

Whole-body Vibration, Occupational Noise, and Postural Analysis in the Coffee Harvesting and Collection Stages Among Mechanized Equipment Operators

Antonio de Oliveira Aparecido, Adriano Bortolotti Putti*

Federal Institute of Education, Science and Technology of Mato Grosso do Sul (IFMS), Campo Grande - Mato Grosso do Sul, Brazil

*Correspondence author

Abstract: *The objective of this study was to evaluate co-exposure to whole-body vibration (WBV), occupational noise, and perform postural analysis during the coffee harvesting and collection stages. Conducted at Fazenda São Manoel, in Muzambinho - MG, a TDI self-propelled harvester and a Valtra® tractor coupled to the AWZ collector were used. Six repetitions were performed for each work set, with different rotations and speeds (2x3), over 100 m per repetition. WBV and noise levels were quantified using a vibration meter (VIB008) and dosimeter (DOS 1000), in accordance with current standards NHO 01, NHO 09, and NR 15. Postural analysis was carried out using the OWAS system. The results indicated that the aren values exceeded the AL ($0,5 \text{ ms}^{-2}$) during harvesting in T1, T2, and T3, and the RVDV only during collection in T3. The occupational noise exposure limit (EL) exceeded 85dB(A) in both stages, and the postural analysis indicated class 2, suggesting regular postural adjustments. The use of coupled implements can worsen the operators' condition, as they need to monitor the rear implements and the front driving of the tractor. It was found that the type of equipment and implement directly influences WBV levels, noise, and operators' posture, with greater noise exposure, especially during the collection stage. Corrective and preventive measures, additional training, and medical control are necessary.*

Keywords: Coffee growing; Ergonomics; Mechanization; Occupational risks.

1. INTRODUCTION

Agriculture in Brazil plays a fundamental role in the country's growth and development, contributing significantly to the economy and social well-being (Salimova et al., 2020; Freire et al., 2024). Coffee farming, one of Brazil's main agricultural activities, is recognized worldwide for its high production and economic importance, in addition to being a vital source of resources and a driver of financial movement (Clay et al., 2018; Pham et al., 2019; Turco et al., 2023).

The harvesting stage represents a substantial part of total costs, and in recent years, coffee farming has faced challenges related to labor shortages, leading to the increasing adoption of mechanization as a strategy to optimize processes, increase efficiency, and reduce costs (Anderson et al., 2024; Mishra; Satapathy, 2019).

However, when not accompanied by adequate measures, mechanization can expose workers to significant occupational risks, including noise, vibrations, and ergonomic factors, both in isolation and simultaneously, a phenomenon known as multi-exposure or co-exposure (Nguyen et al., 2018; Iftime et al., 2020; Júnior et al., 2022). Therefore, it is of great importance to quantify these risk agents to verify if they are within the limits established by current legislation (Leite et al., 2020).

However, in Brazilian agriculture, especially in coffee farming, there are not many academic studies that adequately address the exposure levels resulting from co-exposure to risk agents, noise and vibration, and even fewer studies that specifically investigate vibration exposure (Nguyen et al., 2018; Saliba, 2019).

It is emphasized that the adverse effects of exposure to these agents result in hearing loss and musculoskeletal disorders, which can harm workers' occupational health and may be exacerbated by simultaneous co-exposure (Nguyen et al., 2018; Iftime et al., 2020).

Additionally, operators of mechanized equipment face ergonomic and safety risks, such as excessive working hours, repetitive movements, and twisting, which can result in work accidents and inefficiency in performing

activities (Benos; Tsaopoulos; Bochtis, 2020; Pereira et al., 2021).

The objective of this study was to quantify noise levels, whole-body vibration, and analyze posture during the coffee harvesting and collection stages in operators of mechanized equipment. The data obtained in the field will be compared with current standards, taking into account the established exposure limits (EL) and action levels (AL). With this, it is intended to develop effective prevention, correction, organization, and protection strategies to safeguard the health of these workers.

2. METHODOLOGY

The research began after approval by the Research Ethics Committee (CEP) of the Federal Institute of Education, Science and Technology of Southern Minas Gerais (IFSULDEMINAS), under number 44314721.1.0000.8158, as well as the use of the Informed Consent Form (ICF) with the research participants.

The study was conducted at Fazenda São Manoel, located in the municipality of Muzambinho, in the Southern region of Minas Gerais (Figure 1), with a total area of 98 hectares, of which 60 hectares are dedicated to coffee cultivation, resulting in an average productivity of 2,500 bags/ano⁻¹.

