

Original Research Article

Posture Analyses and Biomechanical Evaluation of Urban Pruning Activities

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, there 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 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

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

37 occupational risk factors, aiming to perform ergonomic procedures that intervene in an appropriate
38 manner [5].

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

44

45 2. MATERIAL AND METHODS

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

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

53 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.		

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.

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) $10 \text{ kgf} < P < 20 \text{ Kgf}$
(3) Twisted	(3) Both erected above shoulder level	(3) Standing, exerting force on a single leg	(3) Load $\geq 20 \text{ Kgf}$
(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	

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

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

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, thus weighing the trimmer (Figure 1A), the residues (Figure 1B), the broom (Figure 1C) and sickle (Figure 1D).



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

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).

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

⁽¹⁾ Pruning with ladder									
Posture	Repetition	%	T*(min)	Class	Posture	Repetition	%	T*(min)	Class
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	

89 *Time being the estimated posture in each activity

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

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

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

105 In the pruning without the aid of the ladder, the standard postures that presented a greater frequency
106 were the 1/1/2/1 (back straight, both arms below shoulder level, standing, exerting force on both legs,
107 load less than 10 kg) and 2/3/2/1 (curved, both above shoulder level, standing, exerting force on both
108 legs, load less than 10 kg) corresponding to 20% and 17.56% of the total activity.

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

111 **Table 5. Standard postures in each urban pruning activity and their respective categories**
112 **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) Loadig	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

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).

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

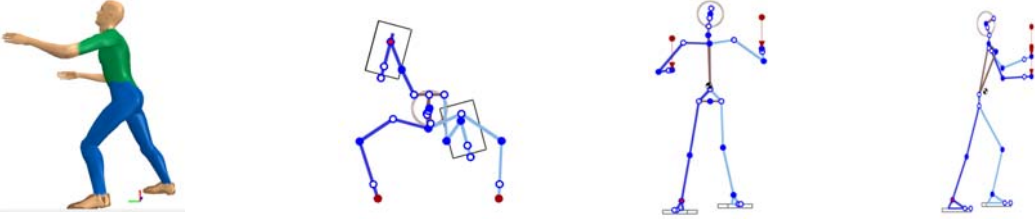
Activitie	Class 1 (%)	Class 2 (%)	Class 3 (%)	Class 4 (%)
(1) Pruning with ladder	60.63	15.96	22.34	1.06
(2) Cleaning of Waste	18.18	81.81	0	0
(3) Drag	16.66	83.33	0	0
(4) Loading	13.34	46.66	40	0
(5) Pruning without ladder	51.23	41.48	6.82	0.49

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 below.

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	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

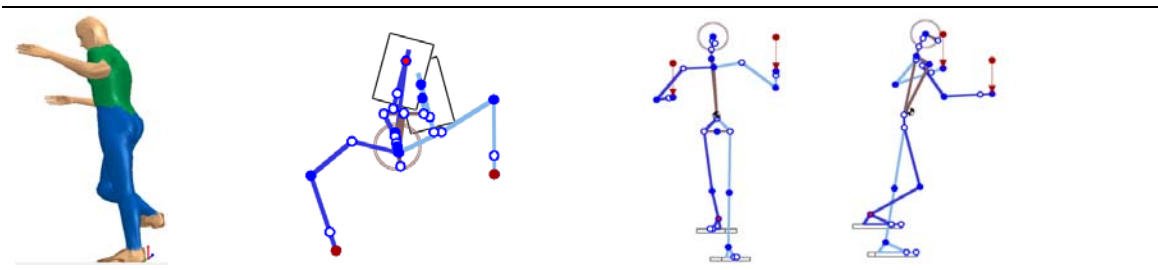
In the pruning activity with the aid of a ladder there is no risk of injury to the disc L5-S1, The sacro-lumbar joint (L5 e S1) corresponds to the equilibrium point of the human body, thus, asymmetrical problems in the hip commonly result in problems throughout the body [8]. However, the knee and ankle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

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.

