Research, Society and Development, v. 11, n. 16, e144111636336, 2022
(CC BY 4.0) | ISSN 2525-3409 | DOI: http://dx.doi.org/10.33448/rsd-v11i16.36336

Impact of occupational noise on the postural control of older adults

Impacto do ruído ocupacional no controle postural de idosos

Impacto del ruido ocupacional en el control postural en ancianos

Received: 10/10/2022 | Revised: 11/09/2022 | Accepted: 11/24/2022 | Published: 12/02/2022

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Abstract
Introduction: The studies on the consequences of noise to the auditory system are well documented, particularly in workers' health. Nevertheless, few studies in the field yet have related postural control to occupational noise exposure. *Objective*: To investigate the association between the history of occupational noise and the postural control in older adults. *Materials and Methods*: Cross-sectional study that included individuals of both sexes older than 60 years. All of them had their postural control assessed on a force platform. The occupational noise was assessed with an audiological anamnesis questionnaire. The hearing loss was assessed using the pure-tone threshold audiometry. The Tinnitus Handicap Inventory questionnaire was used to quantify the impact of tinnitus on daily life of the older adults. *Results*: 90 older adults (87.8% women, 70[64-75] years old) were analyzed. The history of occupational noise exposure was associated with a worse postural control in older adults, regardless of the person's age (ANCOVA; $P < 0.05$). Moreover, the greater the hearing loss, the greater the body instability of the older adults ($r \leq 0.36$ for all). Finally, postural control was related to tinnitus presenting correlations with catastrophic Tinnitus Handicap Inventory ($r = 0.314$; $P = 0.038$) and functional Tinnitus Handicap Inventory ($r = 0.430$; $P = 0.010$). *Conclusion*: Postural control of older adults is related to the history of occupational noise exposure, hearing loss and tinnitus impact on older adult's daily life.
Keywords: Postural control; Occupational noise; Hearing loss; Tinnitus; Older adults.

Resumo
Introdução: Os estudos sobre as consequências do ruído para o sistema auditivo estão bem documentados, principalmente na saúde do trabalhador. Apesar disso, poucos estudos na área ainda relacionam o controle postural à exposição ocupacional ao ruído. *Objetivo*: Investigar a associação entre o histórico de ruído ocupacional e o controle

postural em idosos. *Materiais e Métodos*: Estudo transversal que incluiu indivíduos de ambos os sexos com mais de 60 anos. Todos tiveram seu controle postural avaliado em uma plataforma de força. O ruído ocupacional foi avaliado com um questionário de anamnese audiológica. A perda auditiva foi avaliada por meio da audiometria tonal liminar. O questionário Tinnitus Handicap Inventory foi utilizado para quantificar o impacto do zumbido na vida diária dos idosos. *Resultados*: Foram analisados 90 idosos (87,8% mulheres, 70[64-75] anos). A história de exposição ocupacional ao ruído foi associada a um pior controle postural em idosos, independentemente da idade da pessoa (ANCOVA; P < 0,05). Além disso, quanto maior a perda auditiva, maior a instabilidade corporal dos idosos (r≤0,36 para todos). Por fim, o controle postural foi relacionado ao zumbido apresentando correlações com o Inventário de Deficiência do Zumbido catastrófico (r = 0,314; P = 0,038) e o Inventário de Deficiência do Zumbido funcional (r = 0,430; P = 0,010). *Conclusão*: O controle postural de idosos está relacionado ao histórico de exposição ocupacional ao ruído, perda auditiva e impacto do zumbido no cotidiano do idoso.
Palavras-chave: Controle postural; Ruído ocupacional; Perda de audição; Zumbido; Adultos mais velhos.

Resumen
Introducción: Los estudios sobre las consecuencias del ruido en el sistema auditivo están bien documentados, particularmente en la salud de los trabajadores. Sin embargo, pocos estudios en el campo aún han relacionado el control postural con la exposición al ruido ocupacional. *Objetivo*: Investigar la asociación entre el antecedente de ruido ocupacional y el control postural en adultos mayores. *Materiales y Métodos*: Estudio transversal que incluyó individuos de ambos sexos mayores de 60 años. A todos ellos se les evaluó el control postural en una plataforma de fuerza. El ruido ocupacional se evaluó con un cuestionario de anamis audiológico. La pérdida auditiva se evaluó mediante la umbralmetría de tonos puros. El cuestionario Tinnitus Handicap Inventory se utilizó para cuantificar el impacto del tinnitus en la vida diaria de los adultos mayores. *Resultados*: se analizaron 90 adultos mayores (87,8% mujeres, 70[64-75] años). El antecedente de exposición ocupacional a ruido se asoció con peor control postural en los adultos mayores, independientemente de la edad de la persona (ANCOVA; P < 0,05). Además, a mayor hipoacusia, mayor inestabilidad corporal de los adultos mayores (r≤0,36 para todos). Finalmente, el control postural se relacionó con el tinnitus presentando correlaciones con el Tinnitus Handicap Inventory catastrófico (r = 0,314; P = 0,038) y el Tinnitus Handicap Inventory funcional (r = 0,430; P = 0,010). *Conclusión*: El control postural de los adultos mayores está relacionado con los antecedentes de exposición al ruido ocupacional, la pérdida auditiva y el impacto del tinnitus en la vida diaria del adulto mayor.
Palabras clave: Control postural; Ruido ocupacional; Pérdida de la audición; Tinnitus; Adultos mayores.