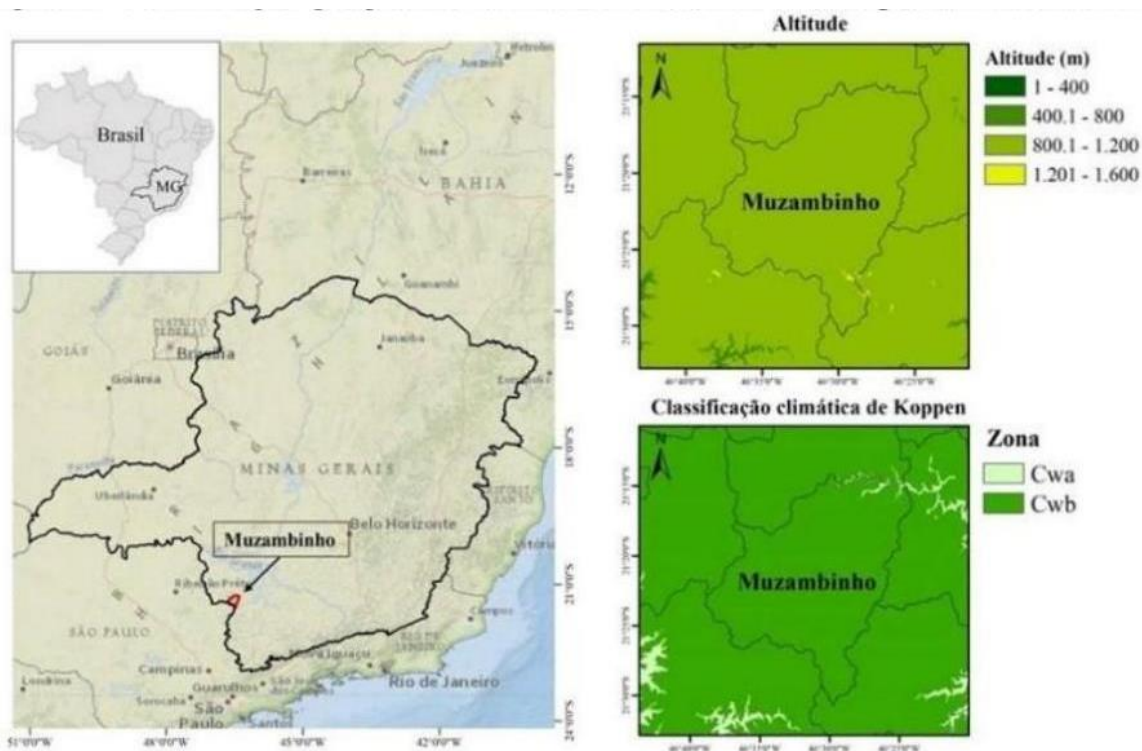


Figure 1: Geographical location of Southern Minas Gerais and the municipality of Muzambinho.

Data collection for the quantitative evaluations was carried out during coffee harvesting activities in the plot named "Café do Curral", with a 10% slope, altitude of 1.030m, occupied with coffee plants (*Coffea arabica* L.) of the Catuai Vermelho 144 cultivar, spacing $3,5 \times 0,8m$, with an average plant height of 2,3m .

2.1 Mechanized Sets

The controlled field experiment was conducted under real operating conditions (ROC), using a mechanized set consisting of an electron auto TDI self-propelled harvester, model MWM D229-4, cabin-equipped, manufactured in 2012, 4-cylinder engine, 67 hp, and a tractor-mounted set composed of a Valtra[®] tractor, model A750F, manufactured in 2019, 78 hp, open-cab, and an AWZ grasshopper collector, model BB 900, manufactured in 2019. It is emphasized that the equipment was in good condition, with up-to-date maintenance, and was operated by experienced operators.

Before starting the evaluations, the front and rear tires of the tractors were characterized, following the

manufacturers' guidelines regarding ballast, water quantity, and tire pressure, both rear and front.

For each mechanized set, the following parameters were established: normalized exposure resultant acceleration (aren) in ms^{-2} , resultant vibration dose (VDVR) in $\text{ms}^{-1,75}$, noise level in dB(A).

2.2 Experimental Design

The experimental design used was a completely randomized design (CRD), with the harvester and the tractor-mounted set operating under 6 different conditions (rotation/speed). For each condition/treatment (Table 1), 6 repetitions were performed, with the collection time being that necessary to travel the 100? m operating strip for each repetition within the coffee plantation.

Table 1: Treatments used for the coffee harvesting and collection stage.

	Automotive harvester TDI	Valtra® + Harvester AWZ
Trt.(1)	rpm/speed(2)	rpm/speed(2)
T1	1800/0,5	1300/0,6
T2	1800/0,6	1300/0,7
T3	1800/0,7	1300/0,8
T4	1900/0,5	1400/0,8
T5	1900/1,0	1400/0,9
T6	1900/1,1	1400/0,9

Legend: (1) Treatment and (2) Speed in Km h^{-1} .

2.3 Whole-Body Vibration Level A (Wbv) and Noise Level

As determined by FUNDACENTRO (2013), the vibration analysis was performed by simultaneously quantifying the orthogonal "x", "y", and "z" axes using a vibration meter, model VIB 008, brand 01dB², calibrated with RBC certificate, meeting the weighting requirements (Wk) for the longitudinal "z" axis and (Wd) for the transverse "x" and "y" axes, as well as the characteristics specified in the international standards ISO 8041 (2005), ISO 2631-1 (1997), and the occupational hygiene standard NHO 09 (Figure 2A).

The whole-body accelerometer was positioned and fixed on the operator's seat as established by NHO 09 (Figure 2B).

After conducting the evaluations, the data collected in 1/1 octave were downloaded and processed using dBMaestro and 01 dB software to assess the WBV. The obtained values were compared with the EL of NR 15, NA of NR 9, and the judgment criteria and decision-making of NHO 09 (Table 2).