Table 8 – Biomechanical analysis of the residue cleaning activity



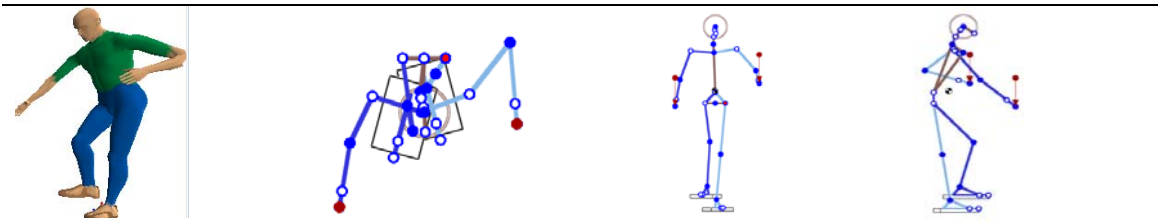
Articulation	%*	Compression force on the vertebral disc, disc L5-S1 (N)	Risk of injury to the disc L5-S1
Pulse	99		
Elbow	100		
Shoulder	100		
Dorse	99	1442	No risk of injury
Coxofemoral	88		
Knee	87		
Ankle	83		

Broom weight (9.06 N). *Percentage of capable

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.

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.

Table 9 – Biomechanical analysis of the drag activity

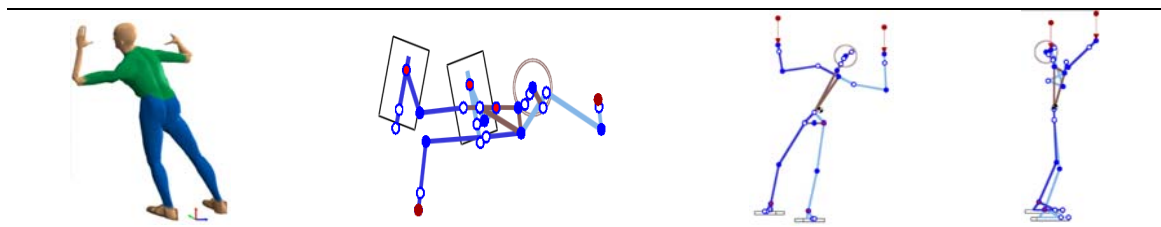


Articulation	%*	Compression force on the vertebral disc, disc L5-S1 (N)	Risk of injury to the disc L5-S1
Pulse	59	3534	Risk of injury
Elbow	98		
Shoulder	61		
Dorse	71		
Coxofemoral	74		
Knee	50		
Ankle	41		

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

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

172 **Table 10 - Biomechanical analysis of loading activity**



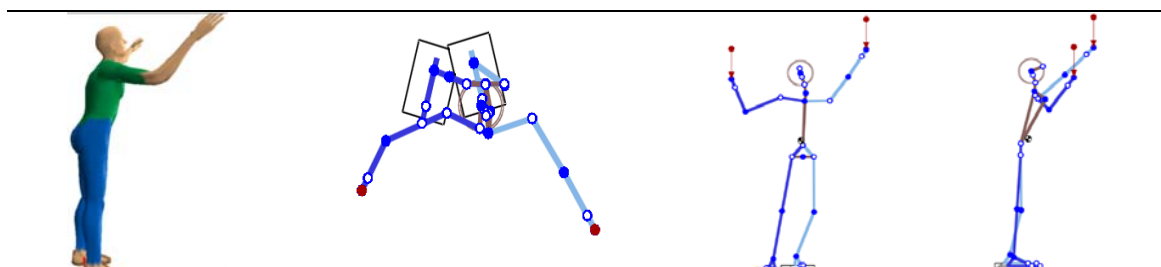
Articulation	%*	Compression force on the vertebral disc, disc L5-S1 (N)	Risk of injury to the disc L5-S1
Pulse	98	1300	No risk of injury
Elbow	96		
Shoulder	100		
Dorse	98		
Coxofemoral	98		
Knee	94		
Ankle	93		

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

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

179

180 **Table 11 – Biomechanical analysis of pruning activity without ladders**



Articulation	%*	Compression force on the vertebral	Risk of injury to the
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		disc, disc L5-S1 (N)	disc L5-S1
Pulse	98		
Elbow	90		
Shoulder	93		
Dorse	100	978	No risk of injury
Coxofemoral	94		
Knee	91		
Ankle	90		

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

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

187 4. CONCLUSION

188

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

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

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

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

200

201 ETHICAL APPROVAL

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

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