1. Introduction

Aging is a completely individual process, though it is continuous and irreversible. It varies greatly from person to person, depending on factors such as heredity, previous and current habits, and biological, sociocultural, and psychic conditions involving these people’s day to day life (Granacher et al., 2011; Pereira et al., 2018). Hence, the reduced physical and cognitive functions of the human body, along with decreased gait safety and postural control, result from a natural physical deterioration in older adults. Consequently, they are at greater risk of falls (Bentley, 2009; Corradini et al., 1997).

Postural control involves the reception and integration of sensory stimuli and the planning and execution of movements to control the center of gravity (Adkin et al., 2000; Bagchee et al., 1998). Researchers suggest that work-related postural instability can be possibly influenced by environmental, task, and personal factors at the workplace – e.g., occupational noise exposure (Adkin et al., 2000; Bagchee et al., 1998; Hsiao & Simeonov, 2001; Mainenti et al., 2007; Teixeira et al., 2010a).

Noise is defined as an unwanted sound or a combination of different sound types and frequencies with likely adverse effects on health (Seidman & Standring, 2010). Noise exposure is the main cause of preventable hearing loss in adults worldwide (Le et al., 2017; Mills & Schmiedt, 2004), followed by debilitating tinnitus (Basner et al., 2014; Themann et al., 2013). The studies on the consequences of noise to the auditory system are well documented (Basner et al., 2014; Le et al., 2017; Mills & Schmiedt, 2004; Themann et al., 2013), particularly in workers’ health. Nevertheless, few studies in the field as yet have related postural control to occupational noise exposure (Azevedo et al., 2016; Bernardo et al., 2020; Park et al., 2011; Teixeira et al., 2010b).

Noteworthy no study has yet investigated the association between postural control assessed with a force platform (which is the gold standard measuring instrument to assess balance) with the history of occupational noise in older adults.

As life expectancy increases worldwide, people with 60 years old or more are working for longer period (Instituto

Brasileiro de Geografia e Estatística (Solé et al., 2006; UN, 2019). However, in order to remain the workforce active for longer, deleterious effects which may result from environmental factors must be considered. Therefore, health prevention and/or maintenance are essential to older adults who intend to remain in the job market.

Thus, this study aimed to investigate the association between the history of occupational noise exposure and postural control in older adults and present the hypothesis that older adults exposed to occupational noise have less postural control than older adults not exposed to occupational noise.

2. Methodology

2.1 Sample and design

This is a cross-sectional observational study that recruited older adults to perform the assessments proposed in an interdisciplinary project entitled: "Active Aging – Stage II", developed at the State University of Londrina (UEL), Londrina, Brazil, in partnership with the Pitágoras Unopar University (UNOPAR), Londrina, Brazil, from July to December 2018, after the approval by the institution's (UEL) Research Ethics Committee, under the certificate of presentation for ethical consideration (CAAE) number: 92480418.8.0000.5231. All the participants signed the informed consent form.

Inclusion criteria: older adults aged 60 years or older of both sexes, who lived physically independently, classified at levels 3 in the hierarchical scale of physical function, as proposed by Spirduso(Spirduso, 2005), non-participants in supervised exercise programs in the last three months, having no decompensated respiratory or heart disease, no neurologic, vestibular, orthopedic, or cardiovascular disease, no psychiatric illness, and no recent surgery that might interfere with the testing. Exclusion criteria: having conductive hearing loss, and Alzheimer's disease, as well as logistical problems in the assessment.

2.2 Assessments

Clinical characteristic

The Londrina ADL Protocol (Sant'Ánna et al., 2017; Paes et al., 2017) is an objective test composed by five stations (Figure 1) in which standardized activities should be performed consecutively in usual pace, to reflect real life (Figure 2). Detailed description is available in the Online Supplement. To identify the sociodemographic characteristics (sex, age, schooling level, marital status, perceived health, self-reported diseases), information was collected with an individual interview, using a diagnostic sheet previously developed by the research group.