Table 2: Judgment criteria and decision-making.

aren*	VDVR**	Technical Consideration	Recommended Action
(m/s^2)	($\text{m/s}^{1,75}$)		
0 a 0,5	0 a 9,1	Acceptable	At minimum, maintain the existing condition
> 0,5 a < 0,9	> 9,1 a < 16,4	Above the action level	At minimum, adopt preventive measures
0,9 a 1,1	16,4 a 21	Uncertainty region	Adoption of preventive and corrective measures aimed at reducing daily exposure
Above 1.1	Above 21	Above the exposure limit	Immediate adoption of corrective measures

Legend: *Normalized exposure resultant acceleration (aren); **Resultant vibration dose value (VDVR).



Figure 2: VIB008 Vibration Meter (A), Transducer mounting direction according to the orthogonal "x", "y", and "z" axes and transducer fixation on the operator's seat (B), and DOS 1000 Noise Meter, Instruthermo

Noise level acquisition was performed using a personal integrating meter (dosimeter), model DOS 1000, brand Instrutherm®, with an octave band filter, datalogger function, configured with "A" weighting circuit, slow response circuit, reference criterion 85 dB (A), integration threshold 80 dB (A), and doubling increments q-5 and q-3, to simultaneously meet the criteria of NR 15 and NHO 01 (Figure 2C).

Evaluations were conducted with the equipment positioned at the operator's ear zone (± 15 cm). The obtained data were downloaded and processed using Instrutherm's Dosimeter Management software, version 5.2 v. Subsequently, the normalized exposure level (NEL) was determined for both NR 15 and NHO 01.

2.4 Postural Analysis

Postural assessment was performed using the Ovako Working Posture Analysing System (OWAS) practical recording system. This method evaluates work demand based on the positions of the back, arms, legs, and load lifting (Figure 3) (Brandl; Mertens; Schlick, 2017; Enez; Nalbantoglu, 2019).



Figure 3: Posture recording system using the Ovako Working Posture Analysing Systems (OWAS) method.

Variations of the back (4 positions), arms (3 positions), and legs (7 positions) were considered, resulting in 84 basic combinations of work postures (Iida; Buarque, 2016). It should be noted that no load lifting occurred in the evaluated positions.

The evaluated postures are those adopted by the harvester and mechanized set operators (Figure 4A and 4B) at the operation station.



Figure 4: Typical positions of operators in the harvester and tractorized assembly used in the mechanized harvesting of the coffee pot: Harvesting (A) and Harvesting (B).

With the postures recorded for each stage of mechanical coffee harvesting, it was possible to combine them to perform the classification analysis according to Table 3.

Table 3: Posture classification by combining the Back, Legs, and Arms variables.

Dorso	Braços	1			2			3			4			5			6			7			Pernas	Cargas
		1	2	3	1	2	3	1	2	3	1	2	3	1	2	3	1	2	3	1	2	3		
1	1	1	1	1	1	1	1	1	1	1	2	2	2	2	2	2	1	1	1	1	1	1		
	2	1	1	1	1	1	1	1	1	1	2	2	2	2	2	2	1	1	1	1	1	1		
	3	1	1	1	1	1	1	1	1	1	2	2	3	2	2	3	1	1	1	1	1	1		
2	1	2	2	3	2	2	3	2	2	3	3	3	3	3	3	3	1	1	1	1	1	2		
	2	2	2	3	2	2	3	2	3	3	3	4	4	3	4	4	3	3	4	2	3	4		
	3	3	3	4	2	2	3	3	3	3	3	4	4	4	4	4	4	4	4	2	3	4		
3	1	1	1	1	1	1	1	1	1	2	3	3	3	4	4	4	1	1	1	1	1	1		
	2	2	2	3	1	1	1	1	1	2	4	4	4	4	4	4	3	3	3	1	1	1		
	3	2	2	3	1	1	1	2	3	3	4	4	4	4	4	4	4	4	4	1	1	1		
4	1	2	3	3	2	2	3	2	2	3	4	4	4	4	4	4	4	4	4	2	3	4		
	2	3	3	4	2	3	4	3	3	4	4	4	4	4	4	4	4	4	4	2	3	4		
	3	4	4	4	2	3	4	3	3	4	4	4	4	4	4	4	4	4	4	2	3	4		

Posture combinations can be classified into 4 (four) distinct classes: Class 1 - normal posture, which requires no attention except in exceptional cases; Class 2 - posture that should be checked routinely; Class 3 - posture that should receive short-term attention; Class 4 - posture that should receive immediate attention (Enez; Nalbantoğlu, 2019).

2.5 Data Analysis

The dataset, noise, and VCI collected were subjected to analysis of variance using the F-test. In cases where the F-test value was significant, Tukey’s mean comparison tests were performed at a 5% significance level. For this purpose, the computational statistical software "Sisvar" (Ferreira, 2011) was used.

3. RESULTS AND DISCUSSIONS

The results of the VCI and noise levels for each machine/mechanized set used in the coffee harvesting stages are presented in Table 4. For the two evaluated stages, harvesting and collection, they showed a significant isolated effect ($p < 0.05$), with no interaction between them.

Table 4: VCI levels (aren and VDVR), noise, and standard deviation (\pm) for the different treatments of the mechanized set for the blowing and sweeping stages.

