Assessment of preferred maximum sound output intensity of personal audio devices on a recommended safety exposure time scale

Adinife Patrick Azodo[1, 2*] and Idama Omokaro[3]

[1]*Department of Mechanical Engineering, Federal University of Agriculture, Abeokuta P.M.B 2240, Nigeria*
[2]*Federal University Wukari, Wukari P.M.B 1020, Nigeria*
[3]*Department of Computer Engineering, Delta State Polytechnic Ozoro P.M.B 05, Nigeria*
[*]*Corresponding author: azodopat@gmail.com*

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ABSTRACT

The operation safety of personal audio device (PAD) as regards sound exposure intensity level considered as a function of exposure duration was carried out in this study. Maximum sound output intensity (MSOI) level from the participants' PADs was determined through physical measurement and analyzed on a sound exposure time guidelines. The PADs MSOI evaluation was conducted in a room environment with a background noise range of 48.4 to 57.3 decibels so as to avoid background noise interference with the choice listening levels of the participants. Analysis carried out on the obtained data showed that, for short exposure time of 0.5-2 minutes, all participants operated within recommended safety exposure time scale. Thereafter, the exposure duration from 4-120 minutes indicated a consistent increase in unsafe operation characteristics and reverse act on safe operation characteristics. It was concluded that a maintained PAD sound output intensity level exposure for an extended time space of 2 hours translated from safe to unsafe operation characteristics. It then means that time space for the PAD should be considered for either tune up or down of one's PAD as recommended safety exposure is a function of time.

Keywords: safety; sound intensity; PAD; exposure time; music

1. INTRODUCTION

A personal audio device (PAD) is a featured sophisticated sound system that allows an individual listener to exert absolute control of his/her auditory environment. PADs as observed by Fligor and Cox (2004) are capable of producing sound pressure at peak levels exceeding 130 decibels (dB) which is typically beyond the uncomfortable loud sound range. Some studies specifically measured the output level of the PAD and found that the sound exposure limits in most of the studies exceeded 85 dBA, which is the US National Institute for Occupational Safety and Health (NIOSH) recommended exposure limit for occupational noise exposure (Fligor and Cox, 2004; Williams, 2005; Keppler et al., 2010; Levey et al., 2011; Portnuff et al., 2011). Fligor and Cox (2004) specifically observed a range of 91 to 121 dBA; 104.6 - 126.9 dBA by Portnuff et al. (2011) and 101 dBA to 107 dBA by Keppler et al. (2010). The average chosen listening levels of 92.6 dBA and 86.1 dBA were found by Levey et al. (2011) and Williams (2005) respectively.

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When the sound output intensity of a PAD is high, it changes the social space dominant auditory characteristics of the listener thereby altering the person's perception of the music venue or space by focusing it on the music (Portnuff, 2016). In achieving this through PADs, it was revealed that young adults utilize their PAD at its maximum volume settings thereby exceeding the specified damage-risk criterion (DRC) for the maximum sound output limit of a particular device to the recommended exposure level (REL) which is unsafe (Hoover and Krishnamurti, 2010; Portnuff, 2016). Exposure to sound and music at high levels can have substantial incessant or intermittent health-damaging effects which can only be ascertained after an extended period of exposure (Portnuff, 2016).

Intricate relationship of adolescents with music and portable devices has diverging effects on their listening characteristics (Portnuff, 2016). The inclined exposure to potentially damaging loud sounds by young people during leisure and social activities is anecdotally believed to be due to their higher tolerance and narcissistic attachment to music played at a high-intensity level (Weinstein, 1994; Widén and Erlandsson, 2004). For the purpose of emphasis, literatures showed that youths adopt the use of PAD and exposure to high sound intensity for different purposes which include moods and emotions regulation (Portnuff, 2016); shaping of their experiences (Simun, 2009) risk-taking behavior (Portnuff, 2016); sensation-seeking preference (Weinstein, 1994; Todd and Cody, 2000; Rawool and Colligon-Wayne, 2008) and an immersion in a shared musical sound field (Hétu and Fortin, 1995). Donovan (1988) further expatiated on this by saying that loud music share common roots as the effects observed with most addictive substances such as induced rapid mood change, arousal levels, and reduction of negative state and induce craving experience.