Postural control

The postural control was assessed with a force platform, the gold standard equipment to assess postural control variables (Howe et al., 2011; Winter et al., 2003). Initially, the participants got familiarized with the equipment and the tasks they were expected to perform on the force platform. For the familiarization, each participant was individually informed about the equipment, the assessment procedures, and the posture for each condition tested. Hence, before each condition, the assessor demonstrated the posture to the individual, who tried it on the platform. After getting familiarized with the instrument and experimental protocol, the participants performed three postural control tasks on the force platform (EMG SYSTEM – BIOMEC 400), namely: 1) bipedal standing with eyes open; 2) bipedal standing with eyes closed; and 3) unipedal standing on the preference member (Pereira et al., 2018; Shigaki et al., 2013) with eyes open. For each task, two 30-second attempts were made, with 30 seconds to rest in between them. For the statistical analysis, the mean of the attempts was used (Oliveira et al., 2019).

Data collection on the force platform in unipedal stance started immediately after three seconds without having the contralateral foot touching the ground. The protocol was standardized for each task: barefoot, arms relaxed freely, relaxed arms hanging down beside the body, and the head horizontally positioned with the ground plane. For the condition with the eyes open (tasks 1 and 3), each participant looked to a fixed target (black cross = 14.5 cm high x 14.5 cm wide x 4 cm thick), placed on the wall 2.5 meters away, at eye level. For the assessment of balance, the ground reaction force signals furnished by the platform measurements were collected in a 100 Hz sample. All the force signals were filtered with a Butterworth second-order low-pass filter at 35 Hz. Then, the signals were converted through stabilographic analysis in the EMGLab2 software (EMG System). The stabilographic analysis of the A-COP (area of the center of pressure) data calculated the main balance parameters with the force platform: 95% confidence area of the ellipse of the A-COP (A-COP in cm2), mean velocity (VEL in cm/s), and mean frequency (FREQ in Hz), in the anteroposterior (AP) and mediolateral (ML) directions (Silva et al., 2013). The validity and reliability of the A-COP parameters (cm2) computed with the typical force platform have already been studied in young and older adults (Oliveira et al., 2019; da Silva et al., 2013).

The results were transcribed in a pure-tone audiometry form used in the routine care department and later entered into a databank using WinAudio (WinAudio, Curitiba, Paraná, Brazil). Thus, the results were stored and printed to the patient. The audiological assessment was conducted individually in an acoustically treated booth with an audiometer model AD-28 Interacoustics (Middelfart, Denmark), following Meneses-Barriviera et al. (Meneses-Barriviera et al., 2018). As for the criteria to analyze the degree of hearing loss (HL) in each ear, the mean of the 500 Hz, 1000 Hz, and 2000 Hz frequencies was verified. The HL was classified according to Davis and Silverman, who considers normal up to 25 dB, and HL > 26 dB (Davis et al., 1960).

History of occupational noise exposure and auditory assessment

The assessment of occupational noise exposure was obtained through interviews with the participating older adults, using a semi-structured questionnaire. Information was collected on whether they had worked in noisy environments (e.g., previous exposure to noise?; For how many years?; current exposure to noise? ; for how many years?), and whether they had used personal protective equipment (PPE)/hearing protection devices: Use of PPE?. The audiological anamnesis questionnaire was also used to collect self-reported data on the history of tinnitus, aural fullness, vertigo, diabetes mellitus, and arterial hypertension. The otoscopy was performed with a Welch Allyn otoscope (Model 25020; Welch Allyn Inc., Skaneateles Falls, NY) to examine the external acoustic meatus and the tympanic membrane. Then, the pure-tone audiometry threshold (which is considered the gold standard to assess the auditory threshold in adults and older adults) was performed at the frequencies from 250 kHz to 8000 kHz.

The Tinnitus Handicap Inventory (THI), created by Newman et al. (Newman et al., 1996), is a self-reporting measurement easy to interpret and administer, used to quantify the impact of tinnitus on daily life. The THI has been validated for Brazilian Portuguese since 2006(Schmidt et al., 2006). It has 25 questions grouped in scale, numbered with a score ranging from 0 to 100 – the higher the score, the greater is the repercussion of tinnitus on the patient's life. The interviewee can choose one of the three possible answers: ''yes'' (4 points), ''sometimes'' (2 points), or ''no'' (0 points) (Fioretti et al., 2013). The Tinnitus Handicap Inventory (THI) has three domains: The functional domain (11 items) is related to the limitations in mental, social/occupational, and physical functioning; the emotional domain (9 items) is related to frustration, irritability, anger, depression; the catastrophic domain (5 items) is related to the fear of having a terrible disease, despair, loss of control, inability to cope with the tinnitus and escape it (Cortez editora, 2005).

