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EFFECT OF THE USE OF A PROTOTYPE SUPPORT FOR HYDRAULIC PRUNING MOTORCYCLE: PRELIMINARY DATA FROM KINETIC AND KINEMATIC VARIABLES IN A LIVE LINE ELECTRICIAN (ELV)

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Abstract

The study examines the activities performed by Live Line Operators (LLE), highlighting the importance of biomechanics and ergonomics in understanding the risks associated with their work. Several previous studies have examined the causes of musculoskeletal injuries in different work contexts, highlighting the prevalence of manual labor in certain industries, such as iron foundries in India. In addition, the research explores shoulder muscle loading in linemen, comparing the use of ladders with elevated mobile work platforms.

However, there is a gap in the literature on the daily activities of LLEs, especially regarding the behavior of the lower limbs during their tasks. To fill this gap, the study investigated the behavior of the lower limbs of a LLE during vegetation pruning, using a prototype hydraulic power pruner support. The experiment, conducted in a controlled laboratory environment, analyzed kinematic and kinetic variables.

The results indicated that the support had a significant impact on the stability of the center of mass (CoM) displacement of the LLE, particularly in the medial lateral axis. Furthermore, ground reaction forces (GRFs) showed less variability when the support was used, suggesting less physical strain on the ELV under these conditions. The research highlights the importance of considering biomechanical and ergonomic factors when designing supports and equipment to improve the working conditions of ELVs.

Keywords: Live Line Electrician; 2. Biomechanics; 3. Ergonomics.

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1. INTRODUCTION

Many studies involving the areas of biomechanics and ergonomics aim to verify the causes of injuries and/or pain caused by physical overload and/or repetitive movements (Błaszczyk & Ogurkowska, 2022; Liu et al., 2022; Skovlund et al., 2022). Predominantly manual work has been the focus of other studies, in the example of the research carried out by (Kataria et al., 2022) reinforce the idea that in developing countries, many companies lack modern equipment and often rely heavily on manual labor. Therefore, their aim was to investigate the exposure of work-related musculoskeletal injuries among employees in iron foundries in northern India. The results suggest that factors such as manual labor demands, poor workstation structure, repetitive actions, and inadequate postures maintained for a long time may probably be associated with the severity of the risk of musculoskeletal injuries. The aforementioned study can guide foundry manufacturers in analyzing the mismatch between the work profiles of workers and in redesigning the *layouts* of workstations in small-scale foundries based on minimizing the severity of the risks associated with the tasks performed by employees. To check the shoulder muscle load in workers using ladders or Elevated Mobile Work Platforms (Phelan & O'Sullivan, 2014) they evaluated experienced electricians on a construction site and found that workers spent approximately 28% of their working time on stairs versus 6% on platforms. However, the durations of individual tasks were longer on platforms (153 s) than on ladders (73 s). The results in the electromyographic activity showed that on the platform the task had a significant effect ($p < 0.05$) on the anterior deltoid and upper trapezius. For the deltoid, the peak amplitudes were, on average, higher for ladder work than platform work. The overall implication was that working on platforms involves lower shoulder muscle load when compared to work performed on stairs.

Few studies have aimed to verify the performance of Live Line Electricians (ELV) performing their daily activities, some examples of these studies were those carried out by (Bento da Silva et al., 2020; Bento da Silva et al., 2021; Traldi De Lima et al., 2020), who focused their efforts on analyzing the activities that were most physically and mentally demanding, specifically by ELVs.

Exploring the databases of scientific works, it is noted that this subject is still little studied and thus it is necessary that there are more studies that involve biomechanics and ergonomics acting to understand the human activity of the ELV, aiming to understand these activities in a systemic way, involving all the processes of the activity.

Thus, the **objective** of the present study was to verify the behavior of the lower limbs of the ELV without the use of a support prototype and with the use of the support prototype for hydraulic pruning during vegetation pruning from kinematic and kinetic variables.

2. METHODOLOGY

One (01) experienced ELV, male, 38 years old, right-handed, who has been working for 6 years directly in the field with a live line and is hired by the energy concessionaire that was the focus of the study, participated in the study. The Electrician signed the Informed Consent Form and this study was approved by the Research Ethics Committee of UNICAMP – State University of Campinas, CAAE: 33462920.3.0000.5404. Opinion number: 4.151.017.