Music sound just as noise comprises three basic parts; the tonal distribution, the sound intensity and time (Fields, 1984). The sensitivity of the human ear to either noise or music sound at high-intensity level depends on measured physical sound pressure ranging from 0 to a threshold of 140 dB (Levitt, 2001). Since the response to sound or noise depends on its characteristics such as intensity, frequency, complexity, duration and narcissistic meaning, its unwantedness may then be defined by the intensity, tonal distribution, and duration (Stephen and Mark, 2003). Therefore, listening to loudly amplified music can be responsible for hearing damage as that caused by industrial noise (Meyer-Bisch, 1996). The associated risk reference of the damage-risk criterion in this study adopted the US National Institute for Occupational Safety and Health (NIOSH, 1998). Industrial noise exposure in different occupational noise prone dispensations has several set damage-risk criteria limits. However, recreational noise, sound or music exposure is yet to have a globally established damage-risk criterion.

According to Portnuff (2016) study, exposure due to PAD use evaluation should be by measurement of the actual exposure intensity with due consideration to exposure time. Evaluation of music exposure level from PAD by measurement of the actual exposure intensity at continuous but specified time intervals has not been considered in the literature. Therefore, this study assessed the preferred maximum sound output intensity level of PADs over a period of two hours on a recommended safety exposure time scale.

2. MATERIALS AND METHODS

This study was conducted between the months of September to December 2018 in Abeokuta, Ogun state, Nigeria. The following research instrumentations were used for data collection; a Benetech Model GM 1352 digital sound level meter (Shenzhen Jumaoyuan Science and Technology Co., Ltd., China) and a generic silicone human ear model. The digital sound level meter operates slow response mode and records A-weighted frequency. The resolution setting was 0.1 dB accurate to ±1.5 dB. The measurement and frequency ranges of the noise level meter were 30-130 dBA and 31.5-8 KHz, respectively.

This study adopted purposive sampling technique in the selection of the study participants. An eligibility form was designed which contained gender, age, mobile contact, purpose of the study, and the participants inclusion/exclusion criteria such as personal audio device ownership (phone adapted with MP3 player accessory inclusive), age between the ranges of 15-20 years and no history auditory health challenges. This was administered to the targeted participants on the first contact with the researchers. The completed eligibility forms were assessed according to the inclusion/exclusion criteria for recruitment. Eligible participants were contacted and appointment were scheduled for the assessment of preferred maximum sound output intensity of from their PADs. Those who turned down participation as well as incomplete assessment were excluded. The environment considered for the study has a background noise range of 48.4 to 57.3 dB, according to a typical noise levels scale by Aaberg (2007), is within the range of quiet to moderately quiet noise levels which does not interfere with communication. This was to avoid environmental noise interference with the choice listening levels by the participants as music sound within this range found in the literature (Portnuff et al., 2011) does not influence the choice listening level.

A pilot study was first conducted in the same environment and monitored for maintained background noise within the stated range guided the choice of the maximum number of two participants assessment per time so as to avoid communication among the participants as such influencing the choice of listening output levels of the PAD by the participants owing background noise. All the PADs used by the participants has volume setting indication. This enabled the participants to select and play their preferred music files from their phone galleries at their considered volume settings, which they of course notified the researchers should they need to adjust the volume settings at anytime. This was carried out for a continuous play of time space of 120 minutes. The 120-minute assessment duration adopted was guided by the predominant average report of 2 hours per day of listening to music on PAD reported in literatures among youths within the same age bracket in this study (Portnuff et al., 2011; Ahmed et al., 2006, Hoover & Krishnamurti, 2010, Danhauer et al., 2009). The music selected by participants' on their PADs were observed and noted within the assessment time intervals. The continuous sound output of the same set of selected music and volume set played by each participant from their PADs measured in dB was assessed with the aid of the a generic silicone human ear model and a Benetech GM1351 digital sound level meter for measurement of the maximum output intensity level. This was done by plugging ear-piece of the participants' phone on the entrance of ear canal of generic silicone model artificial ear (pinna side) while digital sound level meter on the other end. The maximum sound output levels were recorded within the stipulated exposure time intervals of 0.5, 1.0, 2.0, 4.0, 7.5, 15, 30, 60 and 120 minutes by NIOSH.