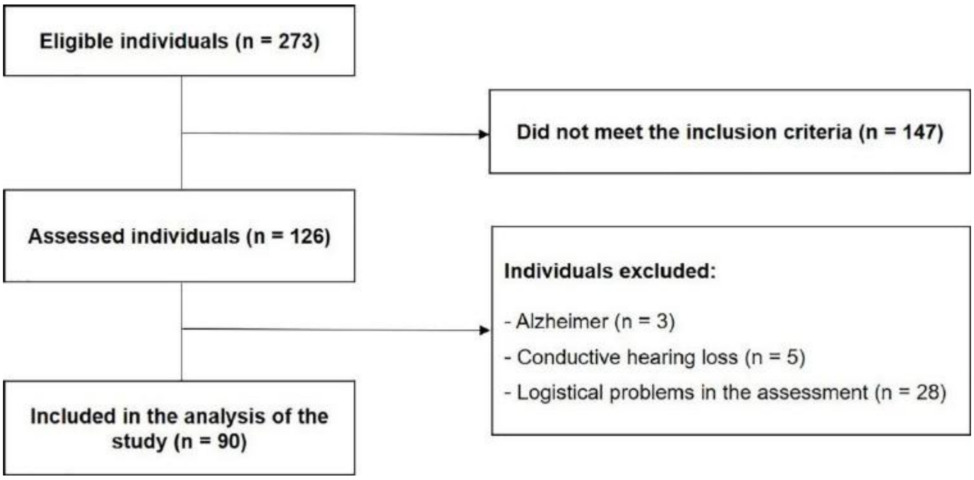
Statistical analysis

The software used for the analyses was SPSS 22.0 (IBM, Armonk, NY, USA). Descriptive analysis was used; the numerical data were analyzed regarding the normality of the distribution with the Shapiro-Wilk test. Firstly, the comparison of the postural control variables was performed with Student's t-test for independent samples, or with Mann-Whitney U-test. To this end, the older adults were divided into two groups, in two forms (with and without a history of previous occupational noise; with and without a history of current occupational noise). A covariance analysis (ANCOVA) was made to compare the groups with and without a history of occupational noise exposure. Adjustments were made for age, as the postural control worsens with the advancement of age; hence, it could be a confounding factor when comparing the groups regarding the occupational noise. Afterward, to verify the relationship between the continuous variables, Pearson's or Spearman's correlation coefficient was used., following the correlation coefficient interpretation proposed by Schober et al. (Schober et al., 2018): insignificant (0.00-0.10), weak (0.10-0.39), moderate (0.40-0.69), strong (0.70-0.89), very strong (0.90-1.00). The significance level was set at $P < 0.05$.

3. Results

There were 273 older adults enrolled to participate in the project; however, only 126 of them met the inclusion criteria and were recruited for the assessments in this study. The flowchart with the recruitment for the study is shown in Figure 1.

Figure 1 - Flowchart of participants.



Source: This figure was developed by the authors.

The total of older adults that were included in the analyses was 90, most of whom were females (87.8%), whose ages ranged from 60 to 93 years. Only 68 older adults were able to perform the unipedal assessment. The sample's socioeconomic and anthropometric descriptive data are given in Table 1.

Table 1 - Socioeconomic and anthropometric descriptive data (n = 90).

Characteristics	Total
Age (years)	70 [64 - 75]
Sex	
Female	79 (87.8)
Male	11 (12.2)
Ethnicity	
White	57 (63.3)
Black	10 (11.1)
Multiracial	19 (21.1)
Asian	4 (4.4)
Educational level	
Illiterate	5 (5.6)
Unfinished Middle School	38 (42.2)
Finished Middle School	14 (15.6)
Unfinished High School	5 (5.6)
Finished High School	19 (21.1)
Bachelor's Degree	6 (6.7)
Postgraduate Degree	3 (3.3)
Marital Status	
Single	6 (6.7)
Married	45 (50)
Divorced	14 (15.6)
Widow(er)	25 (27.8)
Income (Satisfaction)	
Low	15 (16.7)
Medium	44 (48.9)
High	16 (17.8)
Complete	15 (16.7)

Categorical variables were described in absolute and relative frequency [n (%)], whereas the continuous variables in median and interquartile range (25 – 75%). Source: This table was developed by the authors.