Etap	Conjunto Mecanizado	Tratamento			* aren (ms^{-2})	** VDVR ($\text{ms}^{-1.75}$)	*** NEN (NHO 01) dB (A)	TE (min)(3)	*** NEN (NR 15) dB (A)	TE (min)(3)
		T1	rpm	Km/h						
enjoyo	RIOPENTO O ICL zunowome	T1	1800	0,5	0,55±0,04 a	8,55±0,52 a	87,87±1,90 a	240,00	87,23±1,08 a	300,00
		T2	1800	0,6	0,51±0,06 a	7,91±1,01 a	86,47±1,43 a	302,38	86,12±1,44 a	360,00
		T3	1800	0,7	0,55±0,07 a	8,80±1,35 a	88,43±3,43 a	190,48	87,55±2,47 a	300,00
		T4	1900	0,5	0,41±0,02 a	8,00±1,33 a	86,92±1,83 a	302,38	86,37±1,43 a	360,00
		T5	1900	1,0	0,35±0,02 a	5,98±0,90 b	88,32±1,37 a	190,48	87,87±1,24 a	300,00
		T6	1900	1,1	0,36±0,02 a	5,86±0,62 b	88,15±1,47 a	190,48	88,67±1,33 a	270,00
		C.V. (%) ⁽²⁾				9,57	13,40	2,32	-	1,80
onju guo usly	+HOSLY ⑧cQ1PCA riopsylosed ZMV	T1	1300	0,6	0,29±0,02 b	5,78±2,53 b	92,30±2,13 a	75,59	91,75±1,58 a	180,00
		T2	1300	0,7	0,32±0,04 ab	6,16±2,29 ab	93,52±3,41 a	60,00	92,98±2,78 a	160,00
		T3	1300	0,8	0,37±0,05 a	10,13±4,23 b	93,45±1,48 a	60,00	93,20±0,99 a	135,00
		T4	1400	0,7	0,32±0,03 ab	5,95±1,36 ab	91,93±0,93 a	95,24	91,62±0,80 a	180,00
		T5	1400	0,8	0,32±0,03 ab	4,87±0,82 b	91,62±0,96 a	95,24	91,60±0,96 a	180,00
		T6	1400	0,9	0,32±0,04 ab	5,40±1,67 b	94,95±3,59 a	47,62	93,92±2,82 a	135,00
		C.V. (%) ⁽²⁾				11,28	37,34	2,53	-	2,01
Stage	Machined Assembly	Treatment			* aren (ms^{-2})	** VDVR ($\text{ms}^{-1.75}$)	*** NEN (NHO 01) dB (A)	TE (min)(3)	*** NEN (NR 15) dB (A)	TE (min)(3)
		T1	rpm	Km/h						
enjoyo	RIOPENTO O ICL zunowome	T1	1800	0,5	0,55±0,04 a	8,55±0,52 a	87,87±1,90 a	240,00	87,23±1,08 a	300,00
		T2	1800	0,6	0,51±0,06 a	7,91±1,01 a	86,47±1,43 a	302,38	86,12±1,44 a	360,00
		T3	1800	0,7	0,55±0,07 a	8,80±1,35 a	88,43±3,43 a	190,48	87,55±2,47 a	300,00
		T4	1900	0,5	0,41±0,02 a	8,00±1,33 a	86,92±1,83 a	302,38	86,37±1,43 a	360,00
		T5	1900	1,0	0,35±0,02 a	5,98±0,90 b	88,32±1,37 a	190,48	87,87±1,24 a	300,00
		T6	1900	1,1	0,36±0,02 a	5,86±0,62 b	88,15±1,47 a	190,48	88,67±1,33 a	270,00
		C.V. (%) ⁽²⁾				9,57	13,40	2,32	-	1,80
onju guo usly	+HOSLY ⑧cQ1PCA riopsylosed ZMV	T1	1300	0,6	0,29±0,02 b	5,78±2,53 b	92,30±2,13 a	75,59	91,75±1,58 a	180,00
		T2	1300	0,7	0,32±0,04 ab	6,16±2,29 ab	93,52±3,41 a	60,00	92,98±2,78 a	160,00
		T3	1300	0,8	0,37±0,05 a	10,13±4,23 b	93,45±1,48 a	60,00	93,20±0,99 a	135,00
		T4	1400	0,7	0,32±0,03 ab	5,95±1,36 ab	91,93±0,93 a	95,24	91,62±0,80 a	180,00
		T5	1400	0,8	0,32±0,03 ab	4,87±0,82 b	91,62±0,96 a	95,24	91,60±0,96 a	180,00
		T6	1400	0,9	0,32±0,04 ab	5,40±1,67 b	94,95±3,59 a	47,62	93,92±2,82 a	135,00
		C.V. (%) ⁽²⁾				11,28	37,34	2,53	-	2,01

Legend: *Normalized exposure resultant acceleration; **Resultant vibration dose value; ***Normalized exposure level according to NHO 01; ****Normalized exposure level according to NR 15; (1) Treatments; (2) Coefficient of variation in percentage; (3) Maximum allowed exposure time in minutes according to NHO 01 and NR 15; means followed by the same letter in the column do not differ by the Tukey Test.

It was observed that the average aren varied between 0.35 m s^{-2} to 0.55 m s^{-2} to 0.55 m s^{-2} in the harvesting stage and $0,29 \text{ ms}^{-2}$ to $0,37 \text{ ms}^{-2}$ in the sweeping stage, as shown in Table 4, with the NA being exceeded in 50% of the treatments used only with the harvester.

