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DANCING THE AEROBICS "HEARING LOSS CHOREOGRAPHY"

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ABSTRACT
This paper presents an overview of the health clubs acoustic problems when used for aerobics exercises classes (and similar) with loud noise levels in sound amplified music. A sample of five schools in Portugal was chosen for this survey. Noise levels in each room were measured and analyzed to calculate the standardized daily personal noise exposure levels (*Leq8*). *Leq8* values up to 96 dB(A) were found in this type of room inducing a health risk for its occupants. This type of gymnasium is usually a highly reverberant space, which is consequence of a large room volume surrounded by hard surfaces. The reverberation time (*RT*) values were also measured and compared with some European legal requirements (Portugal, France, and Belgium) for nearly similar situations. *RT* values (1 kHz) from 0.9 s to 2.8 s were found and clearly differentiate between good and acoustically inadequate rooms. Some noise level and *RT* limits for this type of environment are given and suggestions for the improvement of the acoustical environment are shown. Significant reductions in *RT* values and noise levels can be obtained by simple measures as presented.

1 - INTRODUCTION

In urban areas where we have a little number of safe and well-illuminated spaces, far from traffic, to enjoy free exercise we see everyday the increase in the number of gymnasiums and health clubs.

The benefits of regular physical activity are known. However, the acoustic environments of the spaces where that practice is possible are many times inadequate, originating negative auditory effects. The exposure to high noise levels for considerable periods of time may result in the reduction in hearing sensitivity or even in hearing loss, beyond the possible effects in extra-auditory systems.

The acoustic problems of health clubs, when used for lessons of aerobics or similar, constitute the central subject of this work. The acoustic comfort of the rooms for aerobics depends not only on the existing background music but also on the physical characteristics of the rooms. They are usually very reverberant spaces (closed and little absorbent spaces) where a sound source (tape recorder or CD player) installs high levels of sound. The long reverberation times (*RT*), besides masking the direct sounds, increase the sound level, constituting a kind of natural amplification. The different *RT* of the rooms can also be an indicative of the acoustics quality of this type of place.

2 - METHODOLOGY

2.1 - Sample and Equipment

Five spaces taken as representative of this type of rooms were analyzed by measuring the sound pressure levels and the reverberation times. The five health clubs are situated in the district of Porto (Portugal) and present the main physical characteristics described in Table 1.

The sound pressure levels were measured with an integrator sound level meter (B&K 2260) and allowed the calculation of the personal daily noise exposure of students and professors. The measurement of the reverberation time was made using a sound source (B&K 4224) that emits a noise whose signal is co-ordinated by the sound level meter through adequate software.

ARCHITECTURAL FEATURE	HC 1 *Maia Club*	HC 2 *Academia Impacto*	HC 3 *Life Club*	HC 4 *Exercícius*	HC 5 *Jardins da Bélgica*
Height (m)	3.35	3.85	2.43	3.13	2.78
Length (m)	25.40	16.50	8.00	8.10	8.92
Width (m)	13.80	5.70	16.50	20.50	10.51
Volume (m^3)	1175	360	320	520	260

Table 1 – Main characteristics of the five health clubs (HC).

2.2 - Method

2.2.1 - Sound pressure levels

The characterization of the emitted noise level within each room was made by the measurement of the sound pressure levels of the music during the lessons (Fig. 1). The aerobics lesson is divided in three phases: the warm up (general mobilization; duration between 8 and 15 minutes), the choreography (main and longer part; duration between 35 and 47 minutes) and the cool down (return to calm; duration between 5 and 10 minutes).

In the "warm up" and "cool down" the noise level is habitually a little lower than in the "choreography" however, this difference is many times not significant. Therefore, the students will be about one hour under high sound pressure levels aggravating the situation for the professor that is exposed to about 3 hours (however, currently a significant number of students remains more than 1 hour in the health club in two consecutive lessons).

All the measurements were made in one-third octave bands during each of the three phases and allowed the calculation of the personal daily exposure noise level of the students and professors.

Figures 1 and 2 - Images of two of the rooms tested (HC 4 and HC 2).

