WORK PRECARIOUSNESS: ERGONOMIC RISKS TO OPERATORS OF MACHINES ADAPTED FOR FOREST HARVESTING[1]

Stanley Schettino[2*], Julio Cesar Costa Campos[3], Luciano José Minette[3] and Amaury Paulo de Souza[4]

[1] Received on 09.03.2016 accepted for publication on 26.09.2016.
[2] Universidade Federal de Minas Gerais, Instituto de Ciências Agrárias, Montes Claros, MG - Brasil. E-mail: <stanley.sst@hotmail.com>.
[3] Universidade Federal de Viçosa, Departamento de Engenharia de Produção e Mecânica, Viçosa, MG - Brasil. E-mail: <julio.campos@ufv.br> and <minette@ufv.br>.
[4] Universidade Federal de Viçosa, Departamento de Engenharia Florestal, Viçosa, MG - Brasil. E-mail: <amaury@ufv.br>.
*Corresponding author.

ABSTRACT – This study aimed to assess different types of machines adapted for mechanized forest harvesting activities in order to quantify the degree of compliance with ergonomic principles applicable to forest machines, as well as the ergonomic risks to which workers are exposed. The following machines were evaluated: a feller buncher adapted into a wheel loader; a mini skidder coupled to an agricultural tractor; and a forest loader adapted to an agricultural tractor; operating in the states of Paraná and Minas Gerais. Biomechanical working conditions were assessed by applying a *checklist* for simplified assessment of the workplace biomechanical conditions. The forced postures assessment was performed using the REBA - "*Rapid Entire Body Assessment*" method. In turn, ergonomic classification was through guidelines contained in the ergonomic classification manual "*Ergonomic Guidelines for Forest Machines*". Moreover, the environmental factors noise, temperature and vibration to which the operators of these machines were exposed were assessed. The results showed all assessed machines had ergonomic standards below those indicated in all assessed aspects, mainly related to access and dimensions of the workplace, need to adopt forced postures during working hours, and exposure to environmental factors assessed above tolerance limits. It is concluded that machines adapted for use in forest harvesting processes have shown significant gaps in relation to ergonomic aspects, presenting high and imminent risk of development of occupational diseases in their operators.

Keywords: Forest operations; Forest mechanization; Occupational health.

PRECARIZAÇÃO DO TRABALHO: RISCOS ERGONÔMICOS AOS OPERADORES DE MÁQUINAS ADAPTADAS PARA COLHEITA FLORESTAL

RESUMO – Este estudo teve como objetivo avaliar diferentes tipos de máquinas adaptadas para as atividades de colheita florestal mecanizada, de forma a quantificar o grau de atendimento aos princípios ergonômicos aplicáveis às máquinas florestais, bem como os riscos ergonômicos aos quais os trabalhadores estão expostos. Foram avaliadas as seguintes máquinas: um feller buncher adaptado em uma pá carregadeira de rodas; um mini skidder acoplado a um trator agrícola; e um carregador florestal adaptado a um trator agrícola; operando nos estados do Paraná e Minas Gerais. As condições biomecânicas do trabalho foram avaliadas através da aplicação de um ***check-list*** *para avaliação simplificada das condições biomecânicas do posto de trabalho. A avaliação das posturas forçadas foi realizada utilizando o método REBA – "****Rapid Entire Body Assessment****". Por sua vez, a classificação ergonômica foi através das diretrizes contidas no manual de classificação ergonômica "****Ergonomic Guidelines for Forest Machines****". Ainda, foram avaliados os fatores ambientais ruído, temperatura e vibração aos quais os operadores destas máquinas estavam expostos. Os resultados apontaram que todas as máquinas avaliadas apresentaram padrões ergonômicos abaixo dos indicados em todos os aspectos avaliados, principalmente relacionados ao acesso e dimensões do posto de trabalho,*

http://dx.doi.org/10.1590/1806-90882017000100009

necessidade de adoção de posturas forçadas durante a jornada de trabalho, e exposição aos fatores ambientais avaliados acima dos limites de tolerância. Conclui-se que as máquinas adaptadas para utilização em processos de colheita florestal tem apresentado importantes lacunas em relação aos aspectos ergonômicos, apresentando elevado e iminente risco de desenvolvimento de doenças ocupacionais em seus operadores.