Of the older adults, 28 had a history of previous occupational noise exposure, whereas only six had a history of current noise exposure. None of the noise-exposed subjects reported using hearing protection devices while working. The descriptive data regarding the sample's occupational noise and audiological assessment are presented in Table 2.

Table 2 - Descriptive data on occupational noise and audiological assessment (n = 90).

Characteristics	Total
Hearing loss	
Yes	29 (31.9)
No	62 (68.1)
Right Ear (dB)	25 [20 - 30]
Left Ear (dB)	20 [15 - 30]
Aural Fullness	
Yes	24 (73.3)
No	66 (26.7)
Vertigo	
Yes	38 (42.2)
No	52 (57.8)
Tinnitus	
Yes	44 (48.9)
No	46 (51.1)
Tinnitus Handicap Inventory (THI)	
Functional (score)	8 [1 - 12]
Emotional (score)	7 [2 - 12]
Catastrophic (score)	7 [0 - 8]
Total (score)	19 [10 - 36]
Previous Noise Exposure	
Yes	28 (31.1)
No	62 (68.9)
Current Noise Exposure	
Yes	6 (6.7)
No	84 (93.3)
Noise Exposure (years)	15 [4 - 30]
Diabetes	
Yes	25 (27.8)
No	65 (72.2)
Hypertension	
Yes	48 (53.3)
No	42 (46.7)

The categorical variables were expressed in absolute and relative frequency ([n (%)], whereas the continuous variables in median and interquartile range (25 – 75%). Source: This table was developed by the authors.

The descriptive data on the sample's postural control are given in Table 3.

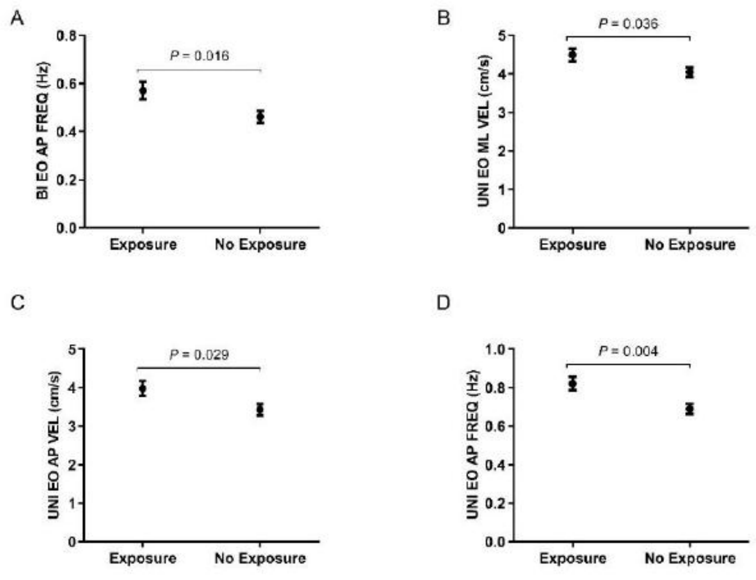
Table 3 - Descriptive data on postural control (n = 90).

Characteristics	Total
BI EO A-COP (cm^2)	1.1 [0.8 - 1.7]
BI EO ML VEL (cm/s)	1.5 [1.3 - 1.7]
BI EO AP VEL (cm/s)	1.7 [1.6 - 1.9]
BI EO ML FREQ (Hz)	1.5 [1.1 - 2.1]
BI EO AP FREQ (Hz)	0.4 [0.3 - 0.6]
BI EC A-COP (cm^2)	1.2 [0.9 - 1.9]
BI EC ML VEL (cm/s)	1.5 [1.3 - 1.7]
BI EC AP VEL (cm/s)	1.9 [1.7 - 2.1]
BI EC ML FREQ (Hz)	1.6 [1.1 - 2.2]
BI EC AP FREQ (Hz)	0.5 [0.4 - 0.6]
UNI EO A-COP (cm^2)[a]	9.8 [4.5 - 12.5]
UNI EO ML VEL (cm/s)[a]	3.7 [1.9 - 4.6]
UNI EO AP VEL (cm/s)[a]	3.1 [1.8 - 3.7]
UNI EO ML FREQ (Hz)[a]	0.7 [0.2 - 0.8]
UNI EO AP FREQ (Hz)[a]	0.6 [0.1 - 0.8]

BI= Bipedal; EO = eyes open; EC = eyes closed; UNI = Unipedal; A-COP = area of the center of pressure; VEL = Velocity; FREQ = Frequency; ML = Mediolateral; AP = Anteroposterior. The variables are expressed in median and interquartile range (25 – 75%). [a]n = 68. Source: This table was developed by the authors.

