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Efficiency of anti-vibration gloves in soil preparation using a micro tractor

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ABSTRACT: During the working day, agricultural machinery operators are often exposed to physical risks, such as vibration, which can compromise their health and performance. Micro tractors emit high levels of vibration, which mainly affect their hands and arms. Thus, this study aims at evaluating the efficiency of different glove models in reducing vibration transmitted by the micro tractor/rotary tiller assembly according to the operating velocity and the rotation of the rotary tiller rotor. A completely randomized block design was used in a 4 x 2 x 2 factorial arrangement with five replicates. The study analyzed three glove models (G1 and G2 anti-vibration models, and anti-impact model G3) and a control treatment under the same operating conditions, but without the use of protective equipment. The study was conducted at two operating velocities (V1 = 0.98 km h^{-1} and V2 = 1.6 km h^{-1}) and two rotations of the rotary tiller rotor (R1 = 265 rpm and R2 = 520 rpm). None of the evaluated glove models reached the attenuation capacity required by the Occupational Hygiene Standard (Norma de Higiene Ocupacional - NHO 10) and, under some operating conditions, they raised the incident vibration levels, exceeding the values obtained when the work was performed without a protective equipment. Although the anti-impact model G3 and the anti-vibration model G2 did not reduce the transmitted vibration to the levels considered acceptable by NHO 10, the anti-impact G3 and anti-vibration G2 models showed better performance in the work performed at a velocity of 0.98 km h^{-1} and a rotation of 520 rpm of the rotary tiller rotor.

Key words: personal protective equipment, vibration transmissibility, ergonomics

Eficiência de luvas antivibratórias na operação de preparo de solo utilizando microtrator

RESUMO: Durante a jornada de trabalho, o operador de máquinas agrícolas se encontra frequentemente exposto a riscos físicos, como a vibração, que podem comprometer sua saúde e desempenho. Os microtratores emitem elevados níveis de vibração que afetam especialmente o sistema mãos e braços. Assim, objetivou-se avaliar a eficiência de diferentes modelos de luvas na redução da vibração transmitida pelo conjunto microtrator/enxada rotativa em função da velocidade de operação e da rotação do rotor da enxada rotativa. O experimento foi conduzido no delineamento experimental inteiramente casualizado em esquema fatorial 4 x 2 x 2 com cinco repetições, sendo três modelos de luvas (L1 e L2, modelos antivibratórias, e L3 modelo anti-impacto) e um tratamento controle que consistiu das mesmas condições de operação sem o uso do equipamento de proteção, duas velocidades de operação (V1 = 0,98 km h^{-1} e V2 = 1,6 km h^{-1}) e duas rotações do rotor da enxada (R1 = 265 rpm e R2 = 520 rpm). Nenhum dos modelos de luvas experimentadas apresentou capacidade de atenuação exigida pela Norma de Higiene Ocupacional (NHO 10) e em algumas condições de operação elevaram os níveis de vibração incidente, superando os valores obtidos na realização do trabalho sem o uso do equipamento de proteção. Embora não reduzindo a vibração transmitida aos níveis considerados aceitáveis pela NHO 10, os modelos anti-impacto L3 e antivibratório L2 apresentaram melhor desempenho na operação realizada na velocidade de 0,98 km h^{-1} e rotação de 520 rpm no rotor da enxada rotativa.

Palavras-chave: equipamento de proteção individual, transmissibilidade de vibração, ergonomia

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Introduction

Farmers are adhering to increasingly advanced technologies to achieve production targets. The use of agricultural machinery and implements is an important factor in this context, allowing the rationalization of agricultural work, increasing productivity, and reducing worker effort (Rodrigues et al., 2006).

Tractors have been rapidly following technological developments in response to the growth of demand. However, the size of agricultural machinery must consider several factors in order to reduce costs and waste. Therefore, in the production of vegetables, micro tractors are recommended in family farming or areas with topography unfavorable to the use of robust machines.