Palavras-chave: Operações florestais; Mecanização florestal; Saúde ocupacional.

1. INTRODUCTION

With an area of 7.74 million hectares of reforestation (IBA, 2015), coupled with favorable climate and soils, the Brazilian forest sector has experienced constant development, leading to increasing demands for forest-based products. To meet this growing demand, in a scenario on which the labor is increasingly scarce, the competitiveness of the sector is growing and the demands of globalized consumer markets are increasing, mechanization of timber production activities has become imperative for forest business sustainability. The aim is to thereby minimize production costs, decrease dependency on labor, increase productivity, reduce rates of work accidents and damage to the environment, besides ensuring a continuous flow of timber supply to consumer units.

Among the various activities necessary for timber production, harvesting is the most economically important stage, due to its large representativeness in the product final cost composition, and along with the transport, it can reach up to 50% of costs of industry put timber (Machado and Lopes, 2000). Mechanization of forest harvesting in Brazil, in most cases, takes place from imported machinery and with high acquisition and maintenance costs, not always accessible to all companies and much less to small timber producers. These factors of financial order have led national mechanical industry to develop, adapt and test many machine models with different principles, whether from agricultural tractors or machines developed for civil construction, among others; and this has been the alternative found by small and medium sized forestry companies, as well as independent timber producers or producers linked to companies through forestry fomentation contracts for the mechanization of their timber harvesting activities.

According to Rozin et al. (2010), during the operation of these adapted machines the operator is exposed to environmental factors that directly influence their output, health and safety as, for example, body position to access cabins and in the workplace, position of commands and levers; climate conditions, such as extreme temperatures, solar radiation, humidity and ventilation problems; sound intensity level produced by the engine and or machine transmission; airborne particles such as dust and exhaust gases; seat vibration caused by the machine and by ground irregularities.

All these factors are contrary to the ergonomics basic principle, whichever it is of adapting the work to the human being (Iida, 1995). Moreover, according to the author, in an ideal situation the ergonomics must be applied from the early stages of machine design, environment or workplace. These should always include the human being as the main component. Thus, the operator characteristics should be considered in conjunction with the characteristics of mechanical or environmental parts to adapt to each other mutually, assumptions that in general have not been observed in the design of machines adapted for forest harvesting.

The objective of this study was to assess different types of machines adapted for mechanized forest harvesting activities in order to quantify the degree of compliance with ergonomic principles applicable to forest machines, as well as the ergonomic risks to which workers are exposed.

2. MATERIALS AND METHODS

2.1. Assessed machines

The methodology consisted of assessments of the following machines, with their respective adaptations:

Machine 1 - SEM brand Wheel Loader, model 616B, manufactured in China, adapted for tree felling using TMO brand felling head, model CD 350.

Machine 2 - Valtra brand Agricultural Tractor, model BM 110, 4x4 version, without cabin and with hood, manufactured in Brazil, adapted for tree extraction using Rotokran brand mini skidder, model MS-120.

Machine 3 - Valtra brand Agricultural Tractor, model BM 125i, 4x4 version, without cabin and without hood, manufactured in Brazil, adapted for timber loading using TMO brand forest loader, model C1070.

2.2. Characterization of study area and harvesting systems

This study was developed with data collected in forestry companies between December 2012 and October 2014, with machines operating in areas of *Eucalyptus* and *Pinus* timber harvesting, being one in the state of Minas Gerais and two in the state of Paraná, with the following characteristics:

Três Marias, MG: 18°12'21" south latitude, 45°14'31" west longitude. The region climate is classified as tropical with dry season (Aw), with average annual rainfall of 1,500 mm, ranging from 750 to 2,000 mm, average annual temperature of 24°C and mostly flat relief (Carvalho et al., 2005). In the study area forests are cultivated with *Eucalyptus* hybrid clones with productivities ranging from 140 to 240 m³/ha in first rotation regime and 3 x 2.5 meters spacing. Harvesting is performed through the full-tree system, on which, according to Malinovsky et al. (2014), the tree is felled and taken to the road side or intermediate courtyard, where it is processed in the form of short logs, with less than six meters long. In this area, machine 1 was assessed, and the cutting operation was performed in rows of two tree lines, always moving through the inter-row.

