	LS	Pr < x	LI	LS	Pr < x	LI	LS	Pr < x	LI	LS
80	0,13	0,09	0,19	0,16	0,11	0,21	0,18	0,33	0,23	0,20	0,15	0,26
85	0,24	0,18	0,30	0,26	0,20	0,32	0,28	0,22	0,34	0,30	0,24	0,37
90	0,36	0,30	0,43	0,38	0,32	0,45	0,39	0,32	0,46	0,41	0,34	0,48
95	0,50	0,43	0,57	0,51	0,44	0,58	0,51	0,44	0,58	0,52	0,45	0,59
100	0,62	0,56	0,69	0,63	0,57	0,70	0,62	0,55	0,69	0,63	0,56	0,69
105	0,73	0,67	0,79	0,74	0,67	0,80	0,72	0,66	0,78	0,72	0,65	0,78
110	0,82	0,76	0,87	0,82	0,76	0,87	0,80	0,74	0,85	0,80	0,73	0,85
115	0,89	0,84	0,92	0,88	0,83	0,92	0,86	0,81	0,91	0,85	0,80	0,90
120	0,93	0,89	0,96	0,93	0,99	0,95	0,91	0,86	0,94	0,90	0,85	0,93

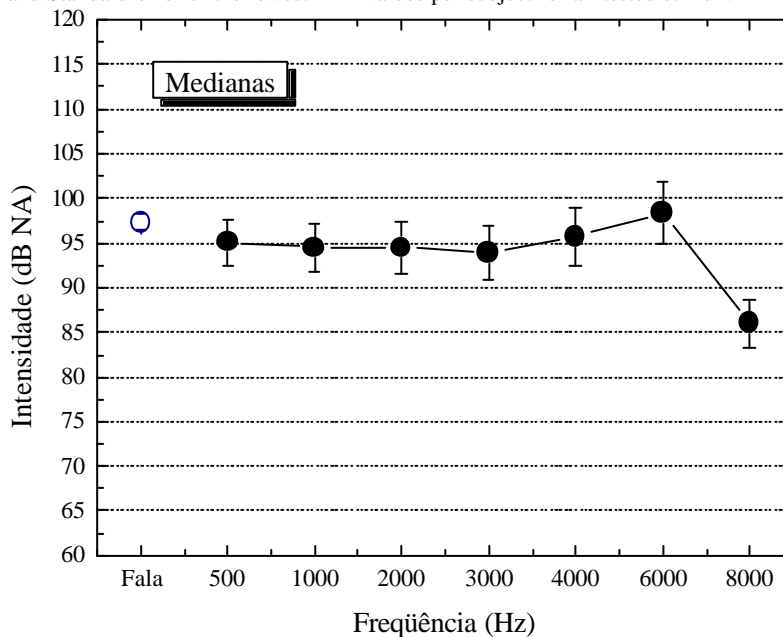
Legend: Pr<x= probability of a normal hearing subject to present a LDL lower than the "x" intensity, LL= lowest limit of such probability, UL= upper limit of such probability

TABLE VII. Estimate log-normal distribution function for the frequencies between 4000 and 8000 Hz and for the speech.

x dB	4.000Hz		6.000Hz			8.000Hz			Fala			
	Pr < x	LI	LS	Pr < x	LI	LS	Pr < x	LI	LS	Pr < x	LI	LS
80	0,18	0,13	0,24	0,15	0,11	0,21	0,35	0,28	0,41	0,00	0,00	0,00
85	0,27	0,21	0,33	0,23	0,18	0,30	0,47	0,40	0,54	0,00	0,00	0,01
90	0,37	0,31	0,44	0,33	0,27	0,40	0,60	0,53	0,66	0,06	0,03	0,09
95	0,48	0,42	0,55	0,43	0,36	0,50	0,70	0,64	0,77	0,31	0,25	0,33
100	0,59	0,52	0,66	0,53	0,46	0,60	0,79	0,73	0,85	0,71	0,65	0,77
105	0,68	0,62	0,74	0,63	0,56	0,69	0,86	0,81	0,90	0,94	0,90	0,96
110	0,76	0,70	0,82	0,71	0,64	0,77	0,91	0,86	0,94	0,99	0,98	0,99
115	0,83	0,77	0,88	0,78	0,72	0,83	0,94	0,91	0,97	0,99	0,99	0,99
120	0,88	0,83	0,92	0,84	0,78	0,88	0,96	0,94	0,98	1,0	0,99	1,0

Legend: Pr<x= probability of a normal hearing subject to present a LDL lower than the "x" intensity, LL= lowest limit of such probability, UL= upper limit of such probability

GRAPH 5. Median and Standard-error of the lowest LDL values per subject for all tested stimuli.