The mean values of VDVR (Table 4) are between $5.86 \text{ m s}^{-1.75}$ to $8.80 \text{ m s}^{-1.75}$ and $4.87 \text{ m s}^{-1.75}$ to $10,13 \text{ ms}^{-1.75}$ for the harvesting and collection stages, respectively. However, according to the data presented in the same table, for the tractor set used for collection, it was observed that the mean VDVR value in T3 was above the NA ($9,1 \text{ ms}^{-1.75}$).

Although, as regulated by NR 15, for an 8-hour workday the values found for the HAV did not exceed the EL (aren $1,1 \text{ ms}^{-2}$; VDVR $21 \text{ ms}^{-1.75}$) have reached the NA (aren $0,5 \text{ ms}^{-2}$; VDVR $9,1 \text{ ms}^{-1.75}$), NHO 9 and NR 9 stipulate that preventive measures must be adopted to avoid conditions that expose workers from reaching the EL, in order to protect the worker's health (Fundacentro, 2013; Brasil, 2021)

It should be emphasized that, according to NR 15 for the characterization of unhealthiness due to HAV exposure, the employer must compulsorily prove the evaluation of the two parameters, aren and VDVR (Brasil, 2021).

The NA for the areca was reached by the harvester at speeds of $0,5 \text{ kmh}^{-1}$, $0,6 \text{ kmh}^{-1}$ and $0,7 \text{ kmh}^{-1}$, while for the tractor set used for collection, it was at $0,8 \text{ kmh}^{-1}$ for the VDVR, with the NA being reached at a speed above $3,5 \text{ kmh}^{-1}$ when evaluating vibration and noise at the operating position of a coffee tractor coupled to a turbo sprayer under different working speeds (Júnior et al., 2022). This may be due to the necessary working conditions

employed, as well as the type of equipment/machinery set used.

As for occupational noise, it is noted that the average NEN values (Table 4) found range from 86.47 dB(A) to 88.43 dB(A) according to NHO 01 and 86.12 dB(A) to 88.67 dB(A) in relation to NR 15 during the harvesting stage. For the collection stage, the values found are 91.62 dB(A) to 94.95 dB(A) and 91.60 dB(A) to 93.92 dB(A), according to the same standards, exceeding the LE (80 dB(A)) for an 8-hour workday (NHO 01 and NR 15). In the study by (Santos et al., 2014), the authors reported values between 97.4 and 98.2 dB(A) when evaluating noise and vibration levels in a tractor-sprayer set, also finding levels above the exposure limit of 85 dB(A). The difference between the values found in the two studies may be related to technical differences between the machinery sets used and operating rotation.

The average occupational noise values found in the harvesting stage, even with the same equipment, are lower than those found by Silva et al. (2018) (93.8±1.78), which may be because the harvester had undergone maintenance and part replacement, as the lack of periodic maintenance and replacement of parts or their components when necessary, and lack of lubrication can contribute to increased noise and vibration levels (Saliba, 2019; Silva et al., 2021).

Considering the rotations used in each stage of harvesting, observing the requirements for the proper functioning of each equipment/tractor set, the maximum permitted exposure time according to NHO 01 is 190 minutes and 47.62 minutes for harvesting, and 270 minutes and 135 minutes for the collection stage in relation to NR 15 (Table 4) (Fundacentro, 2001). This may indicate greater protection for the worker by NHO 01 compared to NR 15, as the former uses q-3 and the latter q-5.

It was observed that the TDI self-propelled harvester generated a lower amount of noise compared to the tractor set, which may be due to the fact that this equipment is cabs, acting as an acoustic barrier and offering greater protection to the operator. A similar situation was found by (Martins et al., 2022) when evaluating the occupational noise level emitted by self-propelled harvesters during mechanical coffee harvesting, comparing the operator in a cabs operating position and the assistant in an external environment, with the latter being more exposed.

In a study conducted on the level of occupational noise during mechanical coffee harvesting by Silva et al. (2018), the values for the collection stage were lower than those obtained in the present study. This difference may be related to the different models used.

With the presented noise level results, they may imply the need to use ear protectors with adequate attenuation levels, emphasizing the importance of the attenuation being above 70dB (A) and below 80dB (A) to avoid over-attenuation, which hinders the perception of warning signals, moving vehicles and equipment, among others (Fundacentro, 2018).

It should be emphasized that exposure to WBV and noise can vary considerably depending on the activity performed and the equipment attached to the tractor (Brunetti; D’Ambrogio; Fregolent, 2021).

From Table 4, the behavior of the data in the evaluated stages is presented through Figure 6.

Figure 6 presents the behavior of the data generated for aren, VDVR, and noise by the self-propelled harvester and the Valtra® mechanized set + collector during the coffee harvesting and collection stages.

