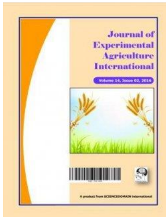


Journal of Experimental Agriculture International

29(2): 1-10, 2019; Article no.JEAI.45354
ISSN: 2457-0591
(Past name: American Journal of Experimental Agriculture, Past ISSN: 2231-0606)

Posture Analyses and Biomechanical Evaluation of Urban Pruning Activities

Valdirene Henrique Nunes[1], Flávio Cipriano de Assis do Carmo[1], Yasmim Yathiara Gomes Araújo Morais[2], Patrícia Carneiro Souto[1], Vinicius Staynne Gomes Ferreira[1], Hanne Alves Bakke[3], Pompeu Paes Guimarães[4] and Giselle Lemos Moreira[2*]

[1]Department of Forestry Engineering, Federal University of Campina Grande, Brazil.
[2]Department of Forestry Science, Federal Rural University of Pernambuco, Brazil.
[3]Federal Institute of Education, Science and Technology of Paraíba, Brazil.
[4]Departament of Agronomic and Forest Sciences, Federal Rural Semi-Arid University, Brazil.

Authors' contributions

This work was carried out in collaboration between all authors. Authors VHN and FCAC designed the study. Author VHN managed the analysis and wrote the protocol and wrote the first draft of the manuscript. All authors performed the corrections and reviewed the drafts of the manuscript, as well as, approved the final manuscript.

Article Information

DOI: 10.9734/JEAI/2019/45354
Editor(s):
(1) Dr. Aleksander Lisowski, Professor, Department Agricultural and Forestry Engineering, Warsaw University of Life Sciences, Poland.
Reviewers:
(1) Kai Moriguchi, Kyoto University, Japan.
(2) Lincoln Villi Gerke, State University of Western Paraná, Brazil.
(3) Murad Canakci, Akdeniz University, Turkey.
Complete Peer review History: http://www.sciencedomain.org/review-history/28044

Original Research Article

Received 25 September 2018
Accepted 06 December 2018
Published 01 January 2019

ABSTRACT

The pruning of urban trees is one of the practices used to adapt the projections of the branches to the inserted environment. The objective of this study was to analyze biomechanical factors such as posture and weight management in manual urban pruning activities in the city of Patos - Paraíba. The research was carried out with the employees responsible for the pruning activity of trees. For the posture analysis, the was use a photographic camera, followed by the movements and positions in each activity performed and then analyzed each shoot. The video was performed with the monitoring of the movements of the profile with the intention of observing the joints at the moment of

**Corresponding author: E-mail: celly_eng.florestal@hotmail.com;*

work. For the biomechanical analysis, we used the weighing of the tools used, using a precision scale. The results showed that the highest percentage of the postures adopted in urban pruning activities, was considered adequate according to the OWAS method, obtaining a higher percentage of classes 1 and 2. However, the drag activity was the only classified in the class that requires measures as soon as possible and that risk may occur in the spine, so that corrective measures are necessary to implement it. Among all the activities analyzed, the knee and ankle joints presented a percentage of compression, due to the worker maintaining the flexed legs most of the time.

Keywords: Urban afforestation; biomechanical factors; ergonomics.

1. INTRODUCTION

The ergonomics has as finality modify the working procedures according to the limitations and characteristics of each worker, so that it provides greater efficiency of operations, associate with greater comfort and safety [1]. Ergonomic assessments have immense influence on improving working conditions, directly affecting the quality of life of each worker, providing necessary subsidies for the success of the company or enterprise [2].

One of the variables studied in ergonomics is the biomechanics that is responsible for studying the interactions between the human being and the work [2,3]. Thus, the analyzes of posture at work provide subsidies to generate possible solutions that can be used to solve problems of production drops.