Although other researchers have applied the LDL in normal hearing subjects, our study was the first one aiming at investigating systematically the loudness discomfort level for pure tones in the frequencies of 500 to 8000 Hz, including 3000 and 6000 Hz, and for speech sounds, as recommended by tinnitus and hyperacusis evaluation and treatment centers (American Academy of Audiology, 2001; Jastreboff & Jastreboff, 2000; Jastreboff & Jastreboff, 2002; Gold et al., 2002; Jastreboff & Jastreboff, 2004). Therefore, our results provide normality values that may support the diagnosis criteria of sound intolerance by the LDL. As this test may obtain varying results depending on the instructions given to the patients (Beattie et al., 1979; Bornstein & Musiek, 1993), this research also proposes the standardization of four instructions provided before the exam (adapted from Hawkins, 1980a) and of the procedures used during the exam to allow a better comparison of results with future researches involving sound intolerance and/or tinnitus.

Despite the good reproductibility of the test, we observed an increased standard deviation (between 13.2 dBHL in 500 Hz and 17.9 dBHL in 6000 Hz). This great variability of inter-subjects responses alerts for the risk of foreseeing the individual result of the LDL from a group of individuals (Beattie et al., 1979; Hawkins, 1980; Knobel et al., 2002; Nelting, 2002). Our observations emphasize the importance of combining a detailed anamnesis on sound intolerance and the audiological evaluation data (Anari et al., 1999; Jastreboff & Jastreboff, 2002; Knobel & Sanchez, 2002; Jastreboff & Jastreboff, 2004).

On the other hand, the comparison of a subject LDL with his own LDL is highly confident, once there is a good reproductibility of this test. This makes the LDL a reliable test for the follow up of patients in treatment for sound intolerance, as recommended by Gold et al. (2002) and Hazell et al. (2002).

We applied a linear regression model in order to study the relationship between the LDL and the acoustic reflex threshold (ART) where the LDL was the dependent variable. Although the coefficient of determination (r^2 value) in 4.000 Hz was slightly above those found in other frequencies, there was no correlation between the LDL and the ART in both ears in all tested frequencies, as well as concluded by Goldstein and Shulman (1996). This lack of correlation may be better understood if we analyze the different physiological characteristics of the acoustic reflex and of the loudness. While the acoustic reflex is triggered in the olivary complex, the loudness is coded in all structures of the auditory pathway, including the auditory cortex. Furthermore, the loudness depends on the subjective perception and evaluation of each subject which does not occur with the acoustic reflex. Therefore, there still isn't an objective measure that can assist the sound intolerance diagnosis, which basically depends on the association of the anamnesis and the LDL data.

Conclusions

In young normal hearing individuals without tinnitus or sound intolerance complaints, the LDL median for all frequencies varied from 86 and 98 dBHL. As this test presented great inter-subject differences, we recommend that the individual interpretation of the LDL should be carefully done and always associated with the anamnesis data. However, the high reproductibility of this test suggests that the LDL is a good instrument for the follow up of patients with sound intolerance complaints.

There was no correlation between the LDL and the ART and, therefore, the ART can not be used to predict the LDL.