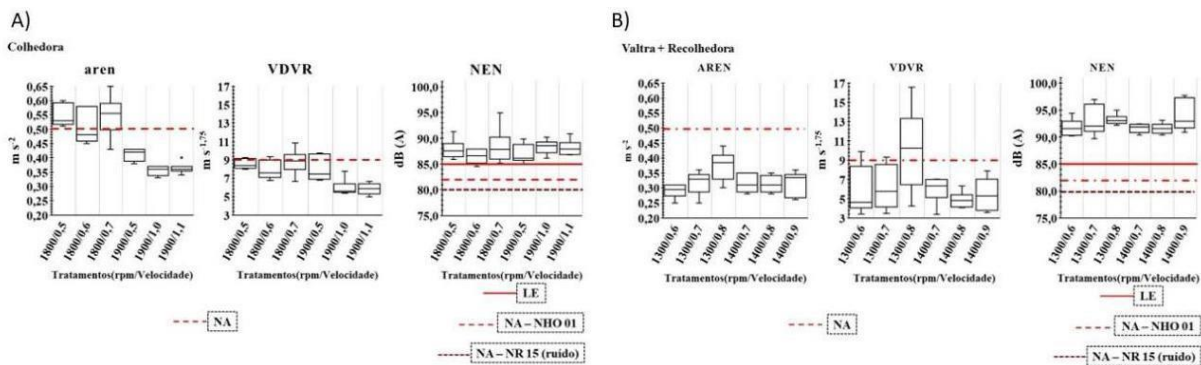


Figure 6: Box-plot of aren (ms⁻²), VDVR (ms^{-1,75}), and NEN (NHO 01 and NR 15) generated by the

harvester and the Valtra® mechanized set + collector in the coffee harvesting (A) and collection (B) stages.

It was observed that the harvester contributed the least to noise generation, indicating that the operator of this mechanized set could perform their functions for a longer period of activity using an ear protector with lower attenuation.

As for the collection stage, it presented lower aren values and only in one of the treatments (T3) (Table 4) and Figure 6 (B) shows that the AL was reached by the VDVR, which may be due to the need for the operator to monitor the set and the direct contact of the attached equipment with the ground, favoring the generation of vibration peaks. It is recommended to adopt preventive measures, such as informing and guiding workers about the risks and precautions to be taken, periodic monitoring of exposure, as well as medical control through examinations and recording of previous exposures, aiming to protect the operator’s health (Fundacentro, 2013).

From the postural assessment of each mechanical harvesting stage, using Figure 4 and applying the data from Table 3, the result of the postural analysis (OWAS) was generated, which can be observed in Table 5.

Table 5: Postural analysis of the coffee harvesting stages.

Stage	Characterization	Index	Class
1. Harvest	Back: inclined	Back: 2	2
	Arm: two arms down	Arm: 1	
	Leg: two flexed legs	Leg: 3	
2. Collection	Back: inclined and twisted; Arm: two arms down*	Back: 4 Arm: 1	2
	Leg: two flexed legs;	Leg: 3	

Legend: *Two arms below shoulder level; however, the right arm makes repetitive rotational movements, accompanying the torso, previously aligning the implement with the hydraulic points using the tractor’s power take-off; Load: No load.

The analyses showed that during harvesting activities, the operator adopted postures with potential long-term health risks, especially those involving the neck, torso, and arms. Using the OWAS method, under the evaluated conditions, it was found that workers have an inclined and twisted back, two arms down, or one down and one up, two flexed legs, and frequent torso rotation to observe the implement attached to the rear of the tractor, as shown in Table 5.

In contrast, when using the self-propelled harvester, its viewing angle does not require torso twisting or constant arm movement up and down, indicating a better working posture compared to other stages.

In the collection activity, the operator’s posture is more critical due to the need to constantly check the working conditions of the implements attached to the rear of the tractor, as described by (Iida; Buarque, 2016).

According to Table 5, the classification of the combination of postures adopted (Figure 4) by the operators of the tractorized equipment/set used resulted in class 2, which suggests routine verification of the operator’s posture. Thus, improvements in work organizational processes are recommended, such as: ergonomics training, encouragement of more frequent breaks, stretching of muscle groups, posture changes, and task execution with more people (Barneo-Alcántara et al., 2021).

Thus, improvements in work organizational processes are recommended, such as: ergonomics training, encouragement of more frequent breaks, stretching of muscle groups, posture changes, and task execution with more people (Barneo-Alcántara et al., 2021).

4. CONCLUSION

Under the conditions used for the development of the work, the operator is more exposed to the physical agent noise in relation to the WBV, and ergonomic postures should be analyzed routinely.

The RMS levels exceeded the NA during the harvesting stage, while the VDV level only reached the NA at T3 during the collection stage, and noise levels were above the LE in both stages.

The type of equipment used and the attached implement, as well as the activity to be performed and the posture adopted by the operator, directly influence the level of WBV and noise generated during the activity.

Ergonomic risk factors should be monitored frequently, as they can harm the worker's health during their working life.

The results suggest that values similar to or higher than those found in the present study are expected under normal working conditions.

ACKNOWLEDGMENTS

The authors thank the Federal Institute of Education, Science and Technology of Southern Minas Gerais (IFSULDEMINAS) - Muzambinho Campus, for financial and technological support; the Coordination for the Improvement of Higher Education Personnel (CAPES), for the scholarship grant; and the owners and employees of Fazenda São Manoel, who collaborated with data collection for this study.