Since these machines transmit high levels of vibration, it is important to prepare a work schedule to reduce exposure (Albiero et al., 2015).

Vibration is a harmful physical agent that can be observed in several rural activities and can transmit vibrations to the hands and arms or the whole body of workers (Moraes, 2015).

Vibrations can affect vision, cause irritability, lumbar deformations, and digestive problems, so they should be eliminated or reduced to the maximum possible (Cunha et al., 2009). Frequent occupational vibrations exposure can cause pathological changes in the involved body parts, resulting in different pathologies depending on which one is receiving vibration (Regis Filho et al., 2010).

Anti-vibration gloves have been used to help reduce vibration exposure in hands and arms (Dong et al., 2009).

Thus, the present study aimed at evaluating the efficiency of different glove models in reducing the vibration transmitted to hands and arms by the micro tractor/rotary tiller assembly, being conducted at two operating velocities and two rotations of the rotary tiller rotor.

Material and Methods

The study was conducted in the experimental area of the Laboratory for Investigation of Accidents with Agricultural Machines (Laboratório de Investigação de Acidentes com Maquinas Agrícolas), linked to the Department of Agricultural Engineering of the Federal University of Ceará located between the latitudes of 3° 44' 45,72” and 3° 44' 48,67” South of the Equator and the longitudes 38° 34' 51,05 'and 38° 34' 53,52' West of Greenwich and 27 m from sea level. The soil of the area is classified as Ultisol with sandy loam texture and being composed of 82.90% sand, 10.60% clay, and 6.40% silt, respectively (Macedo et al., 2016).

A completely randomized block design was used in a 4 x 2 x 2 factorial arrangement. The study analyzed three glove models (G1 and G2, anti-vibration models, and G3, anti-impact model) and a control treatment under the same operating conditions, but without the use of gloves (WG). The study was conducted at two operating velocities (V1 = 0.98 km h^{-1} and V2 = 1.6 km h^{-1}) and two rotations of the rotary tiller rotor (R1 = 265 rpm and R2 = 520 rpm) and using five replicates, totaling 80 plots.

A 2 x 2 Yanmar Agritech TC14S two-wheeled micro tractor with a power from 10.3 kW to 2,400 rpm, total mass of 498 kg, with 6-12 tires on the drive wheels, according to information in the operator's manual, was used. The rotary tiller used has a working depth of 200 mm and a cutting width of 750 mm.

In order to determine the average operating velocities, the micro tractor operated in the first and second gears and travelled five times a range of 50 m reaching average velocities of V1 = 0.98 km h^{-1} and V2 = 1.6 km h^{-1}, respectively.

The gloves evaluated were: the anti-vibration gloves (G1 and G2) and the anti-impact glove (G3) models developed for protecting the hands in activities involving risk of impact on the hand back. Specifications of each model are presented in Table 1.

A triaxial accelerometer model 356A02 fixed on the right handle of the micro tractor, the side that provides more ability of action to the operator, was used to evaluate the vibration emitted by the mechanized assembly and transmitted to the operator. The collected samples were recorded and stored using a Delta OHM's HD 2030 vibration analyzer.

During the study, the following vibration exposure variables were evaluated:

1. Root-mean-square single-axis acceleration value- rms: effective value of vibration movement, which indicates the destructive potential of vibration towards the X, Y and Z axes, in m s^{-2}.

2. EAT (%): effective amplitude of glove transmissibility, adapted from the SEAT (%) method proposed by Costa (2018), who used the methodology to evaluate the transmissibility of the material used for manufacturing tractors cushions, and Adam & Jalil (2017), who used the variable rms (average acceleration on the axes) for calculating this value.