The pruning of urban trees is one of the practices which aims to adapt the projections of the trees to the place that is inserted. There are different types of pruning techniques, for example: pruning of formation that is used to direct the development of the crown according to the conditions of the planting site; pruning of maintenance that has as purpose to eliminate branches that can facilitate the occurrence of xylophages and; safety pruning that is performed to remove branches that could cause an accident.

The greatest worry in carrying out the activities urban pruning is related to the fact that the workers do not take an adequate position in the performance of their duties, which may result in damage to the health and safety of the employee. Due to exposure to certain periods with an inappropriate posture, the employee may develop pains and fatigue such as (lack of disposition, loss of productivity, slowness, fatigue, etc.) [4]. The control and the precaution of the pains caused by the posture exerted in the work, can be carried out through evaluations carried out in the working mode and in occupational risk factors, aiming to perform ergonomic procedures that intervene in an appropriate manner [5].

One of the major obstacles found in the analysis of inappropriate postures it's in fact that the identification and declarations are taken as a basis in the opinion of each worker, thus, resolving measures are taken when the employee is already in health [6]. Thus, the objective was to analyze biomechanical factors in the manual activities of urban pruning and propose improvements so that the activities can be developed with comfort, health and safety.

2. MATERIALS AND METHODS

The research was carried out with the employees responsible for the pruning activity of trees in the city of Patos, Paraíba carried out manually between February and June 2018.

The posture data were analyzed in 6 employees of the company responsible for performing urban pruning in the city according to approved methods at the Research Ethics Committee of the Integrated Faculties of Patos (CEP-FIP, CAAE: 84398318.7.0000.5181). The pruning activities, performed in a manual way, that were evaluated in this research are described as shown in Table 1.

For biomechanics analysis, the OWAS method was used in which the pruning activities were subdivided and filmed with the aid of a camcorder [7]. For the posture evaluation, the collected images were frozen at intervals of five seconds, thus verifying the postures adopted in each activity. The parameters used for the posture analysis according to the OWAS method are described in Table 2.

The daily work corresponded to 480 minutes, then we multiply the percentage obtained with the percentage of the total time (100% results in 480 minutes).

Table 1. Description of activities evaluated

Activities	Description	Activities	Description
	(1) Pruning with ladder - Activity performed with the purpose of eliminating the branches in the upper part of the canopy (above 2 meters in height) with the aid of stairs.		(4) Cleaning of waste - Cleaning of the area that was pruned, in order to remove remaining branches and leaves.
	(2) Loading - Activity carried out with the purpose of piling up waste from pruning into the truck's cargo compartment.		(5) Pruning without ladder - Activity performed to eliminate the branches in the lower part of the crown (up to 2 meters high).
	(3) Drag - Activity for the purpose of transporting the waste to the stacking place in the truck.		

Table 2. Determination of posture according to the OWAS method

Back	Arms	Legs	Weight or force required
(1) Erect	(1) Both below shoulder level	(1) Sitting, with legs below the level of the buttocks	(1) Load ≤ 10 kgf
(2) Curved	(2) Only one erect above shoulder level	(2) Standing, exerting force on both legs	(2) 10 kgf<P< 20 kgf
(3) Twisted	(3) Both erected above shoulder level	(3) Standing, exerting force on a single leg	(3) Load ≥ 20 kgf
(4) Curved and twisted		(4) Standing or lowered on both feet, with legs bent	
		(5) Standing or lowered with one foot and leg articulated	
		(6) Kneeling with one or both knees	
		(7) Walking or jogging	

Table 3. Action categories according to WinOWAS software

Categories	Actions
Class 1	No corrective action is required
Class 2	Corrections are needed in the near future
Class 3	Corrections are required as soon as possible
Class 4	Immediate corrections are required