2.2.2 - Reverberation time

The determination of the acoustic characteristics of the rooms was made by measurements of the reverberation time (*RT*) in octave bands (125 - 8000 Hz). The measurements were made in three positions of the microphone within each room only with the presence of three persons (Fig. 2). From these three measured values, a mean *RT* value was calculated for each room.

3 - RESULTS AND ANALYSES

3.1 - Sound Pressure Levels

The measured sound levels are displayed in Table 2 for each part of the lessons. These health clubs are characterized by relatively similar sound levels (around 93 dBA) but some differences were found that are caused by distinct intensities of the emitted music.

According to the measurements made, the sound levels are usually higher in phase 2 of each lesson (choreography) in about 2 dB(A) (Table 2).

LAeq (dB)	HC 1	HC 2	HC 3	HC 4	HC 5	$L_{A\ eq\ Average}$
Phase 1 - warm up (8-15 mnts)	88	96	93	93	89	92
Phase 2 - choreography (35-47 mnts)	88	102	92	94	94	94
Phase 3 - cool down (5-10 mnts)	88	96	93	93	92	92
All phases (60 mnts)	88	100	92	94	93	93

Table 2 – Sound levels for each class phase in dB(A) in the five health clubs (HC).

3.2 - Frequency Spectra

The Figure 3 shows the five frequency spectra regarding the emitted sound pressure levels in the five health clubs (during the choreography phase, the noisiest). Differences up to 20 dB were found between the spectra that show the two extreme sound behaviours (HC 1 and HC 2)

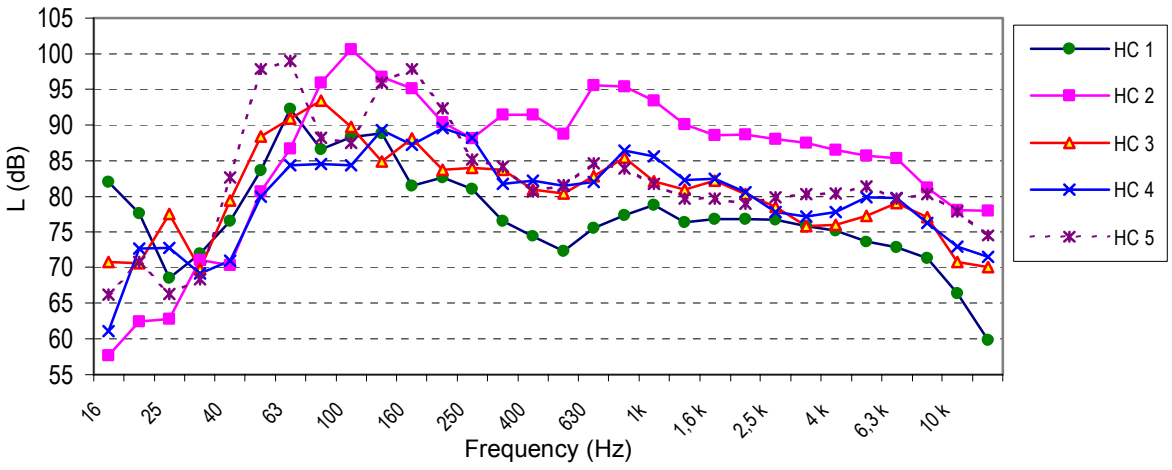

Fig. 3 – Frequency spectra for the "choreography" (phase 2 of the lessons) in the five health clubs (HC).

3.3 - Daily Personal Noise Exposure

The daily personal noise exposure (*LAeq 8*) is expressed by the following standard expression (ISO 1999):

$$L_{A\,eq\,8} = 10\,.\,\log\left[(1/8)\sum_{k=1}^{n} T_k\,.10^{(0.1\,L_{Aeq\,,Tk})}\right]$$

where $L_{Aeq,Tk}$ is the equivalent continuous A-weighted noise level over a period of time T (hours) for the noise k that the person is exposed over a nominal eight-hour workday.