Table 1. Glove models evaluated in the study

Glove 1 (G1)	Safety glove knitted in cotton, covered with chlorine neoprene buds on the palm and fingers. Model: Vibraflex Manufacturer: DANNY	
Glove 2 (G2)	Safety glove made of natural and synthetic fibers, palm padding, tips and palm padding of fingers in foam in the shape of buds. Model: Gorilla Volk Manufacturer: VOLK	
Glove 3 (G3)	Safety glove made of synthetic fibers, 13 gauge, covering the palmar face and fingertips in corrugated latex; back with buds in thermoplastic rubber (TPR), handle with inserts of elastic fibers and finishing in synthetic fibers. Model: Cut Volk Manufacturer: VOLK	

The percentage values of effective amplitude of glove transmissibility calculated according to Eq. 1 are compared graphically to the r.m.s transmitted by the control treatment, determining the percentage of attenuation or amplification of the transmitted vibration by the difference between them.

$$EAT(\%) = \frac{rms_g}{rms_{wg}} \times 100 \qquad (1)$$

where:

EAT(%) - effective amplitude of glove transmissibility;

rms_g - average acceleration on the X, Y or Z axes with the gloves, m s^{-2}; and

rms_{wg} - average acceleration on X, Y or Z axes without gloves, m s^{-2}.

3. Acceleration resulting from normalized exposure - A(8): corresponds to the acceleration resulting from exposure for a standard 8-hour workday.

The normality of the data was determined by the coefficients of symmetry and kurtosis. According to Oliveira (2010), values between -3 and 3 indicate normality in agricultural studies.

The data of rms and A(8) were submitted to analysis of variance by the F-test and the averages of the treatments were compared with the means of the control treatment by the Dunnet test at $p \leq 0.05$.

Results and Discussion

The average acceleration values indicate that there was no significant difference in any of the treatments on the X axis compared to the control treatment (Table 2).

Table 2. Average acceleration values on the X, Y and Z axes

	Average acceleration on the:		
	X axis	Y axis	Z axis
		(m s^{-2})	
	Velocity 1- Rotation 1		
WG	1,295	1,392	2,560
G1	1,415 ns	1,535 ns	4,327 *
G2	2,108 ns	1,846 *	4,562 *
G3	1,656 ns	1,892 *	4,992 *
LSD	0,698	0,214	0,578
	Veloccity 1- Rotation 2		
WG	2,130	1,730	3,692
G1	1,564 ns	1,728 ns	3,620 ns
G2	1,535 ns	1,634 ns	2,906 *
G3	1,536 ns	1,652 ns	3,022 *
LSD	0,726	0,203	0,387
	Velocity 2- Rotation 1		
WG	1,228	1,390	3,658
G1	1,340 ns	1,486 ns	3,548 ns
G2	1,290 ns	1,480 ns	3,398 ns
G3	1,378 ns	1,480 ns	4,024 ns
LSD	0,328	0,289	0,426
	Velocity 2- Rotation 2		
WG	1,230	1,400	3,368
G1	1,392 ns	1,546 ns	3,602 ns
G2	1,168 ns	1,300 ns	4,018 ns
G3	1,244 ns	1,364 ns	4,168 *
LSD	0,211	0,176	0,428

Velocity 1 = 0,98 km h^{-1}; Velocity 2 = 1,2 km h^{-1}; Rotation 1 = 265 rpm; Rotation 2 = 520 rpm; WG - Without glove; G1 - Glove 1; G2 - Glove 2; G3 - Glove 3; ns, * - Not significant and significant at $p \leq 0.05$, respectively, by the Dunnutt test; LSD - Least significant difference

The average acceleration values on the Z axis differed statistically from the averages of control treatment obtained by the Dunnett test, all glove models operating at velocity 1 and rotation 1 of the rotary tiller rotor on this axis differed from the control treatment, amplifying the vibration.

Under these operating conditions, amplification was observed on the Z axis in the treatments with gloves G2 and G3. Hamouda et al. (2018) found that gloves can reduce exposure to finger vibration, especially when using portable power tools with predominant vibration in the frequency bands of 30 and 160 Hz, and 10 and 200 Hz in the index and middle fingers, respectively. However, the authors observed that some gloves amplified vibration at frequencies higher than 160 Hz in the index finger and higher than 200 Hz in the middle finger.