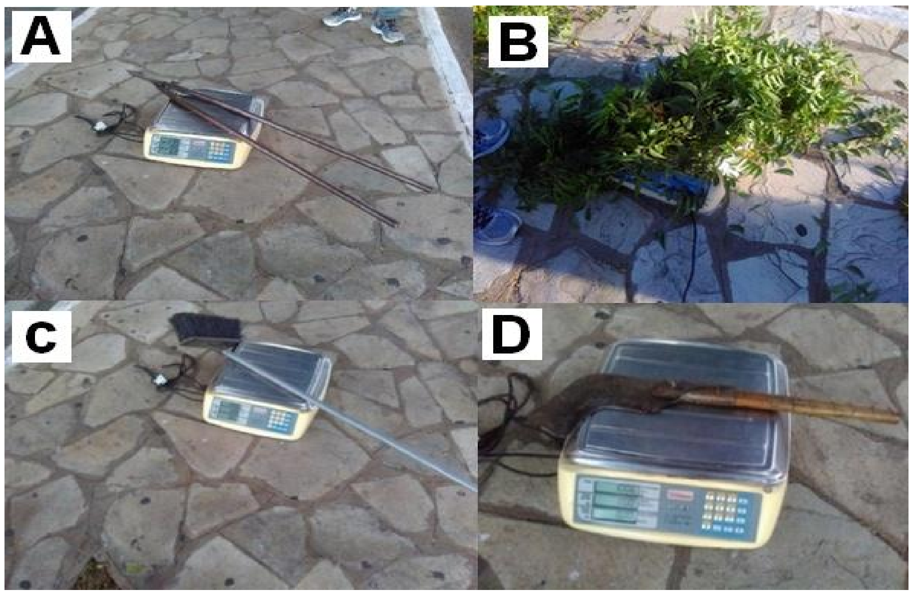


Fig. 1. Determination of tool weight and waste load used in urban pruning activities

In this method, after the coding of the postures, by means of Table 1, we obtain the categories of actions categories (Table 3).

For the biomechanical analysis, we first carried out the weighing of the tools used in the urban pruning activity, by means of a precision scale (0.1 gram), thus weighing the trimmer (Fig. 1A), the residues (Fig. 1B), the broom (Fig. 1C) and sickle (Fig. 1D).

Based on the values obtained through weighing, it was estimated, with the aid of software 3DSSPP (3D Static Strength Prediction Program) developed by the University of Michigan, USA, the force exerted on each articulation of the workers.

With the use of the software it was possible to collect biomechanical data through the force applied to the joints (elbow, wrists, trunk, shoulder, hips, knee and ankle) and the spine on the L5 - S1 discs (situated between the lumbar vertebra L5 and the sacral S1).

3. RESULTS AND DISCUSSION

3.1 Posture Analysis

By means of the analysis of the filming, the results of the postures adopted for urban pruning activity cycle were obtained, thus, it was possible to determine the standard postures and the percentage of each positioning found (Table 4).

It is verified that in the activity pruning with ladder, the postures 1/1/2/1 (back straight, both arms below shoulder level, standing, exerting force on both legs and load less than 10 kgf) and 1/1/3/1 (back straight, both arms below shoulder level, standing, exerting force on a single leg and load less than 10 kgf) appeared with a higher frequency totalizing 40.42% of all adopted postures. Thus, they were considered as the standard postures for this activity (Table 4).

In the cleaning activity of the pruning residues, carried out by means of a broom, obtained the standard postures 2/1/3/1 (bent, both arms below shoulder level, standing, exerting force on a single leg and load less than 10 kgf) representing a frequency of 36.36%, being the posture that was most repeated in this activity. For the drag activity, the standard posture was the 2/1/4/3 (curved, both arms below shoulder level, standing, or lowered on both feet, with legs bent and load less than 10 kgf) which represents about 83% of the total cycle.

Concerning the loading of urban pruning residues into the vehicle compartment, the posture 1/3/4/1 (back straight, both above the level of the shoulder standing, or lowered in both feet, with bent legs and loads less than 10 kgf) obtained a total of 33.33% of the repetitions, which resulted in a standard posture classification for the activity performed.