Because it is a risky job, collection in a real environment is not feasible, so with the help of an experienced electrician, a structure ("tree") was built on a pole with a crosshead using wooden handles and screws, inside the biomechanics laboratory, aiming to simulate as faithfully as possible the structure of the branches to be pruned. The two upper branches were positioned 85 cm from the wall and the lower ones 65 cm, according to the diagram shown in figure 1.

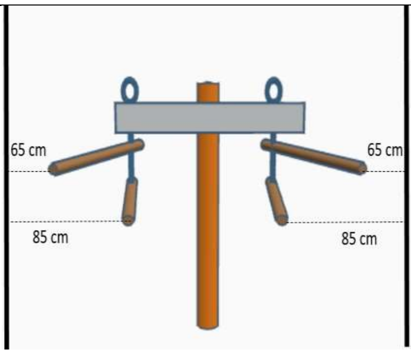

Figure 1. Structure assembled in the laboratory to be used in the simulation of vegetation pruning activity.

The collection was divided into two different days, the ELV was instructed to carry out the movement in the way that was closest to their daily work reality, starting with the cut at the bottom of the branch and ending at the top of the branch. On the second day of collection, the ELV simulated the activity of pruning vegetation similar to the first collection, however, on this occasion it made the movements with the help of the prototype of a support to support the hydraulic saw (figure 2b). On both days, the ELV was positioned on two force platforms to obtain the ground reaction force (FRS) data. The platforms were connected and synchronized to the *Optitrack* system through *eSync* (figure 2a).

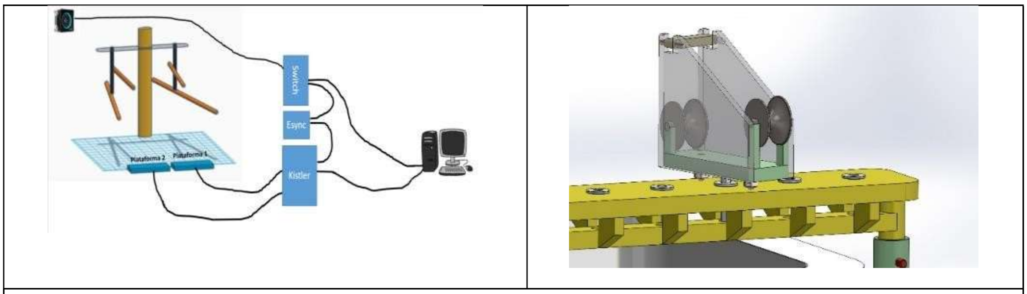

Figure 2: a) Schematically, synchronization procedure of the *motion capture* system and force platforms; b) Prototype of support for hydraulic pruning.

When performing the vegetation pruning operation with hydraulic motor, the ELV begins by cutting the smaller branches and in stages, "dividing" the branch into proximal and distal cutting zones, duly identified with cardboard markings, zones: (Left side of the ELV: E1; E2; E3; E4 and E5. Right side: D1; D2; D3; D4 and D5, each cutting zone measures 15cm and for the present study the ELV performed the operation in zones E3 and D3.

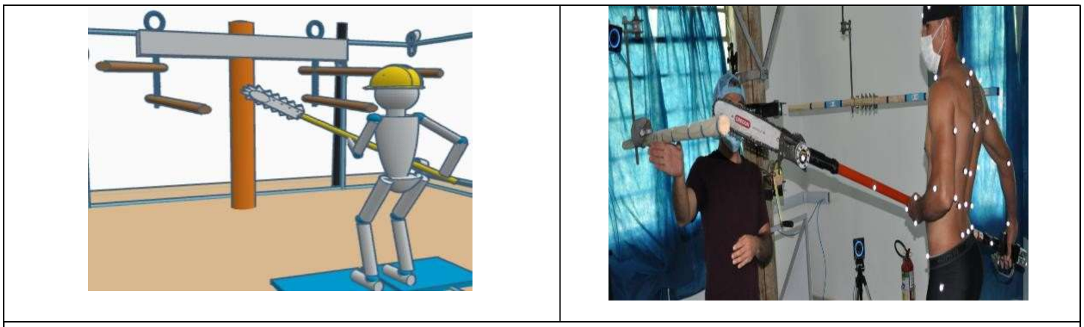

Figure 3: a) Scheme of how the ELV positioned itself at the time of data collection between the left and right "branches"; b) ELV positioned before the start of collection.