Jaguariaíva, PR: 24°14'34" south latitude, 49°41'04" west longitude. The predominant climate in the region is transitional between subtropical (Cfa) and temperate (Cfb), according to Köppen's classification, with average annual rainfall of 1,400 to 1,600 mm, average annual temperatures ranging from 19 and 20°C and an average altitude of 840 m (Goulart et al., 2015). In this area, forests are, in their totality, cultivated with *Pinus* in stands of productivities from 100 to 220 m³/ha in first rotation regime with 15 years of age, 3 x 3 meters spacing and relief ranging from soft wavy to wavy, and the mechanical harvesting operations are limited to 20º declivity. Harvesting is performed through the full-tree system, as already defined, with the fell being performed by a crawler and beams Harvester being formed by three trees each, on average. Machine 2 was assessed in this area, which performed the drag of trees to the road side, with a beam with three trees per cycle at an average distance of 120 meters.

Tibagi, PR: 24°33'11" south latitude, 50°27'22" west longitude, with temperate subtropical climate (Cfb), average annual temperature of 17ºC, average annual rainfall of 1,500 mm, average altitude of 750 m and soft wavy relief (Carmo et al., 2012). Harvesting is performed using the cut-to-length system on which, according to Malinovsky et al. (2014), the tree is felled, delimbed and sectioned still inside the patches and led to the side of the road or intermediate courtyard in the form of short logs, with less than six meters long. Machine 3 was assessed, performing the loading of trucks on the road side with *Pinus* short logs ranging from 2.4 to 4.0 meters long, according to products mix demanded by timber consumers.

2.3. Ergonomic assessments

For the assessment of work biomechanical conditions with machines, the checklist for simplified assessment of workplace biomechanical conditions proposed by Couto (2002) was used to assess the biomechanical factor in the risk for musculoskeletal disorders of the upper limbs related to work conditions. This structured questionnaire assesses physical overload, hand grip strength, working posture, repetitiveness and work organization and tools or working instruments of the operator. The instrument consists of 12 questions related to the work characteristics. For each question, there is a combination of YES or NO answers on which a score is obtained, interpreted according to Table 1.

In turn, to assess forced postures, often observed in the operation of the machines in the study, we used the REBA - "Rapid Entire Body Assessment" method (Hignett and Mcatammey, 2000), developed to estimate the risk of body disorders to which workers are exposed. The risk assessment is made from a systematic observation of work cycles, scoring trunk, neck, legs, load, arms, forearms and wrists postures in specific tables for each group. After the score of each group, final score is obtained which is compared with a table of risk and action levels in a scale ranging from 0 (zero), corresponding to the interval of acceptable movement

Table 1 – Score for the classification of work biomechanical conditions.
Tabela 1 – *Score para classificação das condições biomecânicas do trabalho.*

Score	Biomechanical condition
11 to 13	Excellent
8 to 10	Good
6 to 7	Reasonable
5 to 6	Bad
Less than 4	Very bad

Source: Couto (2002).

or working posture and that does not require improvements in the activity until value four (4), on which the risk factor is considered very high requiring immediate action.

2.4. Ergonomic classification

The various components of the machines were assessed quantitatively, based on methodologies proposed by Gellerstedt (2006) and ergonomic guidelines contained in the ergonomic classification manual "Ergonomic Guidelines for Forest Machines" (Skogforsk, 1999), and the following items were assessed: access to the cabin, controls and instruments, seat, cabin, cabin acclimatization, visibility, lighting, noise, vibration and exhaust gases and dust.

The assessed machines were classified, for each item and according to the ergonomic profile, in five classes from A (best ergonomic condition) to E (worst ergonomic condition), according to Table 2.