According to Welcome et al. (2014), vibration frequencies emitted by machines interfere with the efficiency of insulating materials, and the use of certified anti-vibration gloves is unlikely to be beneficial when using low-frequency vibration tools (< 25 Hz).

When operating at velocity 1 and rotation 520 rpm of the rotary tiller rotor on axis Z, there was significant difference between the model G2 and the anti-impact model G3. In these cases, the average values indicated vibration attenuation compared to the control treatment.

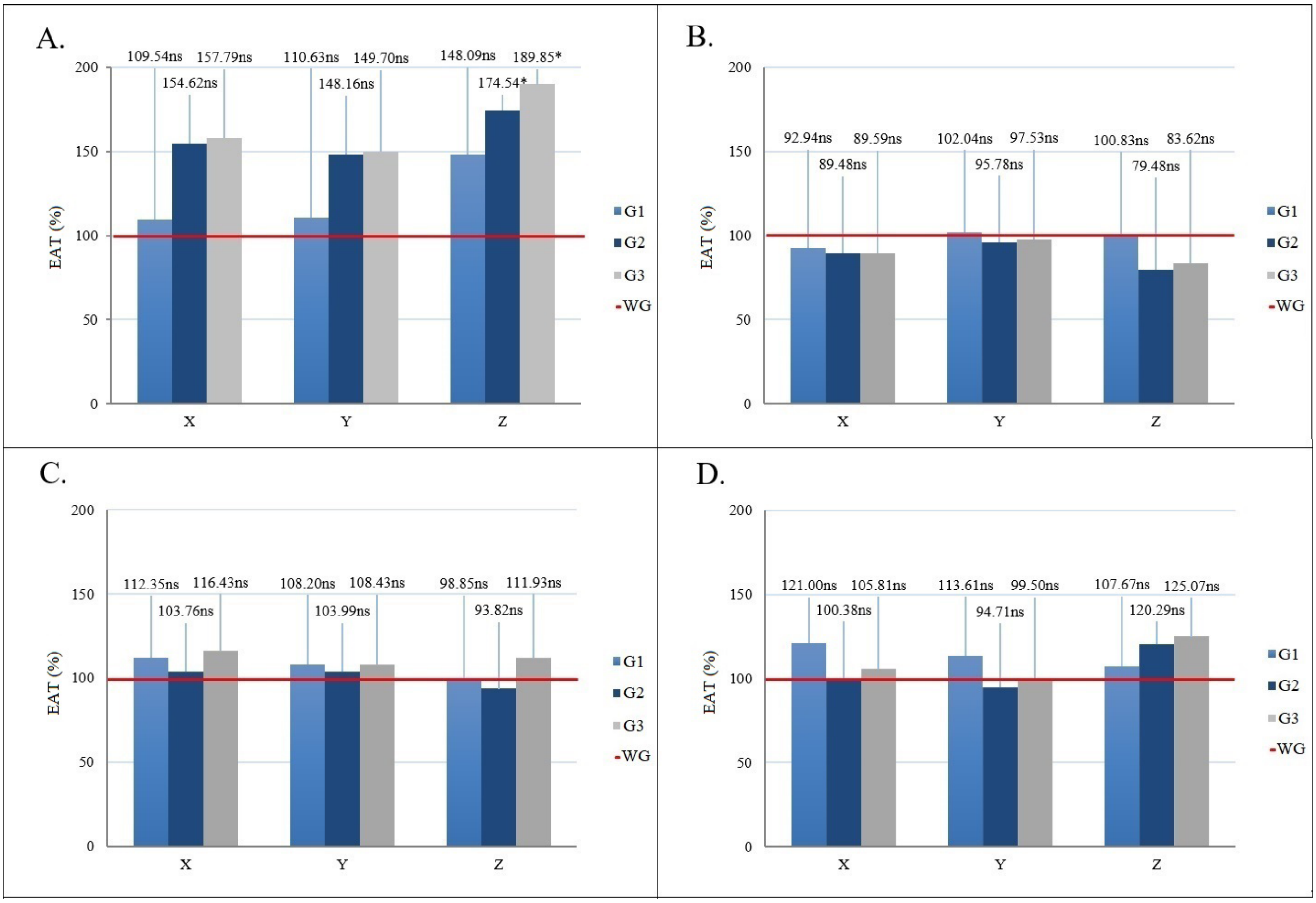
At velocity 2 and 520 rpm rotation, there was a significant difference only in model G3, with amplification of the vibration transmitted on the Z axis. According to Ribas (2012) the winding soil contributes to the highest values on the Z axis, which makes it the most difficult to attenuate in agricultural activities.