REFERENCES

- [1] ANDERSON, C. G.; SABINO, P. H. de S.; OLIVEIRA JÚNIOR, G. G. de; SILVA, G. O. A. da. Octave band sound pressure level emitted by agricultural implements in coffee plantations. *Ciência Rural*, Santa Maria, v. 54, p. e20230062, February 23, 2024. <https://doi.org/10.1590/0103-8478cr20230062>.
- [2] BARNEO-ALCÁNTARA, M.; DÍAZ-PÉREZ, M.; GÓMEZ-GALÁN, M.; CARREÑO-ORTEGA, Á.; CALLEJÓN-FERRE, Á.-J. Musculoskeletal Disorders in Agriculture: A Review from Web of Science Core Collection. *Agronomy*, Basel, v. 11, n. 10, p. 2017, October 2021. <https://doi.org/10.3390/agronomy11102017>.
- [3] BENOS, L.; TSAOPOULOS, D.; BOCHTIS, D. A Review on Ergonomics in Agriculture. Part II: Mechanized Operations. *Applied Sciences*, Cranfield, v. 10, n. 10, p. 3484, January 2020. <https://doi.org/10.3390/app10103484>.
- [4] BRANDL, C.; MERTENS, A.; SCHLICK, C. M. Effect of sampling interval on the reliability of ergonomic analysis using the Ovako working posture analysing system (OWAS). *International Journal of Industrial Ergonomics*, Netherlands, v. 57, p. 68-73, January 2017. <https://doi.org/10.1016/j.ergon.2016.11.013>.
- [5] BRAZIL. Regulatory Standard No. 9 (NR-9). 2023. Ministry of Labor and Employment. Available at: <https://www.gov.br/trabalho-e-emprego/pt-br/acao-a-informacao/participacao-social/conselhos-e-orgaos-colegiados/comissao-tripartite-partitativa-permanente/normas-regulamentadora/normas-regulamentadoras-vigentes/norma-regulamentadora-no-9-nr-9>. Accessed on: July 18, 2024.
- [6] BRAZIL, MINISTRY OF LABOR AND EMPLOYMENT. Ordinance MTP No. 426, of February 7, 2021. Available at: <https://www.gov.br/trabalho-e-emprego/pt-br/acao-a-informacao/participacao-social/conselhos-e-orgaos-colegiados/comissao-tripartite-partitativa-permanente/arquivos/normas-regulamentadoras/nr-15-anexo-08.pdf>. Accessed on: September 28, 2024.
- [7] BRUNETTI, J.; D'AMBROGIO, W.; FREGOLENT, A. Analysis of the Vibrations of Operators' Seats in Agricultural Machinery Using Dynamic Substructuring. *Applied Sciences*, Basel, v. 11, n. 11, p. 4749, January 2021. <https://doi.org/10.3390/app11114749>.
- [8] CLAY, D. C.; BRO, A. S.; CHURCH, R. A.; ORTEGA, D. L.; BIZOZA, A. R. Farmer incentives and value chain governance: Critical elements to sustainable growth in Rwanda's coffee sector. *Journal of Rural Studies*, United Kingdom, v. 63, p. 200-213, October 1, 2018. <https://doi.org/10.1016/j.jrurstud.2018.06.007>.
- [9] ENEZ, K.; NALBANTOĞLU, S. S. Comparison of ergonomic risk assessment outputs from OWAS and REBA in forestry timber harvesting. *International Journal of Industrial Ergonomics*, Amsterdam, v. 70, p. 51-57, March 1, 2019. <https://doi.org/10.1016/j.ergon.2019.01.009>.
- [10] FERREIRA, D. F. Sisvar: a computer statistical analysis system. *Ciência e Agrotecnologia*, Lavras, v. 35, p. 1039-1042, December 2011. <https://doi.org/10.1590/S1413-70542011000600001>.
- [11] FREIRE, A. F. do N.; SILVA, E. de M.; SANTOS, T. T. dos; FIGUEIRA, F. da S. Importance, challenges and perspectives of using fungi in the biological control of plant diseases for Brazilian agriculture: Importância, desafios e perspectivas de uso de fungos no controle biológico de doenças de plantas para a agricultura brasileira. *Concilium*, v. 24, n. 1, p. 485-504, 30 Jan. 2024. <https://doi.org/10.53660/CLM-2744-24B11>.
- [12] FUNDACENTRO. Guide of guidelines and minimum parameters for the development and management of the Hearing Conservation Program (HCP). 1st ed. São Paulo: FUNDACENTRO, 2018.
- [13] FUNDACENTRO. Occupational hygiene standard: NHO 01: assessment of occupational noise exposure: technical procedure. 1st ed. São Paulo: FUNDACENTRO, 2001.
- [14] FUNDACENTRO. Occupational hygiene standard: NHO 09: assessment of occupational whole-body vibration exposure: technical procedure. . São Paulo: FUNDACENTRO, 2013.