2.5. Environmental factors

To assess thermal environment Wet Bulb Globe Temperature Index (WBGTI) was used, as stated in Annex 3 of the Regulatory Standard N° 15 - NR 15, of the Ministry of Labor and Employment (Brasil, 1978). In the assessments the WBGT digital thermometer of Instrutherm brand model TGD 400 was used. The device was placed at the workplace, near the activities carried out by the workers and the readings were performed at 2-minute intervals for at least 60 minutes.

Occupational noise assessment was based on the technical criteria established in NR-15, Annex 1 (Brasil, 1978). The noise levels at the workplace were obtained using a 01dB of Brazil brand dosimeter, model Wed 007, operating in compensation circuit "A" and slow response circuit. Readings were performed with the instrument set near the operators ear and the results were shown as equivalent continuous sound level (Leq) for the working day.

For the assessment of occupational exposure to entire-body vibration the technical criteria established in NR-15, Annex 8 (Brasil, 2014) were used. Vibration measurements were made with an accelerometer 01dB of Brazil brand, model Maestro, according to technical procedures established by the 09 and 10 Occupational Hygiene Standards of Jorge Duprat Figueiredo Foundation for Occupational Safety and Medicine - FUNDACENTRO, and to results expressed in normalized exposure (Aren).

3. RESULTS

The results of the ergonomic assessments of the machines assessed in this study are shown in Table 3.

Access to the cabin is deficient in the three machines, because the distance between the ground and the first step is higher than the recommended limit, which is of 40.0 cm, and values 68.0 cm, 51.0 cm and 59.0 cm for machines 1, 2 and 3 respectively have been found. In addition, in the three machines, it is difficult

Table 2 – European ergonomic classification of forest machines according to principles of ergonomics, health and safety of operators.
Tabela 2 *– Classificação ergonômica europeia das máquinas florestais segundo princípios de ergonomia, saúde e segurança dos operadores.*

Ergonomic Classification	Description
A	It has high productivities throughout the year, in all types of land and forest conditions. High level of safety. Easy maintenance and safely performed.
B	It has high productivities, but only in better conditions than in the previous class (ex.: flat land, very high productivity forests and/or favorable climate conditions). Same level of safety, but on the other hand, in less high standards than in class A.
C	It has high productivities in less time, in better soil and forest conditions and/or in better climate conditions than in class B. Same level of safety, but on the other hand, in less high standards than in class B.
D	It hardly has high productivities, in any soil and forest condition and/ or climate conditions. It has low safety standards, with risk of injuries to the operator.
E	The machine does not meet the European safety regulations and/or has serious failures, capable of exposing the operator to imminent risks of injuries. The machine must not be used until the problems are corrected and it can be classified within the previous classes.

Source: Gellerstedt (2006).

Table 3 – Results of ergonomic classification and evaluation of the analyzed machines, and environmental factors evaluated.
Tabela 3 – *Resultados da classificação e avaliação ergonômica das máquinas analisadas, e dos fatores ambientais avaliados.*

Item	Machine 1	Machine 2	Machine 3
Access to cabin	C	C	D
Commands and instruments	C	C	C
Seat	D	D	D
Cabin	C	E	D
Cabin acclimatization	B	E	D
Visibility	C	C	C
Lighting	D	D	D
Noise	B	D	D
Vibration	B	D	D
Exaustion of gases and dust	B	E	D
GENERAL CLASSIFICATION[1/]	**C**	**D**	**D**
Biomechanical Condition[2/]	7	NC[3/]	NC[3/]
REBA	6	8	8
Environmental Factors			
Noise (LAeq) - dB(A)	81.2	90.3	88.7
WBGTI - ºC	29.5	27.7	28.6
Entire Body Vibration - Aren - m/s²	0.95	1.43	1.25

[1/] According to criteria established by Gellerstedt (2006).
[2/] Checklist for simplified assessment of biomechanical conditions of the workplace (Couto, 2002).
[3/] NC = Disqualified in the initial stage of the assessment, meaning VERY BAD ergonomic condition.

to maintain three supporting points during the ascent and descent from the machine. Machine 3 stands out negatively, due to difficulty of access to the loader cabin, using adapted ladder and platform on the rear tire of the machine.