During the collection, the ELV used a hydraulic pruning, Greenlee® of approximately 4 kg in mass and 1.9 m in length and was instructed to perform 11 series of complete movements that consisted of simulating the vegetation pruning movements by touching the branches from bottom to top and from top to bottom in 10 predetermined zones (15 cm) along the branch.

For the collection of kinematic data, the *motion capture* system (Optitrack) was used, with 12 17W prime cameras, which were adjusted to an acquisition frequency of 200 Hz, in order to frame the entire capture area. The whole-body model used was proposed by (Leardini et al., 2011) for the orientations of the upper limbs (Wu et al., 2005) and lower limbs (Wu et al., 2002) which follows the recommendation of the International Society of Biomechanics (ISB). The force platforms used are of the Kistler brand model 9286B (1000hz). The kinematic data was filtered with a 4th-order butterworth digital filter at 10hz and the FRS data at 5hz. To calculate the kinetic and kinematic variables, the Visual3D® software was used, the other processing was carried out in a Matlab® environment.

3. Findings

The values shown refer to: a) variation in the displacement of the center of mass (CoM) of the ELV in the median lateral [x], anteroposterior [y] and vertical [z] axes; b) Ground Reaction Force (FRS) referring to the two force platforms on the axes, middle lateral [x] - FRSML; anteroposterior [y] - FRSAT; vertical [z] – FRSV. The vegetation pruning simulation activity in zones E3 [Left Side] and D3 [Right Side]

a) Center of Mass

The results show that when simulating the pruning of vegetation on the left side, the CoM indicates greater postural balance using the support, presenting a trajectory with less variability, especially in the [x] axis – Middle lateral and [y] Anteroposterior axis (Figure 4).

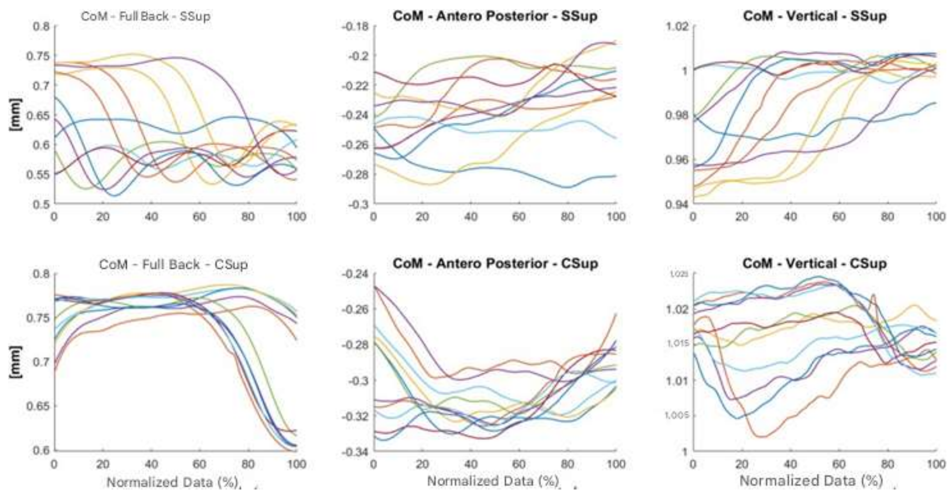

Figure 4: Distribution of the values referring to the variation of the displacement of the center of mass of the ELV, during pruning in **zone E3**, in the situations without support (SSup) and with support (CSup), in the axes, median lateral [x]; anterum posterior [y]; vertical [z].

When the ELV performs the simulation of vegetation pruning on the right side (Zone D3), the CoM also indicates greater postural balance with the use of the support on the axis [x] – Middle lateral (Figure 5). On the other hand, in the anteroposterior [y] axis, there is a pattern of movement (Figure 5).