In the pruning without the aid of the ladder, the standard postures that presented a greater frequency were the 1/1/2/1 (back straight, both arms below shoulder level, standing, exerting force on both legs, load less than 10 kgf) and 2/3/2/1 (curved, both above shoulder level,

Table 4. Repetition, percentage, hourly load and share class by registered position

Posture	Repetition	%	T**(min)	Class	Posture	Repetition	%	T**(min)	Class
(1) Pruning with ladder									
1/1/2/1*	19	20.21	97.02	1	2/2/4/1	4	4.26	20.43	3
1/1/3/1	19	20.21	97.02	1	2/3/2/1	5	5.32	25.53	2
1/2/2/1	2	2.13	10.21	1	2/3/3/1	1	1.06	5.11	3
1/2/3/1	2	2.13	10.21	1	2/3/4/1	4	4.26	20.43	3
1/2/4/1	1	1.06	5.11	2	3/1/3/1	1	1.06	5.11	1
1/3/2/1	9	9.57	45.96	1	3/1/4/1	1	1.06	5.11	3
1/3/3/1	4	4.26	20.43	1	3/2/3/1	1	1.06	5.11	1
2/1/2/1	4	4.26	20.43	2	3/3/4/1	1	1.06	5.11	4
2/1/3/1	2	2.13	10.21	2	4/1/3/1	3	3.19	15.32	2
2/1/4/1	8	8.51	40.85	3	4/3/3/1	2	2.13	10.21	3
2/2/3/1	1	1.06	5.11	3	**Total**	**94**	**100.00**	**480.00**	
(2) Cleaning of Waste									
1/1/3/1	2	18.18	87.27	1	4/1/2/1	1	9.09	43.64	2
1/1/4/1	2	18.18	87.27	2	4/1/3/1	2	18.18	87.27	2
2/1/3/1	4	36.36	174.55	2	**Total**	**11**	**100.00**	**480.00**	
(3) Drag									
1/1/2/3	1	8.33	40.00	1	2/1/4/3	10	83.33	400.00	
2/1/2/3	1	8.33	40.00	1	**Total**	**12**	**100.00**	**480.00**	
(4) Loading									
1/1/2/1	1	6.67	32.00	1	2/1/4/1	1	6.67	32.00	3
1/2/3/1	1	6.67	32.00	1	2/1/4/2	1	6.67	32.00	3
1/3/4/1	5	33.33	160.00	2	2/3/3/1	2	13.33	64.00	3
2/1/3/1	2	13.33	64.00	2	2/3/3/2	2	13.33	64.00	3
					Total	**15**	**100.00**	**480.00**	
(5) Pruning without ladder									
1/1/2/1	41	20.00	96.00	1	2/3/2/1	36	17.56	84.29	2
1/1/3/1	5	2.44	11.71	1	2/3/3/1	4	1.95	9.37	3
1/1/4/1	4	1.95	9.37	2	2/3/4/1	3	1.46	7.02	3
1/2/2/1	6	2.93	14.05	1	3/1/2/1	5	2.44	11.71	1
1/2/3/1	5	2.44	11.71	1	3/1/3/1	2	0.98	4.68	1
1/3/2/1	24	11.71	56.20	1	3/2/2/1	3	1.46	7.02	1
1/3/3/1	13	6.34	30.44	1	3/3/2/1	1	0.49	2.34	1
1/3/4/1	2	0.98	4.68	2	3/3/3/1	2	0.98	4.68	2
2/1/2/1	20	9.76	46.83	2	4/1/2/1	2	0.98	4.68	2
2/1/3/1	13	6.34	30.44	2	4/1/3/1	1	0.49	2.34	2
2/1/4/1	3	1.46	7.02	3	4/2/4/1	1	0.49	2.34	4
2/2/2/1	3	1.46	7.02	2	4/3/2/1	2	0.98	4.68	2
2/2/3/1	4	1.95	9.37	3	**Total**	**205**	**100.00**	**480.00**	

**1/1/2/1: back straight, both arms below shoulder level, standing, exerting force on both legs and load less than 10 kgf; **Time being the estimated posture in each activity* standing, exerting force on both legs, load less than 10 kgf) corresponding to 20% and 17.56% of the total activity.