The same methodology was applied in all the health clubs, admitting the professors with 3 hours of lessons and the students with 1 hour of lesson (however, currently, a significant number of students remains more than 1 hour in the health club in two consecutive lessons). All the attended lessons had a duration of 60 minutes. The calculated results for the professors and students are displayed in Table 3 together with the peak instantaneous sound pressure levels (*LpkMaxP*).

The five analyzed health clubs show values of *Leq8* from 84 to 96 dB(A) for the professors and about 5 dB(A) less for the students (Table 3 and Fig. 4).

The European legislation stipulates that the daily personal noise exposure level for the workers cannot exceed 85 dB(A) and the instantaneous peak sound pressure level cannot exceed 140 dB. Therefore, the analyses demonstrated important risks for the health club professors in 80% of the situations and for the students in 20% of the cases (Fig. 4).

Regarding the instantaneous peak sound pressure levels, the 140 dB are not reached but very high values were found. In three health clubs instantaneous peak values of 123 dB were measured (Fig. 5).

Being 85 dB(A) the legal maximum value from which an intervention is needed, a comfort value is suggested that would be 5 dB(A) less than that limit (that is, 80 dBA), thought adequate as a limit for minimum comfort in these spaces. The instantaneous peak limit for comfort situations is suggested to be set as 100 dB (Fig. 5).

Health club	DAILY NOISE EXPOSURE $L_{A\,eq\,8}$ (dB)		INSTANTANEOUS PEAK VALUE $L_{pk(MaxP)}$ (dB)	
	Student / Professor	Compliance with legal limit	Measured value	Compliance with legal limit
HC 1	79 / 84	*yes*	114	*yes*
HC 2	91 / 96	*no*	123	*yes*
HC 3	84 / 88	*yes / no*	121	*yes*
HC 4	85 / 89	*yes / no*	123	*yes*
HC 5	84 / 89	*yes / no*	123	*yes*

Table 3 – Daily noise exposure levels, instantaneous peak sound pressure levels (students and professors), and their compliance with legal limits.

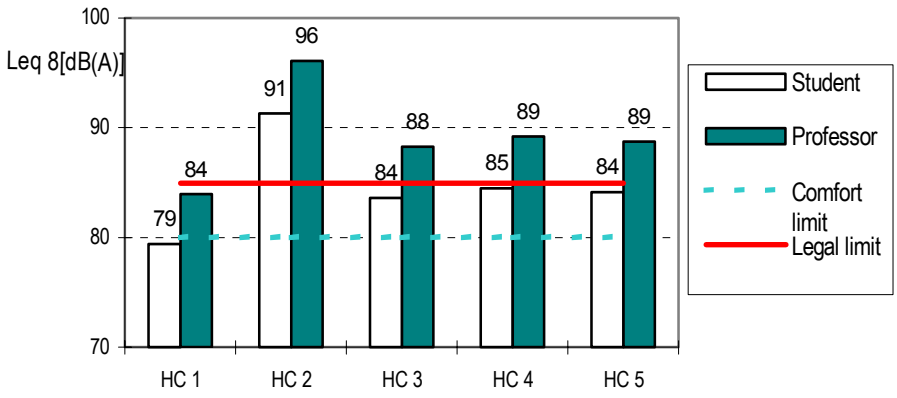

Fig. 4 - Personal daily exposure levels in the five health clubs (HC).