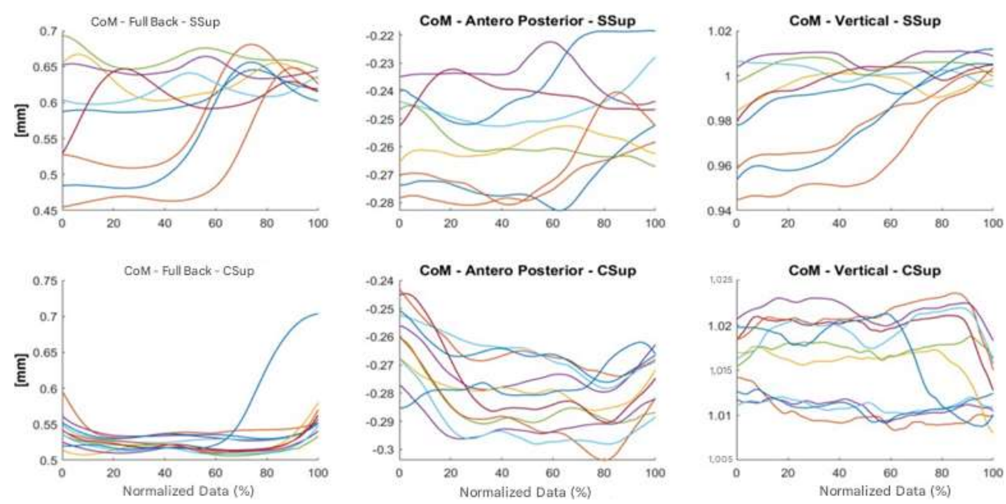

Figure 5: Distribution of the values referring to the variation of the displacement of the center of mass of the ELV, during the simulation of pruning in **zone D3**, in the situations without support (SSup) and with support (CSup), in the axes, median lateral [x]; anteroposterior [y]; vertical [z].

b) Ground Reaction Force (FRS)

The results obtained with the force platforms (FRS) corroborate with the kinematic data (CoM). When the ELV performed the simulation of vegetation pruning on the left side (zone E3) with the use of the support, the soil reaction forces in the axes [x – middle lateral; y – anteroposterior and z – vertical] showed values with less variation. In the results of ELV pruning without the use of support, the values show greater variability and greater effort of the lower limbs that act in a situation of isometry (Figure 6).

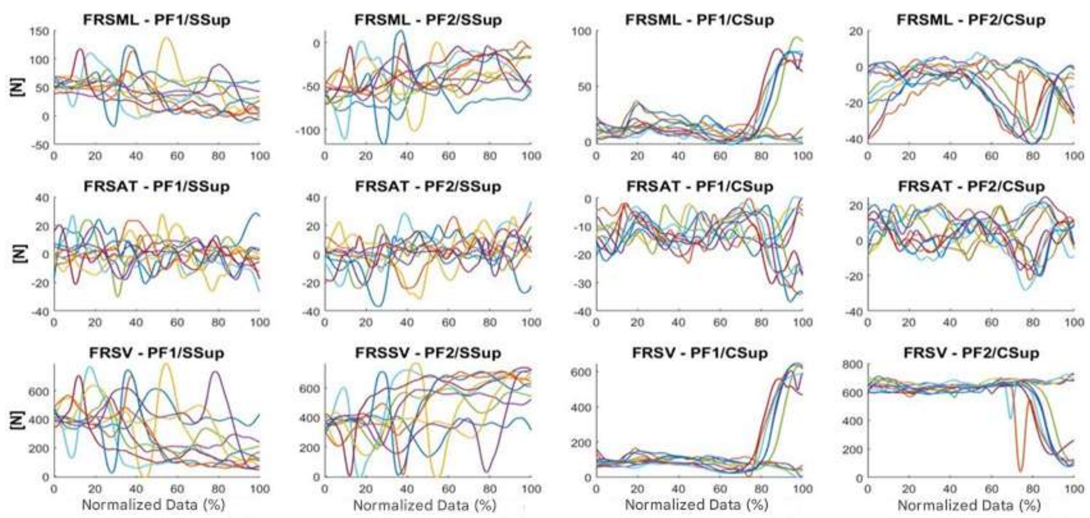

Figure 6: Ground Reaction Force (SRF) referring to the two force platforms (PF1 – left foot and PF2 – right foot) on the axes, median lateral [x] - FRSML; anteroposterior [y] - FRSAT; vertical [z] – FRSV during vegetation pruning in **zone E3** without support (SSup) and with support (CSup).