With the attainment of the standard postures it was possible to classify categories of actions according to the OWAS method (Table 5).

It is verified that in the activity of pruning without ladder the most adopted positions belong to class 1, so that corrective measures are not necessary (Table 5). Regarding the waste cleaning activity, the standard posture belongs to class 2, which infers in a need of correction in the near future, the drag obtained classification 3, which indicates the need to make corrections as soon as possible.

Most activities require a reworking of the operational execution method (Table 5). For this an alternative that can be adopted, would be to conduct adequate training with employees so that they are able to perform all urban pruning activities. From this training the company can adopt a system of rotation between the employees which provides a reduction of exposure to the most critical positions.

In addition, for the drag activity that achieved the worst results, should be guiding employees to divide the loads so that they can handle load lighter, which results in lower energy expenditure and lower pressures on the joints. The percentages of each class according to the OWAS method by specific activity are described in (Table 6).

The postures corresponding to classes 1 and 2 were the most representative in all activities, and class 4 which has a smaller percentage in all analyzed activities (Table 6).

3.2 Biomechanical Analysis 3DSSPP

The results of biomechanics obtained through software 3DSSPP in each specific activity are described in Tables 7 to 11.

In the pruning activity with the aid of a ladder there is no risk of injury to the disc L5-S1, The sacro-lumbar joint (L5 e S1) corresponds to the equilibrium point of the human body, thus, asymmetrical problems in the hip commonly result in problems throughout the body [8]. However, the knee and ankle joints require greater attention because they have a high compression content in these joints.

All workers are able to perform the activity without risk to the elbow and shoulder, however, more than half of the employees may be at risk to the knee when performing the activity with this posture (Table 7). Therefore, it is recommended a reorganization of work, such as the use of a lifting platform, so that it does not require the use of a ladder.

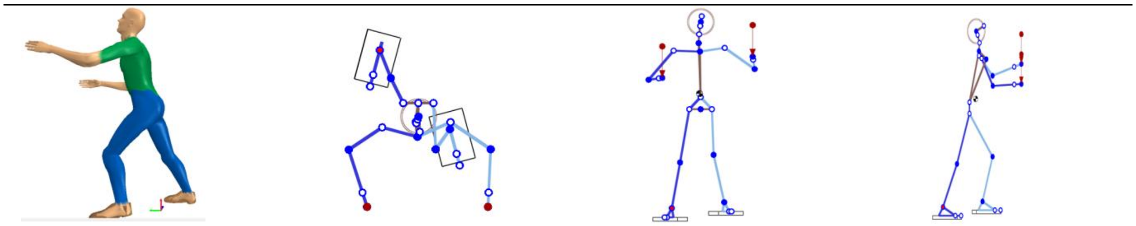
Table 5. Standard postures in each urban pruning activity and their respective categories according to the OWAS model

Activities	Default position	Category of action
(1) Pruning with ladder	1/1/2/1 1/1/3/1	Class 1 - No corrective action is required
(2) Waste cleaning	2/1/3/1	Class 2 - Corrections are required in the near future
(3) Drag	2/1/4/3	Class 3 - Corrections are required as soon as possible
(4) Loading	1/3/4/1	Class 2 - Corrections are required in the near future
(5) Pruning without ladder	1/1/2/1 2/3/2/1	Class 1 - No corrective action is required Class 2 - Corrections are required in the near future

Table 6. Total values as a percentage of each class in its specific activities

Activitie	Class 1 (%)	Class 2 (%)	Class 3 (%)	Class 4 (%)
(1) Pruning with ladder	60.63	15.96	22.34	1.06
(2) Cleaning of Waste	18.18	81.81	0	0
(3) Drag	16.66	83.33	0	0
(4) Loading	13.34	46.66	40	0
(5) Pruning without ladder	51.23	41.48	6.82	0.49