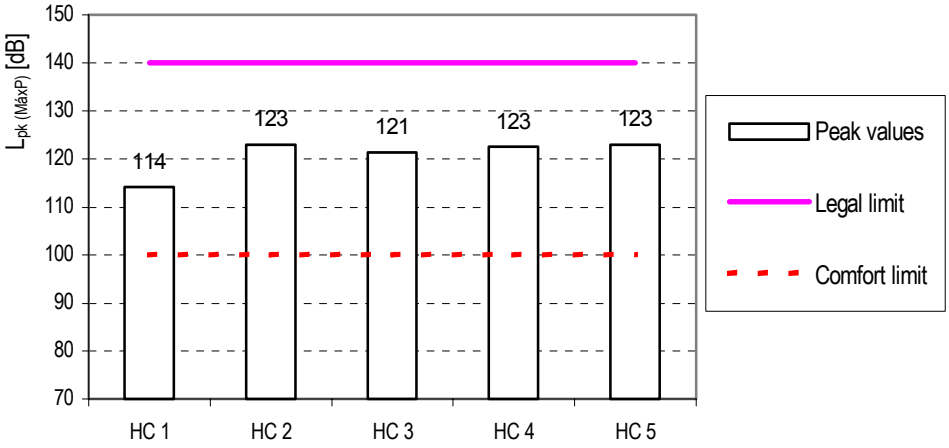

Fig. 5 – Instantaneous peak sound pressure levels ("choreography" phase) in the five health clubs (HC).

In the presence of the above commented situations of general non-compliance of the desired requirements for acoustic comfort, a maximum limit value for the equivalent sound level during each lesson is suggested below that contemplate the auditory health of the persons exposed to high noise during the classes. The worst case was considered, that is, the exposition of the professor to the existing music in each analyzed health club. Imposing the personal daily noise exposure level of the professor to the comfort limit maximum value of 80 dB(A) and keeping the relations found among the sound levels in each phase of the lessons, the maximum value that could exist in class, was calculated. Values not higher than the 85 dB(A) seem, as a general rule, to satisfy the mentioned objective. This maximum sound level of 85 dB(A) during the lessons is easily obtained lowering the music sound level from 4 to 16 dB(A) of the current existing values. The music would still remain high enough to give the much-needed sonorous stimulation to those that practice or teach this type of lessons.

3.4 - Reverberation Time

The values found for the reverberation times by octave band (125 - 8000 Hz) in the five health clubs are displayed in Figure 6. The measured values are, in general, relatively high, a direct consequence of the large room volume with surfaces naked of sound absorbent material that characterizes this type of space. By the analyses on the mean *RT* values in each room, calculated using the arithmetic average of the *RT* in the bands of 500, 1000 and 2000 Hz, the following expression of correlation between the *RT* (s) and the *Volume of the room* (m^3) was found that may characterize the current situation in Portugal:

$$RT\ mean\ (s) = 0.91\ ln\ V - 3.81 \quad \text{(with a } R^2 = 0.80\text{)}.$$

The measured *RT* values were also compared with the limit values stated for similar situations, in the Portuguese law and also in the French and Belgian laws to clarify distinct requirements in diverse countries (Tables 4 and 5) [1,2].

When comparing the measured values with the ones in the legislation there is an almost generalized non-compliance except for Health Club 5, the one with the smallest volume (Table 5).

Country	Rooms (with furniture but without occupancy)	*RT* [mean 500+1k+2k Hz] (s)
Belgium	State schools buildings (rooms and halls for sports)	$RT \leq 1.40 + 0.24 \log V$
France	School buildings (classrooms, music, etc.)	$RT \leq 1.2$
Portugal	Halls for sport and school gymnasiums	$RT \leq 0.1875\ V^{1/3}$

Table 4 – Reverberation time legal values in Belgium, France and Portugal [1, 2].

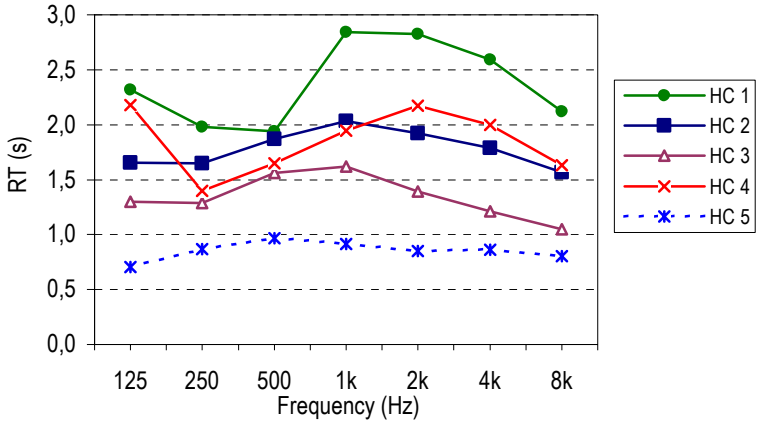

Fig. 6 – Measured reverberation time values for the five health clubs (HC).