There was a significant difference between the groups with and without a history of previous noise exposure in the comparative analysis of postural control for the bipedal stance with eyes open (anteroposterior mean frequency), and unipedal stance with eyes open (mediolateral velocity, anteroposterior velocity, and anteroposterior mean frequency). Such a difference remained significant even after the adjustment for age. The mean adjusted values after controlling age are shown in Figure 2.

Figure 2 - Comparison of the groups with and without previous noise exposure adjusted for age. The values are given in mean and standard deviation.



A) Bipedal stance with eyes open in the anteroposterior mean frequency; B) Unipedal stance with eyes open in the mediolateral velocity; C) Unipedal stance with eyes open in the anteroposterior velocity; D) Unipedal stance with eyes open in the anteroposterior mean frequency. BI= Bipedal; EO = eyes open; UNI = unipedal; AP = anteroposterior; ML = mediolateral; VEL = velocity; FREQ = frequency. Source: This figure was developed by the authors.

The comparison of all the postural control variables between the groups with and without a history of previous noise exposure is described in Table 4.

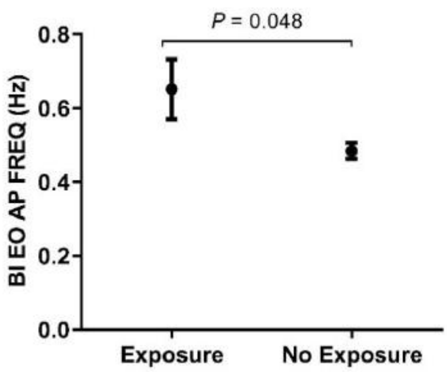
Table 4 - Comparison between the groups with and without previous noise exposure and postural control in older adults

Postural Control	**With Previous Noise Exposure (N = 28)**	**Without Previous Noise Exposure (N = 62)**
BI EO A-COP (cm^2)	1.0 [0.7 - 1.7]	1.2 [0.8 - 1.8]
BI EO ML VEL (cm/s)	1.5 [1.3 - 1.7]	1.6 [1.3 - 1.7]
BI EO AP VEL (cm/s)	1.7 [1.6 - 2.0]	1.8 [1.6 - 2.0]
BI EO ML FREQ (Hz)	1.5 [1.2 - 2.1]	1.5 [1.1 - 1.1]
BI EO AP FREQ (Hz)	0.5 [0.4 - 0.7]*	0.4 [0.3 - 0.5]*
BI EC A-COP (cm^2)	1.1 [0.8 - 1.5]	1.3 [0.9 - 2.1]
BI EC ML VEL (cm/s)	1.5 [1.3 - 1.7]	1.6 [1.3 - 1.7]
BI EC AP VEL (cm/s)	1.9 [1.7 - 2.1]	2.0 [2.1 - 1.7]
BI EC ML FREQ (Hz)	1.7 [1.2 - 2.2]	1.5 [1.2 - 2.1]
BI EC AP FREQ (Hz)	0.5 [0.4 - 0.6]	0.4 [0.3 - 0.5]
UNI EO A-COP (cm^2)[a]	10.4 [9.1 - 13.4]	11.2 [8.7 - 13.8]
UNI EO ML VEL (cm/s)[a]	4.3 [3.8 - 5.3]*	3.8 [3.5 - 4.7]*
UNI EO AP VEL (cm/s)[a]	3.6 [3.2 - 4.3]*	3.3 [2.7 - 3.9]*
UNI EO ML FREQ (Hz)[a]	0.7 [0.6 - 0.8]	0.7 [0.6 - 0.8]
UNI EO AP FREQ (Hz)[a]	0.7 [0.7 - 0.9]*	0.6 [0.5 - 0.8]*

BI= Bipedal; EO = eyes open; EC = eyes closed; UNI = Unipedal; A-COP = area of the center of pressure; VEL = Velocity; FREQ = Frequency; ML = Mediolateral; AP = Anteroposterior. * $P < 0.05$; [a]n = 68. Source: This table was developed by the authors.

Moreover, the group with a history of current noise exposure had worse postural control in the bipedal stance with eyes open (anteroposterior mean frequency $P < 0.05$). This difference remained significant even after controlling age (Figure 3).

Figure 3 - Comparison of the groups with and without current noise exposure adjusted for age.



The values are given in mean and standard deviation. BI= Bipedal; EO = eyes open; AP = anteroposterior; FREQ = frequency. Source: This figure was developed by the authors.