Table 7. Biomechanical analysis of pruning activity with ladder



Articulation	%*	Compression force on the vertebral disc, disc L5-S1 (N)	Risk of injury to the disc L5-S1
Pulse	99	1975.00	No Risk of Injury
Elbow	100		
Shoulder	100		
Dorse	97		
Coxofemoral	93		
Knee	49		
Ankle	70		

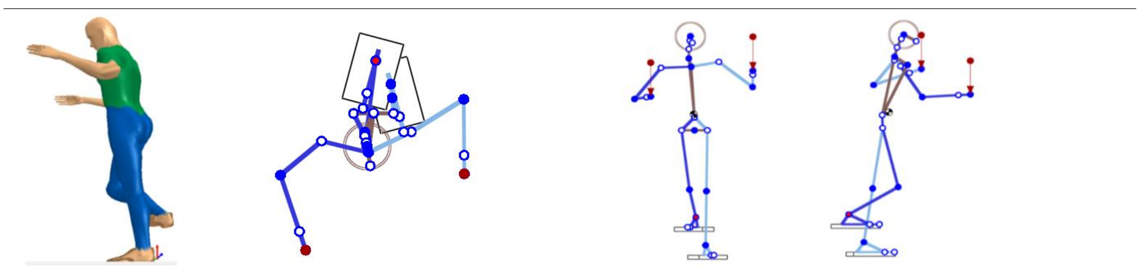
*Weight of pruning shears (21.80 N); *percentage of capable*

The evaluating the biomechanical of workers performing as manual and semi-mechanized pruning activities of *Pinus taeda*, [9] found that the activity performed is not at risk of injury, However, manual pruning exerts a higher pressure on the spine than semi-mechanized pruning, this occurs, this because the activity requires the worker to stay longer with arms raised and with tools more distant from the body.

In the activity of cleaning of residues (Table 8), the joints in which it occurs a greater compression are knee and ankle. This is because workers need to slightly flex the legs to sweep the area, however without causing risks joints of employees.

For the drag activity (Table 9), there is a risk of lesion on the L5-S1 disc, besides the joints suffer a greater compression force, this is due to the fact that the worker needs to handle loads with high weight, which causes a greater physical effort to drag the branches to the loading vehicle (Table 9). In this way the subdivision of load is recommended in order to reduce the weight of the load and consequently the reduction of physical effort and the reduction of the risks the articulations of the employees.

Table 8. Biomechanical analysis of the residue cleaning activity



Articulation	%*	Compression force on the vertebral disc, disc L5-S1 (N)	Risk of injury to the disc L5-S1
Pulse	99	1442.00	No risk of injury
Elbow	100		
Shoulder	100		
Dorse	99		
Coxofemoral	88		
Knee	87		
Ankle	83		

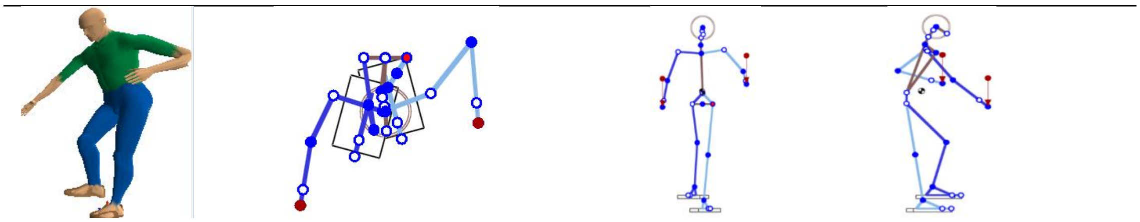
*Broom weight (9.06 N). *Percentage of capable*

The typical posture adopted that provides a risk of disc compression L5-S1 of the spine occurred in the drag activity because it obtained a value of 3.534 N, which is higher than the value of 3,426.3 N which is the maximum limit recommended by the software, so that there is no risk of injury. This fact proves the need to reduce the load to be handled by the employee.