Costa (2018) states that the attenuating capacity of the material used in a product is reduced if it does not promote significant attenuation on the Z axis. Vertical rms acceleration is the most significant variable in studies on vibration in tractors conducted in different terrains and under different operating conditions (Santos Filho et al., 2003).

According to the EAT(%) method, if values of 100% are assumed in the analysis of control treatment WG, a downward variation of this value means that the material attenuated the incident vibration under that condition, while an upwards variation, with EAT(%) values higher than 100%, indicates an increase in the level of transmitted vibration.

At velocity 1 and rotation 1 of the rotary tiller rotor, the vibration transmitted to the operator's hands and arms was amplified by 9.54, 54.62, and 57.79% on the X axis; 10.63, 48.16, and 49.70% on the Y axis; and 48.09, 74.54, and 89.85% on the Z axis in the treatments with Glove 1, Glove 2, and Glove 3, respectively (Figure 1A).

Although anti-vibration gloves were developed to isolate or reduce transmitted vibrations, they may amplify them in some conditions. Hamouda et al. (2017), evaluating the transmissibility of four glove models, found that vibration is amplified by the frequency range of 10 and 40 Hz in the palm of the hand, in 125 and 200 Hz in the fingers when air gloves are used, and above 200 Hz when gel, hybrid, and leather gloves are used. In this study, the combinations of gears and rotations may have enabled frequencies capable of influencing the glove transmissibility values.



WG - Without glove; G1 - Glove 1; G2 - Glove 2; G3 - Glove 3; ns, * - Not significant and significant at p ≤ 00.05, respectively, by the Dunnutt test.

Figure 1. Average values of effective amplitude of transmissibility - EAT (%) on the X, Y and Z axes: (A) Velocity 1 and rotation 1 on the rotary tiller rotor; (B) Velocity 1 and rotation 2 on the rotary tiller rotor; (C) Velocity 2 and rotation 1 on the rotary tiller rotor; (D) Velocity 2 and rotation 2 on the rotary tiller rotor

When operating at velocity 1 and rotation 2 of the rotary tiller rotor, there was attenuation, except for glove 1 on the Y and Z axes. The gloves G2 and G3 stood out in this analysis, with the glove G2 attenuating 10.52% on the X axis and 20.52% on the Z axis. Under these conditions, the glove G3 showed attenuation values of 10.41% and 16.38% on the X and Z axes (Figure 1B).

It is worth noting that glove 3 corresponds to the model developed for protecting the hands in activities involving risk of impact on the hand back. Dong et al. (2014) state that, in some cases, gloves not specifically developed for attenuating vibration may be more effective than vibration gloves in reducing transmitted vibrations depending on the frequencies emitted by the machines used.

The EAT(%) values of the operations performed at velocity 2 did not differ in any of the combinations with tiller rotation, showing values close to the values of the control treatment WG, EAT(%) = 100 (Figures 1C e D). In the treatment with glove G2 at operating velocity 2 and rotation 1 on the Z axis there was an attenuation of 6.18%, and the attenuation was 1.15% in the treatment with Glove 2.