Although all machines had a limited number of commands, it was found that in all three cases some of these were not within the optimal reach area, outside the normal reach radius by the operator, causing him to adopt incorrect working postures.

On the other hand, in the three machines, the seats do not allow many adjustment possibilities to suit operators of different statures and it is even more critical in the machines 2 and 3. In all assessed machines, the seat lumbar support is too low, and also there is no support for the arms and for the head of the operator. However, all of them were securely attached and had seat belts.

Machine 1 is the only one that has closed cabin. Still, the space inside it is reduced and the operator has difficulties switching the postures required during the working day. Machine 2 only has open hood and machine 3 is without hood, with only a small cabin for operation of forest loader, which does not allow the operator to adopt relatively comfortable working positions due to its reduced dimensions.

As the cabin of machine 1 is closed and acclimatized, problems related to noise, heat, or inhalation of gases and dust during operation were not identified. For machines 2 and 3, as there is no cabin, the operator stays permanently exposed to machine noise, environment and machine heat and with possibility of gases and dust inhalation during operation.

Regarding machine 1 visibility, its front windows (narrow but long) do not enable the operator to see the tree base (obstruction in the sight line caused by the head itself); its side and rear windows are large and give a satisfactory visibility for the operator when moving the machine down the field in any situation of land, forest or climate conditions. As for machines 2 and 3, the absence of windows gives a satisfactory visibility for the operator when moving the machine down the field in any situation of land and forest, however it is impaired in adverse climate conditions.

Due to lighting deficiencies (reduced quantity and positioning of headlights), none of the machines showed to be designed to work both during the day and night. In all cases, in the night work, the operator does not have full view of the top and base of the tree to be felled, the tree to be extracted or the log beam to be loaded, and the land view is also deficient, not allowing the operator to see possible obstacles in time.

The assessment of biomechanical conditions of the workplace of machine 1 showed the result 7, indicating it has reasonable biomechanical condition. The negative outstanding points were the working posture and the difficulty of access to commands, due to the small space inside the cabin and deficiencies in the seat of the operator, and also the lighting level is insufficient. Machines 2 and 3 were disqualified already in the initial stage of the assessment of biomechanical conditions of the workplace, indicating that they have very bad biomechanical condition. The disqualification points were the work with extreme postural deviation, the sitting position in poorly dimensioned seat associated with work with very forced trunk deviations, as well as high levels of noise and vibration.

When evaluating forced postures adopted by the operator, the result obtained after the application of REBA methodology was 6 for machine 1, indicating a medium risk of musculoskeletal injury to operators, as well as the need of actions to correct the deviations found; outstanding the need of the operator to laterally incline the trunk and excessively flex the neck for the visualization of the trees. For machines 2 and 3, the REBA score was 8, indicating a high risk of musculoskeletal injury to operators, as well as the brief need of actions to correct the deviations found; outstanding the need of the operator to permanently work with the trunk flexed to simultaneously control the machine direction and perform the task of extracting trees or handling short logs, in addition to the impacts that he receives in the spine due to the vibrations resulting from the operation and displacement of the machine.

Regarding environmental factors, in the days of sampling, the WBGT was lower than the limits imposed by NR-15 for all cases, indicating no thermal overload to operators of the assessed machines. In contrast, the assessment of noise showed that operators are exposed to high noise doses, and the value found for machine 1 was above the action limit stipulated by NR-15, and for machines 2 and 3, it was above the tolerance limit, according to the same regulation. Finally, the entire body vibration levels found for the three machines showed above the action level provided by legislation, indicating the possibility of injury risks to operators if actions are not taken to reduce them.

4. DISCUSSION

The assessed machines showed large ergonomic gaps in all assessed items, from the lack of cabin to the difficulty of access to workplaces, and in all cases these items showed problems with their dimensions, seats, adjustments, commands, visibility and thermal and acoustic comfort.