In loading as well as other activities (Table 10), the joints that suffer greater compression force are ankle and knee, this is because the worker needs to propel the leg to deposit the branches in the truck's cargo compartment. It is worth noting that activities that require overloading can cause health damage, such as: inflammations in the joints, muscle breakdowns, muscle injuries etc. thus interfering with the company's income [10].

For pruning performed without the aid of the ladder (Table 11), the joints that suffer a greater compression were elbow, ankle, knee and shoulder. This is due to the need for the worker to raise his arms and propel the legs to perform pruning on the higher branches. The study the analysis of physical work load and biomechanics in the construction of roofs with wood structure, [11] found that there is risk in the joints, especially for the coxofemoral, followed for ankle, dorse and knee.

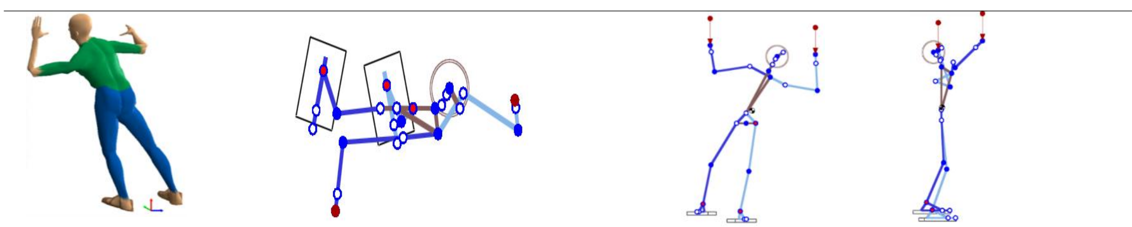
Table 9. Biomechanical analysis of the drag activity



Articulation	%*	Compression force on the vertebral disc, disc L5-S1 (N)	Risk of injury to the disc L5-S1
Pulse	59	3534.00	Risk of injury
Elbow	98		
Shoulder	61		
Dorse	71		
Coxofemoral	74		
Knee	50		
Ankle	41		

*Average weight of the branches (250 N); *Percentage of capable*

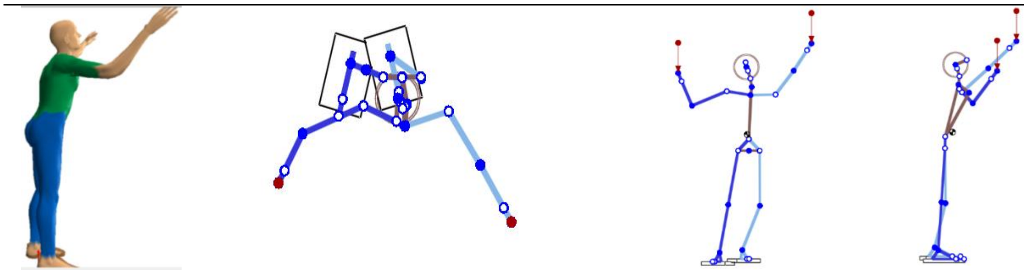
Table 10. Biomechanical analysis of loading activity



Articulation	%*	Compression force on the vertebral disc, disc L5-S1 (N)	Risk of injury to the disc L5-S1
Pulse	98	1300.00	No risk of injury
Elbow	96		
Shoulder	100		
Dorse	98		
Coxofemoral	98		
Knee	94		
Ankle	93		

*Average weight of the waste load (30 N); *Percentage of capable*

Table 11. Biomechanical analysis of pruning activity without ladders



Articulation	%*	Compression force on the vertebral disc, disc L5-S1 (N)	Risk of injury to the disc L5-S1
Pulse	98	978.00	No risk of injury
Elbow	90		
Shoulder	93		
Dorse	100		
Coxofemoral	94		
Knee	91		
Ankle	90		

*Weight of pruning shears (21.80 N); *Percentage of capable*

Regarding the values obtained, it is important to analyze that in the pruning activity without ladder the risk of compression was 978 N and with the aid of the ladder the value found was 1975 N, thus, the activity generated with compression in the spine much larger than in the activity without ladder. This fact can be explained by the position adopted by the worker, which requires it to make a greater effort on the joints to obtain greater stability in the body to perform the activity.