Health club	Volume (m^3)	*RT* [mean: 500+1k+2k Hz] measured (s)	*RT* maximum legal limits (s)			Legislation compliance		
			Belgium	France	Portugal	Belgium	France	Portugal
HC 1	1175	2.5	2.1	1.2	2.0	*no*	*no*	*no*
HC 2	360	1.9	2.0	1.2	1.3	*yes*	*no*	*no*
HC 3	320	1.5	2.0	1.2	1.3	*yes*	*no*	*no*
HC 4	520	1.9	2.1	1.2	1.5	*yes*	*no*	*no*
HC 5	260	0.9	2.0	1.2	1.2	*yes*	*yes*	*yes*

Table 5 – Reverberation time values compliance with legislation in Belgium, France and Portugal.

Regarding the interior acoustics of these spaces it is possible to correct the reverberation time with simple measures. The ideal will be to start for defining an ideal reverberation time for this specific type of space and to make it an imperative in the design of these rooms.

As the legislation regarding *RT* in some countries is not well adjusted to this type of spaces a specific ideal value is suggested below. It contemplates the usual range of room volumes (about 250 to 1500 m^3) and the specific characteristics of these places to reach the desired acoustic comfort.

A legal dependence of a maximum *RT* with the room volume does not bring great benefits. The same happens with the use of an average value among several octave frequency bands. Thus, the ideal mean reverberation time for this type of rooms is suggested to be referenced to the octave frequency band of 1 kHz and to be independent of the room volume. A maximum reverberation time of 1.5 s seems appropriate. Such value is perfectly possible to reach with the use of sound absorptive material (to coat total or partially the ceiling, for instance).

In the tested sample of health clubs and for a maximum average reverberation time of 1.5 s (judged ideal) the ceiling area that it would have to be covered by absorptive material (with a sound absorption coefficient not inferior to 0.8) will be between 50% and 100% of its total.

4 - CONCLUSIONS

4.1 - Situation in Portugal

The goal for this study was the characterization of the acoustic environments in rooms for aerobic classes or similar since their specific characteristics of use do not facilitate a direct application of the legislation.

The existing general situation in Portugal is summarized in Table 6 where it is presented the range of values found for some parameters (sound level, personal daily noise exposure, instantaneous

peak sound pressure levels and average reverberation time) in a sample of five representative health clubs.

Parameter	Range of values	Comments
L_p (dBA)	88 - 102	Very high values. Some of these values will imply the surpass of the 80 dB(A) minimum comfort limit for the daily noise exposure
Leq 8 (dBA)	79 - 96	Generally high values because the legal limit is 85 dB(A) and the suggested minimum comfort is 80 dB(A)
$L_{pk(MaxP)}$ (dB)	114 - 123	High values (but within legal limits) that surpass the proposed minimum comfort of 100 dB
RT mean (s)	0.9 – 2.5	Generally high values potentially causing acoustic discomfort

Table 6 – Summary of the sampled situation in Portugal (*L, Leq 8*, *Lpeak* and *RT*).

4.2 - Design Goals

In summary, a set of ideal objectives can be defined as design goals for this type of space (see Table 7).

Parameter	Proposed limit values for minimum comfort	Comments
Leq,8 (dBA)	80	Maximum admissible value for the personal daily exposure level
Lpk(MaxP) (dB)	100	Maximum admissible value for the instantaneous peak sound pressure level
L_p (dBA)	85	Maximum sound level that can exist in each lesson so that the daily noise exposure of the professor does not exceed the 80 dB(A)
RT (s)	1.5	Referenced to the octave frequency band of 1 kHz and independent of room volume
Sound absorption (% ceiling area)	50% - 80%	Ceiling area that should be covered with sound absorptive material ($\alpha \geq 0.8$) to allow, in general, a maximum average *RT* of 1.5 s

Table 7 – Ideal design goals for minimum comfort (*Leq 8*, *Lpeak*, *Lp, RT* and *Sound Absorption*).

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