According to Fernandes et al. (2010), positioning and characteristics of the access roads to the machine operator station can often be a cause of accidents. The steps dimensions, the distance between them, the height of the first step to the ground and the vertical distance from the last step to the platform of the machine should be designed according to the anthropometric variables of machine operators. In addition, poorly designed access can also be an obstacle for older operators (Skogforsk, 1999). In fact, this seems to be a recurring problem in the forestry sector, according to the results found by Minette et al. (2008), by assessing 13 forest harvesting machines and conclude that all were with the access variables out of the indicated parameters.

The machines assessed in this study also showed deficiencies in controls and instruments, since their location must be designed so that the arms reach them within its normal action radius, without the operator needing to bend the back or move the body, thus avoiding greater fatigue and greater time in tasks execution (Barreto et al., 2013; Silva et al, 2014). Regarding the commands moved by legs, they can be of greater demand for strength, if the ideal position that permits the exact movement is observed (Merino et al., 2012). The issue of non compliance of controls and instruments in agricultural tractors was clearly approached by Rozin et al. (2010) who, by analyzing 35 operating stations of 101 models of national agricultural tractors, concluded that only 23.1% of those operating stations met the current regulations.

The seats of the assessed machines were considered poor in all cases, whether it was for the lack of support for the arms, dimensions, and especially the absence of height adjustments and, or, depth. When an operation can be performed by a person sitting, there should be a seat for this person, whose design, construction and dimensions are appropriate to him and to the task. There must be an inclination between the seat and the backrest higher than 90 degrees to force the trunk against the backrest, in order to make full use of the seat (Tewari and Dewangan, 2009). Still, according to Skogforsk (1999), the seat must have height, distance and length adjustment and support for the arms should be adjustable in height. Such variables of seat and support for the arms should be sized according to the anthropometric standards of workers of the region.

Another item that showed worrying results were the cabins, or workplaces in machines without cabin; and this had reduced dimensions in machine 1 and was nonexistent in machines 2 and 3. The correct sizing of the workplace must allow that inside the cabin there is sufficient space, so that the operator, regardless of his physical condition and weight, can adopt comfortable working positions. To avoid fatigue, the operator must be able to sit comfortably, adopting a correct posture, especially regarding the use of muscles and joints, avoiding twists, bendings and other uncomfortable movements (Skogforsk, 1999). The absence of cabins also potentiates other problems such as exposure to noise above the tolerance limits stipulated by the Brazilian legislation and to gas and dust, besides the possibility of insect or other predators attacks, and in these cases it is necessary the use of personal protective equipment by operators.

Work visibility was bad in the three machines, being affected by the feller head in machine 1, by the positioning of the implement in machine 2 and by the crane tower in machine 3. According to Minette et al. (2008), the above problems are common in relation to visibility and the ideal is that the forest harvesting machine operator has a clear sight of the operating area without the need to adopt incorrect working postures, which can cause tension in the muscles resulting initially in fatigue and pain, and in the medium and long term, in musculoskeletal disorders.

Given the above, machine 1 received the C overall classification, according to criteria established by Gellerstedt (2006), indicating that it is only able to have high productivities in better soil and forest conditions and, or, in better climate conditions, however with low safety levels and a high risk of developing disturbances for operators. Machines 2 and 3, in turn, received the D overall classification, following the same criteria, indicating that they will hardly have high productivities, whichever the soil and forests condition is and, or, the climate condition, as well as a high risk of accidents and damage the health of operators.

After the biomechanical conditions of the workplace were accessed, machine 1 had reasonable biomechanical condition, mainly due to the need of the operator to have to work with flexed trunk and neck in order to obtain better visibility of the trees to be felled. In contrast, machines 2 and 3 were disqualified in the initial stage of the assessment, indicative of their very bad ergonomic conditions, due to position and work with very flexed trunk and inadequate workplace, leading to forced postural deviations and exposure to environmental agents (noise and vibration). According to the results of this and other studies (Fontana and Seixas, 2007; Minette et al., 2008), the workplaces of forest machines, those conceptually forest and also the adapted ones, need ergonomic interventions to fit the biotype of Brazilian workers.