4. CONCLUSION

With the results of posture and biomechanics obtained in this research it can be concluded:

The highest concentration of the postures adopted in the urban pruning activity was considered adequate according to the OWAS method and without risk of injury by the 3DSSPP method.

The drag activity was the only one classified in class 3 by the OWAS method, in which corrective measures are necessary as soon as possible and classified as activity with risk of spine injury according to 3DSSPP software, in this way the subdivision of load is recommended so as to reduce the weight of the load and consequently the reduction of physical effort and the reduction of risks to the joints of the employees.

In the pruning activity with ladder it was observed the occurrence of a higher compression in the spine than in the activity of pruning without ladder. In all activities analyzed, the knee and ankle joints presented a percentage of compression.

ETHICAL APPROVAL

All authors hereby declare that all experiments have been examined and approved by the appropriate ethics committee (Research Ethics Committee of the Integrated Faculties of Patos) and have therefore been performed in accordance with the ethical standards laid down in the 1964 Declaration of Helsinki.

COMPETING INTERESTS

Authors have declared that no competing interests exist.

REFERENCES

1. ABERGO – Associação Brasileira de Ergonomia. A certificação do ergonomista brasileiro. Editorial do Boletim 1; 2000. Portuguese
2. Alves JU, Souza AP, Minette LJ, Gomes JM, Silva KR, Marçal MA, Silva EP. Avaliação biomecânica de atividades de produção de mudas de *Eucalyptus ssp*. Revista Árvore. 2006;30(3):331-335. Portuguese Available:http://dx.doi.org/10.1590/S0100-67622006000300002
3. Iida I. Ergonomia: Projeto e produção. São Paulo: Edgard Blücher; 2005. Portuguese

4. Iida I, Guimarães LBM. Ergonomia: Projeto e produção. 3rd Ed. São Paulo: Edgard Blücher. 2016;850. Portuguese
5. Gandaseca S, Yoshimura T, Yamamoto T, Mylyono S. A biomechanical analysis of industrial forest plantation workers in East Kalimantan. Journal Forest Research. 1998;3(2):75-78. Available:https://doi.org/10.1007/BF02760305
6. Silva WG. Análise ergonômica do posto de trabalho do armador de ferro da construção civil. UFSC, Universidade Federal de Santa Catarina. Dissertação de Mestrado em Engenharia de Produção. 2001;100. Portuguese
7. OWAS. Manual Ovako working analysing system. Helsinki, Finnish Institute of Occupational Health; 1990.
8. Meldau DC. Lombociatalgia. In: Info Escola; 2011. Portuguese Available:https://www.infoescola.com/doencas/lombociatalgia/
9. Lopes ES, Oliveira FM, Malinovski JR, Silva RH. Avaliação biomecânica de trabalhadores de poda manual e semimecanizada de *Pinus taeda*. Revista Floresta. 2013;43(1):9-18. Portuguese Available:http://dx.doi.org/10.5380/rf.v43i1.26953
10. Couto HA. Ergonomia aplicada ao trabalho: O manual técnico da máquina humana. Belo Horizonte: Ergo Editora. 1995;1(2). Portuguese
11. Maziero R, Fiedler NC, Segundinho PGA, Carmo FCA. Análise de carga física de trabalho e biomecânica na construção de telhados com estruturas de madeira. Floresta e Ambiente. 2018;25(1):e00072114. Portuguese Available:http://dx.doi.org/10.1590/2179-8087.072114

Peer-review history:
The peer review history for this paper can be accessed here:
http://www.sciencedomain.org/review-history/28044