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References

- AL-AZAZI, M. F.; OTHMAN, B. M. Acoustic reflex threshold and loudness discomfort. *Saudi. Med. J.*, v. 21, n. 3, p. 251-256, 2000.
- AMERICAN ACADEMY OF AUDIOLOGY. *Audiologic guidelines for the diagnosis and management of tinnitus patients*. 2001. Disponível em: <<http://www.audiology.org/professional/positions/tinnitus.php>>. Acesso em: 31 jan. 2001.
- ARAÚJO, V.; IORIO, M. C. M. Nível de desconforto e limiar do reflexo acústico contra-lateral: um estudo em idosos. *Rev. Soc. Br. Fonoaudiol.*, v. 8, n. 1, p. 19-26, 2003.
- ANARI, M.; AXELSSON, A.; ELIANSOON, A.; MAGNUSSON, L. Hypersensitivity to sound. Questionnaire data, audiometry and classification. *Scand. Audiol.*, v. 28, n. 4, p. 219-230, 1999.
- BEATTIE, R. C.; EDGERTON, B. J.; GAGER, D. W. Effects of speech materials on the loudness discomfort level. *J. Speech Hear. Dis.*, v. 44, p. 435-458, 1979.
- BENTLER, R. A.; COOLEY, L. J. An examination of several characteristics that affect the prediction of OSPL90 in hearing aids. *Ear&Hearing*, v. 22, n. 1, p. 58-64, 2001.
- BENTLER, R.A.; PAVLOVIC, C.V. Comparison of discomfort levels obtained with pure tones and multitone complexes. *J. Acoust. Soc. Am.*, v. 86, p. 126-132, 1989.
- BORNSTEIN, S. P.; MUSIEK, F. E. Loudness discomfort level and reliability as a function of instructional set. *Scand. Audiol.*, v. 22, p. 125-131, 1993.
- BREUEL, M. L. F.; SANCHEZ, T. G.; BENTO, R. F. Vias auditivas eferentes e seu papel no sistema auditivo. *@rq. Otorrinolaringol.*, v. 5, n. 2, p. 62-67, 2001.
- GOLD, S. L.; FORMBY, C.; FREDERICK, E. A.; SUTER, C. Shifts of loudness discomfort level in tinnitus patients with and without hyperacusis. In: INTERNATIONAL TINNITUS SEMINAR, 7., 2002, Perth. *Proceedings...* Perth: The University of Western Australia, 2002. p. 170-172.
- GOLDSTEIN, B.; SHULMAN, A. Tinnitus, hyperacusis and loudness discomfort level test: a preliminary report. *Int. Tinnitus J.*, v. 2, n. 1, p. 83-89, 1996.
- HAWKINS, D. B. Loudness discomfort levels: a clinical procedure for hearing aid evaluations. *J. Speech Hear. Dis.*, v. 45, p. 3-15, 1980a.
- HAWKINS, D. B. The effect of signal type on the loudness discomfort level. *Ear Hear.*, v. 1, p. 38-41, 1980b.
- HAZELL, J. W. P.; SHELDRAKE, J. B.; GRAHAM, R. L. Decreased sound tolerance: predisposing factors, triggers and outcomes after TRT. In: INTERNATIONAL TINNITUS SEMINAR, 7., 2002, Fremantle, Australia. *Proceedings...* Perth, Australia: The University of Western Australia, 2002. p. 255-261.
- HENRY, J. A.; MEIKLE, M. B. Psychoacoustic measures of tinnitus. *J. Am. Acad. Audiol.*, v. 11, n.1, p. 138-155, 2000.
- HOOD, J. D.; POOLE, J. P. Tolerable limit of loudness: its clinical and physiological significance. *J. Acoust. Soc. Am.*, v. 40, n. 1, p. 47-53, 1966.
- JASTREBOFF, M. M.; JASTREBOFF, P. J. *Hyperacusis*, 2002. Disponível em: <<http://www.healthyhearing.com/healthyhearing/newroot/articles>>. Acesso em: 10 jan. 2003.
- JASTREBOFF, P.; JASTREBOFF, M. M. Tinnitus retraining therapy (TRT) as a method for treatment of tinnitus and hyperacusis patients. *J. Am. Acad. Audiol.*, v. 11, n. 3, p. 162-177, 2000.
- JASTREBOFF, P.; JASTREBOFF, M. M. Decreased sound tolerance. In: SNOW, J. *Tinnitus: theory and management*. Hamilton: BC Decker, 2004. p. 8-15.
- KATZENELL, U.; SEGAL, S. Hyperacusis: review and clinical guidelines. *Otol. Neurotol.*, v. 22, n. 3, p. 321-327, 2001.
- KNOBEL, K. A. B.; SANCHEZ, T. G. Atuação dos fonoaudiólogos do estado de São Paulo na avaliação do paciente com zumbido e/ou hipersensibilidade a sons. *Pró-Fono Revista de Atualização Científica*, v. 14, n. 2, p. 215-224, 2002.
- KNOBEL, K. A. B.; SANCHEZ, T. G. Intolerância a sons. In: SAMELLI, A. G. *Zumbido: avaliação, diagnóstico e reabilitação*. Abordagens atuais. São Paulo: Lovise, 2004. p. 45-54.
- KNOBEL, K. A. B.; SANCHEZ, T. G.; PFEILSTICKER, L. N.; STOLER, G. Valores de referencia de normalidad para la prueba del nivel de disconfort para la sensación de intensidad: resultados preliminares. *Auditio. Rev. E. Audiol.*, v. 1, n. 3, p. 37-40, 2002.
- MAGALHÃES, S. L.; FUKUDA, Y.; LIRIANO, R. I.; CHAMI, F. A.; BARROS, E.; DINIZ, F. L. Relation of hyperacusis in sensorineural tinnitus patients with normal audiological assessment. *Int. Tinnitus. J.*, v. 9, n. 2, p. 79-83, 2003.
- MCLEOD, H. L.; GREENBERG, H. J. Relationship between loudness discomfort level and acoustic reflex threshold for normal and sensorineural hearing-impaired individuals. *J. Speech Hear. Res.*, v. 22, p. 873-882, 1979.
- MUSIEK, F. E.; RINTELMANN, W. F. Reflexo acústico. In: MUSIEK, F. E.; RINTELMANN, W. F. *Perspectivas atuais em avaliação audiológica*. Tamboré: Manole, 2001. p. 127-162.
- NELTING, M. Hyperacusis: an overview of international literature and clinical experience. In: *International Tinnitus Seminar, 7.*, 2002, Fremantle, Australia. *Proceedings...* Perth, Australia: The University of Western Australia, 2002. p. 218-221.
- SANTOS, A. O. Intolerância a sons: hiperacusia, fonofobia e recrutamento. 2000. 121 f. Dissertação (Mestrado em Distúrbios da Comunicação) - Pontifícia Universidade Católica de São Paulo, São Paulo.
- VALENTE, M.; GOEBEL, J.; DUDDY, D.; SINKS, B.; PETEREIN, J. Evaluation and treatment of severe hyperacusis. *J. Am. Acad. Audiol.*, v. 11, p. 295-299, 2000.