The data obtained were analyzed using Microsoft Office Excel version 2007. The participants' safety sound level analysis for exposure time and noise intensity level was assessed with a one-tailed criterion (Equation 1). The recommended exposure time guideline for a continuous time weighted average noise considered were split into two bins for a nine period of analysis: the upper and the lower bin represented the unsafe and safe usage percentage of the exposure time with respect to the noise intensity level.

$$Spl = \frac{\sum(wf_i.t_i)}{\sum t_i} \in [0, 1] \quad (1)$$

$$\begin{bmatrix} Spl_{unsafe} \text{ with } wf_i = \begin{bmatrix} 1 \; if \; I_{sound\ level} > I_{REL\ limit} \\ 0 \; if \; I_{sound\ level} \leq I_{REL\ limit} \end{bmatrix} \\ Spl_{safe} \text{ with } wf_i = \begin{bmatrix} 1 \; if \; I_{sound\ level} < I_{REL\ limit} \\ 0 \; if \; I_{sound\ level} \geq I_{REL\ limit} \end{bmatrix} \end{bmatrix}$$

Table 1 Recommended exposure time guideline for sound levels and duration combination **(**NIOSH, 1998**)**

Sound exposure level (dB)	Exposure duration (minute)
85	480
88	240
91	120
94	60
97	30
100	15
103	7.5
106	3.75 ≈4
109	1.875 ≈2
112	0.9375 ≈1
115	0.46875 ≈0.5

3. RESULTS AND DISCUSSION

There was equal gender distribution for 68 participants in this study. The age distribution of the participants is shown in Figure 1. The maximum age of the participants was 20 years while the minimum age was 15 years. The type of PADs owned and used by the participants in this study were phones of different models; Tecno, Gionne, Samsung, Itel, Infinix, and Blackberry phones. In fact, PAD technology grant users usage flexibility and conveniences to listen to whatever they want and whenever they want at any desired sound output intensity, it is important to note that understanding of the aftermath health implications with respect to exposure intensity and time be known for an individual user's safety regulations (Skånland, 2013). Analysis carried out on the recommended exposure limit for a time-space using NIOSH (1998) (Table 1) showed that, for the first two minutes (0.5-2.0 minutes), a maximum sound output intensity range from 66.1 to 106.5 dB was obtained which was within the recommended exposure range.