The comparison of all the postural control variables between the groups with and without a history of current noise exposure is described in Table 5.

Table 5 - Comparison between the groups with and without current noise exposure and postural control in older adults

Postural Control	**With Current Noise Exposure (N = 6)**	**Without Current Noise Exposure (N = 84)**
BI EO A-COP (cm^2)	2.0 [0.8 - 1.3]	1.1 [0.8 - 1.7]
BI EO ML VEL (cm/s)	1.5 [1.4 - 1.7]	1.5 [1.3 - 1.7]
BI EO AP VEL (cm/s)	1.7 [1.6 - 2.0]	1.7 [1.6 - 2.0]
BI EO ML FREQ (Hz)	1.7 [1.0 - 2.3]	1.5 [1.2 - 2.1]
BI EO AP FREQ (Hz)	0.7 [0.4 - 0.8]*	0.4 [0.3 - 0.6]*
BI EC A-COP (cm^2)	1.4 [1.0 - 2.5]	1.2 [0.9 - 1.8]
BI EC ML VEL (cm/s)	1.5 [1.4 - 1.7]	1.5 [1.3 - 1.7]
BI EC AP VEL (cm/s)	2.0 [1.8 - 2.1]	1.9 [1.7 - 2.1]
BI EC ML FREQ (Hz)	1.4 [0.9 - 2.1]	1.6 [1.1 - 2.2]
BI EC AP FREQ (Hz)	0.5 [0.3 - 0.7]	0.5 [0.4 - 0.6]
UNI EO A-COP (cm^2)[a]	10.1 [6.8 - 11.5]	11.0 [9.2 - 13.6]
UNI EO ML VEL (cm/s)[a]	5.2 [3.47 - 5.3]	3.9 [3.6 - 4.7]
UNI EO AP VEL (cm/s)[a]	3.2 [3.1 - 4.2]	3.4 [2.9 - 4.0]
UNI EO ML FREQ (Hz)[a]	0.9 [0.7 - 1.0]	0.7 [0.6 - 0.8]
UNI EO AP FREQ (Hz)[a]	0.8 [0.6 - 1.0]	0.7 [0.6 - 0.8]

Abbreviations: BI= Bipedal; EO = eyes open; EC = eyes closed; UNI = Unipedal; A-COP = area of the center of pressure; VEL = Velocity; FREQ = Frequency; ML = Mediolateral; AP = Anteroposterior. *P < 0.05; [a]n = 68. Source: This table was developed by the authors.

There was no significant correlation between the time of noise exposure (years) and any of the postural control variables – the results ranged from r=- 0.17; P=0.933 to r=0.380; P=0.067. Between hearing loss and postural control, on the other hand, there was a weak positive correlation in the bipedal stance with eyes open: mediolateral velocity (r=0.356; P=0.001), anteroposterior velocity (r=0.249, P=0.018), and bipedal with eyes closed: mediolateral velocity (r=0.365; P=0.0001). All these postures were correlated with the right ear. As for the left ear, there was a weak positive correlation with bipedal stance with eyes open: mediolateral velocity (r=0.262; P=0.013), and bipedal stance with eyes closed: mediolateral velocity (r=0.269; P=0.010).

In other words, the greater the hearing loss in older adults, in either the right or left ear, the worse is their postural control. Lastly, between postural control and tinnitus, there was a weak positive correlation in the bipedal stance with eyes closed, mediolateral mean frequency, and catastrophic THI (r=0.314; P=0.038), and a moderate positive correlation in the unipedal stance with eyes open, mediolateral mean frequency, and functional THI (r=0.430; P=0.010).

4. Discussion

The present study showed that older adults with a history of previous and current occupational noise exposure present statistically significant associations with changes in postural control. That is, these individuals have worse postural control when compared with those who report not having been exposed to occupational noise, regardless of the person’s age. This study also demonstrated with weak correlations that the greater the hearing loss, the worse the older adults’ postural control. Furthermore, it evidenced a weak and a moderate correlation that the greater the impact tinnitus has on the older adult’s daily life, the worse is their postural control. It should be highlighted that the study’s cross-sectional design does not enable it to infer causality.

In our findings, postural control proved to be more impaired in older adults with a history of previous occupational noise exposure. The variables and postures considered were those commonly used to characterize the changes in postural control in studies with older adults that use the force platform (da Silva et al., 2013; Oliveira et al., 2019). Noise can also affect postural control because of the relationship between the vestibular system and the organ of Corti in the inner ear (Basner et al., 2014; Le et al., 2017; Mills & Schmiedt, 2004; Themann et al., 2013).