The analysis of forced positions (REBA method) corroborated with all previous results demonstrating that the assessed machines have important ergonomic deficiencies. During the development of their activities, the operators are obligated to adopt postures harmful to health, which can cause disturbances, pain and discomfort. The need to make inclination and rotation with trunk and neck, which leads to a pressure increase in intervertebral discs, was observed. According to Couto (2002), disorders of intervertebral discs are more serious and can cause very strong and extremely disabling pain, generating prolonged absences and often permanent disability.

Regarding the environmental factors assessed, noise deserves outstanding, and equivalent noise level values (LAeq) above the tolerable legal limits for machines 2 and 3 were found. According to Brazil (1978), the tolerance limit for continuous/intermittent noise is 85 dB (A) for daily exposure of eight hours. Differently, ergonomic guidelines for forest machines consider ergonomically great a value lower than 65 dB (A) for the machine turned on and lower than 80 dB (A) for the machine in operation (Skogforsk, 1999). In general, forest machines have noise levels above those permitted by Brazilian legislation (Minette et al., 2007), which can cause various side effects to the health of operators, such as tinnitus, increased blood pressure and heart rate, insomnia, stress and irritability, as well as NIHL – Noise-Induced Hearing Loss, characterized by reduced hearing acuity resulting from prolonged exposure and irreversibility (Aybek et al., 2010; Guedes et al., 2010). To avoid these problems, the use of personal protective equipment is of fundamental importance.

The vibration transmission to the operators above tolerable limits for all three machines assessed results in discomfort and efficiency loss, and may constitute a potential risk for them. According to Almeida et al. (2015), vibrations may trigger neurological, muscular or vascular disorders and osteo-articular lesions, in the case of vibrations transmitted to the hand-arm system and pathologies in the lumbar region, and injuries of the spine in the case of vibrations transmitted to the entire body.

5. CONCLUSIONS

· Machines adapted for use in forest harvesting have extremely deficient ergonomic standards in all aspects assessed.

· Machine 1 was classified as C, indicating that it has high productivities only in better soil and forest conditions and, or, in favorable climate conditions, with medium safety standard, with risk of damage to the health of operators.

· Machines 2 and 3 were classified as D, i.e. hardly have high productivities in any soil and forest condition and, or, climate conditions, with low safety standards and high risk of injuries to the operator.

· There is a large and imminent risk of occupational diseases development in the operators of these machines, besides the risk of accidents.

6. ACKNOWLEDGMENTS

This work was supported by Conselho Nacional de Desenvolvimento Científico e Tecnológico (CNPq).

7. REFERENCES

Almeida SF, Abrahão RF, Tereso MJA. Avaliação da exposição ocupacional à vibração de corpo inteiro em máquinas de colheita florestal. Cerne. 2015;21(1):1-8.

Aybek A, Kamer HA, Arslan S. Personal noise exposures of operators of agricultural tractors. Applied Ergonomics. 2010:41:274-81.

Barreto EA, Tereso MJA, Abrahão RF. Projeto de cabine de unidade mecânica de auxílio à colheita da cana-de-açúcar (unimac cana) com base na ergonomia. Ciência Rural. 2013;43(5):823-30.

Brasil. Portaria n.º 3.214, de 08 de junho de 1978 do Ministério do Trabalho e Emprego.. Atividades e operações insalubres, Anexo nº 1 - Ruído. Diário Oficial [da República Federativa do Brasil]. Brasília, 06 de jul. de 1978.

Brasil. Portaria n.º 1.297, de 13 de ago. de 2014 do Ministério do Trabalho e Emprego. Atividades e operações insalubres, Anexo nº 8 – Vibração. Diário Oficial [da República Federativa do Brasil] Brasília, 13 de ago. de 2014.

Carmo MRB, Andrade ALP, Santos GASD, Assis MA. Análise estrutural em relictos de cerrado no Parque Estadual do Guartelá, município de Tibagi, Estado do Paraná, Brasil. Ciência Florestal. 2012;22(3):505-17.