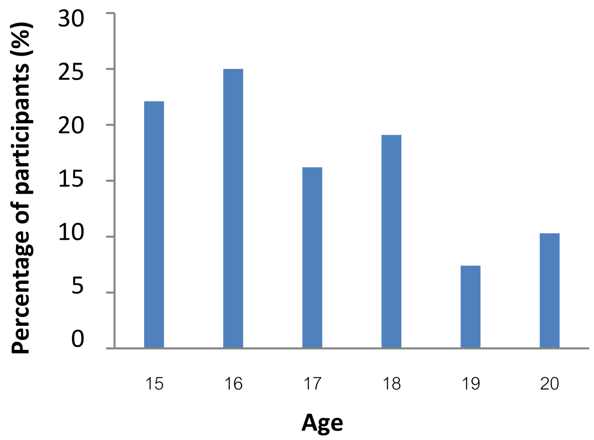

Figure 1 Age of distribution participants

With the preferred MSOI range of 71.9-107.6 dB obtained from the used PADs by the participants. Analysis showed that, after 4 minutes, only 2 participants (representing 2.9% of the study population) operated at an unsafe recommended exposure range. It was found that, from the time space from 4 to 30 minutes, the maximum range of sound output intensity level was consistent to MSOI range between 71.9 and 107.6 dB. However, the number of participants on unsafe operation characteristics increased from 2(2.9%), after 4 minutes, to 30(44.1%) after 30 minutes. The same effect was observed for both genders, as the female gender unsafe practice, after 4.0 minutes, increased from 0(0%) to 14(41.2%) after 30 minutes. The unsafe operation characteristics in the males increased from 2(5.9%) to 16(47.1%) within the same time space (Table 2). The time progress revealed that the number of participants that operated within the safe recommended exposure limit dropped while that of unsafe recommended exposure limit increased. At the end of 120 minutes of exposure, only 20 participants (29.4%) operated within the safe recommended exposure limit while a higher proportion of about 48(70.6%) operated at unsafe recommended exposure limit of sound output intensity level. The observation on the PAD MSOI level showed that, as time progresses, the participants either had a maintained or increased sound intensity which may be due to the arousal levels caused by the played music. The 100% proportion of safe PAD MSOI level among the participants which continued dropping until it translated to 29.4% of the participants who operated their PAD at safe level. This implies that safety of sound exposure level declines as time progress even with maintained PAD MSOI level. This necessitates adjustment of the volume settings for safe listening pleasure using the PADs as it allows an individual listener to exert absolute control of his/her auditory environment differently from other industrial and recreation noises. This study buttressed Portnuff (2016) statement that the risk of music-induced hearing loss from PAD usage can only be checked through the usage evaluation pattern as the analyzed data in this study presented an associated risk at intervals. The operation characteristic of participants evaluated in this study is not consistent with safe recommended exposure limit which decreases with time (NIOSH, 1998). This study also agreed with Stephen and Mark (2003) that unwantedness of noise is a function of sound intensity and duration. The study also agreed with Williams (2009), Levey et al. (2011) and (Fligor et al., 2014) that there is a potential risk to hearing health issue associated with extended use of PAD if exposure levels exceeded the recommended safe sound exposure levels.

4. CONCLUSION

A physical, psychological and physiological effect of noise or sound exposure is a factor of noise or sound intensity and exposure time. The observation in this study showed that recommended safety exposure limits were in terms of sound intensity and exposure duration. An unchanged continuous sound output intensity levels of a PAD with safe operation characteristics is time factor bound. From the results obtained in this study, it can be concluded that prolonged exposure to an unvaried sound output intensity level metamorphosed from safe to unsafe operation characteristics over the time of exposure. Safety of sound exposure level declines as time progress even at a maintained PAD MSOI level. This necessitates reduction adjustment of the volume settings for safe listening pleasure while using the PADs as the mechanism allows an individual listener to exert absolute control of his/her auditory environment differently from other industrial and recreation noises. Since recently developed PADs are capable of emitting sound intensity high-enough to cause music-induced hearing loss over an extended period, this, implies that, for a preferred music volume setting, the sound intensity and exposure time should be considered. It is important to state here that should the adolescents and young adults be exposed to high PAD MSOI level up to 100 dB, it should be within the first 7.5 minutes of usage but, for a prolonged period of 120 minutes, it should be less than 85 dB so as to preserve their hearing.

Table 2 Maximum sound intensity exposure levels (dB) and safety analysis based on the recommended exposure time guideline

Exposure time (minute)	Preferred MSOI range of PAD (dB)	Operation Characteristics	Male (%)	Female (%)	Total (%)
0.5	66.1 -106.5	Safe	34(100.0)	34(100.0)	100(100.0)
		Unsafe	0(0)	0(0)	0(0)
1.0	70.6 -106.6	Safe	34(100.0)	34(100.0)	100(100.0)
		Unsafe	0(0)	0(0)	0(0)
2.0	71.4 -107.5	Safe	34(100.0)	34(100.0)	34(100.0)
		Unsafe	0(0)	0(0)	0(0)
4.0	71.9 -107.6	Safe	32(94.1)	34(100.0)	66(97.1)
		Unsafe	2(5.9)	0(0)	2(2.9)
7.5	71.9 -107.6	Safe	30(88.2)	32(94.1)	62(91.2)
		Unsafe	4(11.8)	2(5.9)	6(8.8)
15	71.9 -107.6	Safe	20(58.8)	23(67.6)	43(63.2)
		Unsafe	14(41.2)	11(32.4)	25(36.7)
30	71.9 -107.6	Safe	18(52.9)	20(58.8)	38(55.8)
		Unsafe	16(47.1)	14(41.2)	30(44.1)
60	71.9 -108.4	Safe	19(55.9)	15(44.1)	33(48.5)
		Unsafe	16(47.1)	18(52.9)	35(51.5)
120	77.2 -108.6	Safe	7(20.6)	13(38.2)	20(29.4)
		Unsafe	27(79.4)	21(61.8)	48(70.6)

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