When pruning vegetation on the right side (zone D3) with the use of support, the reaction forces to the soil in the axes [x – middle lateral; y – anteroposterior and z – vertical] showed a behavior similar to that found in Zone E3, (Figure 7).

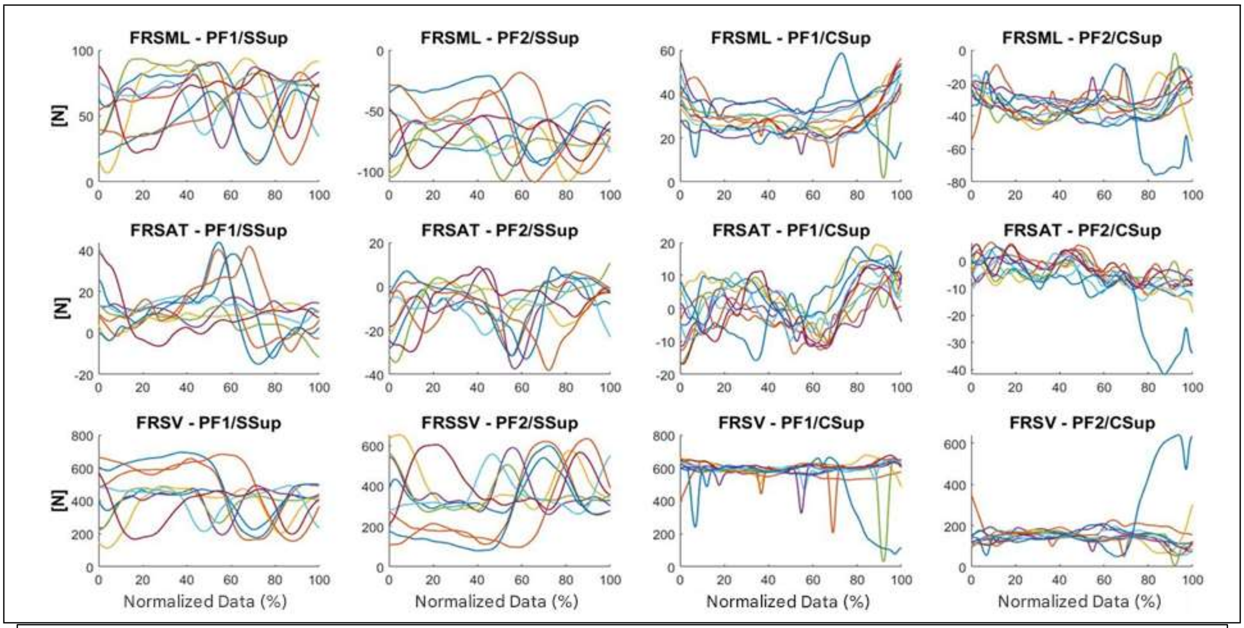

Figure 7: Soil Reaction Force (SRF) referring to the two force platforms (PF1 – left foot and PF2 – right foot) in the axes, median lateral [x] - FRSML; anteroposterior [y] - FRSAT; vertical [z] – FRSV during vegetation pruning simulation in **zone D3** without support (SSup) and with support (CSup).

4. Conclusion

Starting from the analysis of the field work of the ELV, based on the ergonomics of the activity, which pointed out the activity of vegetation pruning as a priority and allowed to know its intricacies, this research aimed to verify the behavior of the lower limbs of the ELV without the use of a support prototype and with the use of the support prototype for hydraulic pruning during the laboratory simulation of vegetation pruning from variables kinematics and kinetics. This simulation of the activity in a laboratory environment tried to get as close as possible, from the point of view of the technical gesture performed by the ELV associated with the physical demand of this operation in terms of biomechanical basis, and integrated with the observation carried out by the ergonomists in the field, except for exposure to the weather. Observing the results, it was found that the support caused a change in the movement of the ELV, the displacement of the CoM was more stable, especially in the lateral middle axis. The reaction forces helped to understand and corroborate with the kinematic data showing that the ELV tends to suffer less wear when it is using the support.

Thanks

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