Carvalho DA, Oliveira Filho AT, Vilela EA, Curi N, van der Berg E. et al. Distribuição de espécies arbóreo-arbustivas ao longo de um gradiente de solos e topografia em um trecho de floresta ripária do Rio São Francisco em Três Marias, MG, Brasil. Revista Brasileira de Botânica. 2005;28(2):329-45.

Couto HA. Ergonomia aplicada ao trabalho em 18 lições. Belo Horizonte: Ergo; 2002. 202p.

Fernandes HC, Brito AB, Minette LJ, Santos NT, Rinaldi PCN. Avaliação ergonômica da cabine de um trator florestal. Revista Ceres. 2010;57(3):307-14.

Fontana G, Seixas F. Avaliação ergonômica do posto de trabalho de modelos de “Forwarder” e “Skidder”. Revista Árvore. 2007;31(1):71-81.

Gellerstedt S, editor. European ergonomic and safety guidelines for forest machines. Uppsala, Sweden: Swedish University of Agricultural Sciences; 2006. 101p.

Goulart AA, Passos E, Nucci JC. Fragmentação da vegetação de Cerrado, entre os Anos de 1984 e 2011 no Parque Estadual do Cerrado (Jaguariaíva-PR) e em sua Zona de Amortecimento. Revista Brasileira de Geografia Física. 2015;8(3):857-66.

Guedes IL, Minette LJ, Silva EP, Souza AP. Avaliação dos níveis de ruído e vibração na atividade de coveamento semimecanizado em região montanhosa. Engenharia na Agricultura. 2010;18(1):9-12.

Hignett S, Mcatammey L. Rapid entire body assessment: REBA. Applied Ergonomics. 2000;31:201-5.

Indústria Brasileira de Árvores - IBA. Relatório IBA 2015. São Paulo: Pöyry Consultoria em Gestão e Negócios; 2015. 64p.

Iida I. Ergonomia: projeto e produção. São Paulo: Edgar Blücher; 1995. 465p.

Machado CC, Lopes ES. Análise da influência do comprimento de toras de eucalipto na produtividade e custo da colheita e transporte florestal. Cerne. 2000;6(2):124-9.

Malinovski JR, Camargo CMS, Malinovski RA, Castro GP. Sistemas. In: Machado CC, editor. Colheita florestal. 3ª.ed. Viçosa, MG: Universidade Federal de Viçosa; 2014. p.178-205.

Merino GSAD, Teixiera CS, Schoenardie RP, Merino EAD, Gontijo LA. Usability in product design - the importance and need for systematic assessment models in product development – Usa-Design Model (U-D). Work. 2012;41(1):1045-52.

Minette LJ, Silva EP, Souza AP, Silva KR. Avaliação dos níveis de ruído, luz e calor em máquinas de colheita florestal. Revista Brasileira de Engenharia Agrícola Ambiental. 2007;11(6):664-7.

Minette LJ, Souza AP, Silva EP, Medeiros NM. Postos de trabalho e perfil de operadores de máquinas de colheita florestal. Revista Ceres. 2008;55(1):66-73.

Rozin D, Schlosser JF, Werner V, Perin GF, Santos PM. Conformidade dos comandos de operação de tratores agrícolas nacionais com a norma NBR ISO 4253. Revista Brasileira de Engenharia Agrícola Ambiental. 2010;14(9):1014-9.

Silva EP, Minette LJ, Sanches ALP, Souza AP, Silva FL, Mafra SCT. Prevalência de sintomas osteomusculares em operadores de máquina de colheita florestal. Revista Árvore. 2014;38(4):739-45.

The Forest Research Institute of Sweden - SKOGFORSK. Ergonomic guidelines for forest machines. Uppsala, Sweden: Swedish National Institute for Working Life; 1999. 86p.

Tewari VK, Dewangan KN. Effect of vibration isolators in reduction of work stress during field operation of hand tractor. Biosystems Engineering. 2009;103(2):146-58.