Curiously, none of the older adults in the study reported having used hearing protection devices while working. This corroborates the study by Teixeira et al (Teixeira et al., 2010), in which none of the students reported having used the hearing protection devices in their workplace. Teixeira et al. (Teixeira et al., 2010) assessed the answers of 32 male individuals, who were divided into two groups: 16 noise-exposed workers, mean age±standard deviation 45.81±7.38 years, and 16 individuals without occupational noise exposure, aged 41.31±5.58 years. They verified in their study that individuals with occupational noise exposure in a printer shop have worse performance in postural control assessment. This is the first study to demonstrate that occupational noise exposure is associated with worse postural control, assessed in older adults with a force platform.

On the other hand, the study by Azevedo et al. (Azevedo et al., 2016) assessed 20 healthy individuals aged approximately 21±1.18 years to analyze the effects of different sound frequencies on the standing postural stability, using baropodometry. No significant changes were found in any of the postures assessed. One of the reasons for the non-association may be on the fact that only 20 individuals were included in the study; hence, a sample with insufficient power for the analysis may have been considered and the instrument (baropodometry). As for this study, 90 individuals were analyzed. It was also verified in the present study that the greater the hearing loss, the worse the postural control in older adults. A previous systematic review by Agmon et al. (Agmon et al., 2017) also provided evidence associating hearing loss with reduced postural control in older adults. Moreover, hearing loss is associated with an increased risk of falls in older adults (Thomas et al., 2018).

It is believed that such a correlation between hearing loss and postural control occurs due to the physiological aging processes and/or are caused by noise exposure, especially because they affect the microvascular blood supply of the hair cells (sensorial type), resulting in ischemia, hypoxia, and oxidative stress (Le et al., 2017; Zahnert, 2011).

Considering the presence of tinnitus in older adults, it was associated with postural control in the present study, in the mediolateral mean frequency in the bipedal stance with eyes closed and unipedal stance with eyes open. These findings corroborate the study by Kapoula et al. (Kapoula et al., 2011), who assessed 23 adults (49.0 ± 12.5 years old) and found instability in individuals with tinnitus. Thus, it is observed that in the present study tinnitus works as an impact factor on the everyday postural control of older adults at the functional level (mental, social/occupational, and physical functioning) and catastrophic level (fear of a terrible disease, despair, loss of control, inability to cope with the tinnitus or escape it). Hence, tinnitus is a prevalent otologic symptom that can cause great physical and emotional disorders (Baguley et al., 2013).

No studies were found in the literature that investigated postural control variables assessed on a force platform, associating them with occupational noise exposure in older adults – which points to the originality of this study. It should be highlighted that two assessment instruments used in the present study are considered gold standard: the force platform and the audiometry. However, some limitations must be identified. The occupational noise exposure was assessed with an interview; yet, although the outcome depends on the person's memory, attention is called to the fact that the older adults included in this study were capable of living in functional independence. Besides, epidemiologic studies widely use self-reports instruments. Another limitation of the study is its cross-sectional design, which does not allow for a time-directed interpretation between exposures and outcomes because the information is obtained in a single moment. Thus, it is not possible to infer cause and effect. In addition, the order of postures on the force platform assessment were not randomized, as well as individuals who reported vertigo were not asked whether they made use of vertiginous drugs or its dosage.

5. Conclusion

Finally, the history of occupational noise exposure was associated with a worse postural control in older adults, regardless of the person's age. This study also demonstrated with weak correlations that the greater the hearing loss, the worse the older adults' postural control. Furthermore, it evidenced a weak and a moderate correlation that the greater the impact tinnitus has on the older adult's daily life, the worse is their postural control.

The clinical applicability of this study can be on grounding the implementation of public policies that focus on occupational noise control as well as hearing loss and tinnitus prevention. These actions are reinforced since postural control of older adults is related to the history of occupational noise exposure, hearing loss and tinnitus impact on older adult's daily life. Future studies aiming at prevention of various health impairments, including postural control and risk of fall with longitudinal and/or clinical trial design might be of interest.

Acknowledgments

The authors thank the following institutions for personal grants: JAB, LLMM, DSAC and CP were supported by the Coordination for the improvement of Higher Education Personnel (CAPES), Brazil. DCT is supported by PROEXT- University Extension Program – MEC - Ministry of Education - Brazil, Grant Number 007/2015. VP is supported by a MSc grant from Coordenação de Aperfeiçoamento de Pessoal de Nível Superior e Programa de Suporte à Pós-Graduação de Instituições de Ensino Particulares CAPES/PROSUP, Brazil. KCF is supported by a personal grant.

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