Similarly, when operating at velocity 2 and 520 rpm rotation of the rotary tiller rotor, there was a reduction of 5.29% in the transmissibility in the treatment with glove G2 on the Y axis.

Since the rotary tiller rotor and the micro tractor motor are located at opposite sides of the machine, the difference between engine speed and tiller rotation may have contributed to the distribution of vibration frequencies in the micro tractor body, reducing the direct incidence in the exposure zone, contributing to a lower amplitude of transmissibility.

The EAT(%) values of the X, Y and Z axes indicate that the gloves do not attenuate and in some cases amplify vibrations under these field and operating conditions. The same was observed by Dong et al. (2014) who states that in many low-frequency tools, or those that vibrate along the axis of the handle, anti-vibration gloves do not reduce the generated vibrations.

Table 3 shows the acceleration averages resulting from normalized exposure. The lines indicate that the levels of the control treatment, in the three models of glove and under all operating conditions, are higher than the recommended by the Occupational Hygiene Standard - NHO 10 for operating in a 8 h workday (FUNDACENTRO, 2013). The standard establishes that A(8) values from 5 m s^{-2} are above the exposure limit, and immediate adoption of corrective measures is recommended in this case.

In soil preparation, the operating velocity and rotation factors of the rotating tiller occur simultaneously, and their combination generate different frequencies and consequently different vibration incidents levels. Thus, velocity and rotation were combined in order to simulate real field conditions and, as the A(8) values are the main parameter for determining the salubrity of an activity, this study analyzed A(8) values for each Glove model under each treatment and operating condition, without interaction.

Table 3. Average values of acceleration resulting from normalized exposure- A(8), m s^{-2})

	WG	G1	G2	G3	LSD
V1R1	5.22	6.97 *	8.08 *	8.68 *	0.619
V1R2	7.10	6.88 ns	6.26 *	6.34 *	0.378
V2R1	6.44	6.34 ns	5.30 *	7.10 *	0.296
V2R2	6.14	6.70 ns	6.64 ns	6.90 *	0.418

Velocity 1 = 0.98 km h^{-1}; Velocity 2 = 1.2 km h^{-1}; Rotation 1 = 265 rpm; Rotation 2 = 520 rpm; SL - Without Glove; G1 - Glove 1; G2 - Glove 2; G3 - Glove 3; ns, * - Not significant and significant at $p \leq 0.05$, respectively, by the Dunnutt test; ; LSD - Least significant difference

Certain materials, even those developed for vibration attenuation, may raise incident levels under certain conditions depending on the vibration frequencies generated and emitted. Thus, there was a significant difference in the acceleration resulting from normalized exposure in the control treatment and the gloves, with an increase in the A(8) values at velocity 1 and rotation 1.

At velocity 1 and rotation 2 of the rotary tiller rotor, although they are above the recommended by NHO 10, an A(8) reduction occurs in the G2 and G3 gloves compared to the control treatment. In velocity 2 and rotation 1 there is also a difference in the values obtained with gloves G2 and G3, showing reduction in glove G2 and amplification in glove G3. For the operation performed at velocity 2 and rotation 2, the glove G3 has the highest A(8) value, differing from the other models that amplified acceleration.

Gloves can have disadvantages such as reduced dexterity and manual sensitivity and can change the dimensions of the hand to the point of interfering with a person's handling ability (Cabeças & Milho, 2011). Such difficulties are clearer in operations with micro tractors in which the operator constantly changes the intensity of hand contact with the source of vibration, the handle, when handling the machine for ensuring that it is aligned to the direction of soil preparation.

Conclusions

1. None of the glove models reached the attenuation capacity required by the Occupational Hygiene Standard - NHO 10 and, under some operating conditions, they increased the incident vibration levels, exceeding the values obtained when the work was performed without a protective equipment.

2. Although the anti-impact G3 and anti-vibration G2 models did not reduce the transmitted vibration to levels considered acceptable by NHO 10, they showed better performance while operating at velocity 1 and rotation 520 rpm of the rotary tiller rotor.

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