- [15] IFTIME, M.-D.; DUMITRASCU, A.-E.; DUMITRASCU, D.-I.; CIOBANU, V. D. An investigation on major physical hazard exposures and health effects of forestry vehicle operators performing wood logging processes. *International Journal of Industrial Ergonomics*, Oxford, v. 80, p. 103041, 1 Nov. 2020. <https://doi.org/10.1016/j.ergon.2020.103041>.
- [16] IIDA, I.; BUARQUE, L. *Ergonomics: Design and Production*. 3rd ed. São Paulo: Blucher, 2016.
- [17] JÚNIOR, G. G. de O.; CUNHA, I. de A. da; SILVA, J. A. R. da; RAMIRIO, L. D.; SILVA, A. B. da; PUTTI, F. F. Vibration and noise at the operating station of a coffee tractor coupled to a turbo sprayer at different working speeds. *Concilium*, v. 22, n. 2, p. 118-130, 10 Feb. 2022. <https://doi.org/10.53660/CLM-098-119>.
- [18] LEITE, D. M.; FERNANDES, H. C.; JUNIOR, M. R. F.; FEITOSA, J. R.; SANTOS, D. W. F. do N. Caracterização das vibrações do posto de operação de um trator agrícola em condição de tração / Characterization of the vibrations of the operation station of an agricultural tractor under traction. *Brazilian Journal of Animal and Environmental Research*, São José dos Pinhais, v. 3, n. 4, p. 3808-3821, 20 Nov. 2020. <https://doi.org/10.34188/bjaerv3n4-081>.
- [19] MARTINS, K. M.; SABINO, P. H. de S.; SILVA, A. B. da; OLIVEIRA JÚNIOR, G. G. de; RAMIRIO, L. D. Occupational noise level emitted by self-propelled harvesters during mechanized coffee harvesting. *Ciência Rural*, Santa Maria, v. 53, p. e20210695, 29 Aug. 2022. <https://doi.org/10.1590/0103-8478cr20210695>.
- [20] MISHRA, D.; SATAPATHY, S. Ergonomic risk assessment of farmers in Odisha (India). *International Journal of System Assurance Engineering and Management*, Odisha, v. 10, n. 5, p. 1121-1132, 1 Oct. 2019. <https://doi.org/10.1007/s13198-019-00842-5>.
- [21] NGUYEN, T. H. Y.; BERTIN, M.; BODIN, J.; FOUQUET, N.; BONVALLOT, N.; ROQUELAURE, Y. Multiple Exposures and Coexposures to Occupational Hazards Among Agricultural Workers: A Systematic Review of Observational Studies. *Safety and Health at Work*, United Kingdom, v. 9, n. 3, p. 239-248, Sep. 2018. <https://doi.org/10.1016/j.shaw.2018.04.002>.
- [22] PEREIRA, A. S.; REIS, Á. V.; NINO, L. B; GOMES, M. C; FERREIRA, M. F. Cognitive mapping of ergonomics and safety on agricultural tractors used in family farming. *Revista de la Facultad de Agronomía, La Plata*, v. 120, p. 2021, 24 Jun. 2021. <https://doi.org/10.24215/16699513e071>.
- [23] PHAM, Y.; REARDON-SMITH, K.; MUSHTAQ, S.; COCKFIELD, G. The impact of climate change and variability on coffee production: a systematic review. *Climatic Change*, Switzerland, v. 156, n. 4, p. 609-630, 1 Oct. 2019. <https://doi.org/10.1007/s10584-019-02538-y>.
- [24] SALIMOVA, G.; ABLEEVA, A.; KHABIROV, G.; ZALILOVA, Z.; VALIEVA, G.; HAZIEVA, A. Evaluation of level of agricultural development based on integration index. *Journal of the Saudi Society of Agricultural Sciences*, Riadi, v. 19, n. 5, p. 319-325, 1 Jul. 2020. <https://doi.org/10.1016/j.jssas.2020.03.001>.
- [25] SANTOS, L. N. dos; FERNANDES, H. C.; SOUZA, A. P. de; JÚNIOR, M. R. F.; SILVA, R. M. F. ASSESSMENT OF NOISE AND VIBRATION LEVELS OF A TRACTOR-SPRAYER COMBINATION AS A FUNCTION OF WORK SPEED. *Revista Engenharia na Agricultura - REVENG*, Viçosa, v. 22, n. 2, p. 112-118, 30 Apr. 2014. <https://doi.org/10.13083/reveng.v22i2.468>.
- [26] SILVA, J. A. R. da; JÚNIOR, G. G. de O.; COSTA, C. E. de M.; SILVA, A. B. da; GABRIEL, C. P. C.; PUTTI, F. F. OCCUPATIONAL NOISE LEVEL IN MECHANIZED AND SEMIMECANIZED HARVEST OF COFFEE FRUITS. *Coffee Science - ISSN 1984-3909*, Lavras, v. 13, n. 4, p. 448-454, 19 Dec. 2018. Available at: <https://coffeescience.ufla.br/index.php/Coffeescience/article/view/1468>. Accessed on: 28 Sep. 2024
- [27] SILVA, M. A. da; JÚNIOR, G. G. de O.; APARECIDO, L. E. de O.; CUNHA, I. de Á. da; SILVA, J. A. R. da; PUTTI, F. F. Dispersion of Noise Generated by a Static Conditioned Tractor Set: Case Study between Different Positions and Distances. *Brazilian Journal of Development*, Curitiba, v. 7, n. 4, p. 37500-37511, 12 Apr. 2021. <https://doi.org/10.34117/bjdv7n4-289>.
- [28] TURCO, P. H. N.; MARTINS, A. N.; FIRETTI, R.; PINATTI, E.; ALVES NETO, A.; POLIS, K. T. F. Costs and profitability of *Coffea arabica* L. (cv. Catuaí IAC 144 and IAPAR 59) for the microregion of Marília, São Paulo, Brazil. *Revista de Economia e Sociologia Rural*, São Paulo, v. 61, n. spe, p. e276484, 2023. <https://doi.org/10.1590/1806-9479.2023.276484>.