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

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Summary: The study addresses the analysis of activities carried out by Live Line Electricians (ELV), highlighting the importance of biomechanics and ergonomics in understanding the risks associated with work. Several previous studies have examined the causes of musculoskeletal injuries in different work contexts, highlighting the prevalence of manual work in certain industries, such as iron foundries in India. Additionally, the research explores shoulder muscle loading in electricians, comparing the use of ladders with elevated mobile work platforms.

However, there is a gap in the literature regarding the daily activities of ELVs, especially in relation to the behavior of the lower limbs during their tasks. To fill this gap, the study investigated the behavior of the lower limbs of an ELV during vegetation pruning, using a prototype support for hydraulic motor pruning. The experiment, carried out 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 ELV, particularly in the midlateral axis. Furthermore, the ground reaction forces (FRS) showed less variability when the support was used, suggesting less physical wear for 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: 1. Live Line Electrician; 2. Biomechanics; 3. Ergonomics.

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, such as the research carried out by (Kataria et al., 2022) reinforcing the idea that in developing countries, many companies lack modern equipment and often depend heavily on manual work. Therefore, their objective 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 work demands, poor workstation structure, repetitive actions and inadequate postures maintained for prolonged periods may probably be associated with the severity of the risk of musculoskeletal injuries. The cited study can guide foundry manufacturers in analyzing the mismatch between workers' work profiles and in redesigning workplace layouts in small-scale foundries based on minimizing the severity of risks associated with the tasks performed by employees. To verify shoulder muscle load in workers using ladders or Mobile Elevated Work Platforms (Phelan & O'Sullivan, 2014), experienced electricians on a construction site were evaluated, finding that workers spent approximately 28% of their working time on ladders versus 6% on platforms. However, individual task durations were longer on platforms (153 s) than on stairs (73 s). The results in 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, peak amplitudes were, on average, greater for ladder work compared to platform work. The general implication was that working on platforms involves muscular loading of the lower shoulder when compared to work performed on stairs.

Few studies aimed to verify the performance of Live Line Electricians (ELV) carrying out their daily activities, some examples of such research 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 for ELVs.

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

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 motor pruning during vegetation pruning based on kinematic and kinetic variables.

DEVELOPMENT

Methodology

One (01) experienced ELV, male, 38 years old, right-handed, who has worked for 6 years directly in the field with live lines and is hired by the energy concessionaire that is the focus of the study, participated in the study. The Electrician signed the Free and Informed Consent Form and this study was approved by the ethics and research committee of UNICAMP – Universidade Estadual de Campinas, CAAE: 33462920.3.0000.5404. Opinion number: 4,151,017.

As it is a risky job, collection in a real environment is not viable, so, with the help of an experienced electrician, a structure ("tree") was built on a pole with a cross using wooden cables 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 as shown in figure 1.

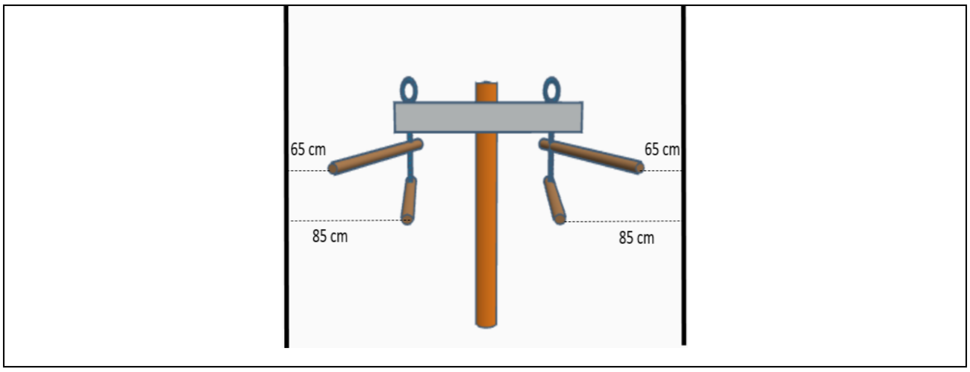

Figure 1. Structure assembled in the laboratory to be used to simulate vegetation pruning activities.

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 the cut at the bottom of the branch and finishing at the top of the branch. On the second day of collection, the ELV carried out a simulation of the vegetation pruning activity similar to the first collection, however, on this occasion it carried out the movements with the help of a prototype of a support to support the hydraulic saw (figure 2b). On both days, the ELV was positioned on two force platforms to obtain ground reaction force (FRS) data. The platforms were connected and synchronized to the Optitrack system using eSync (figure 2a).

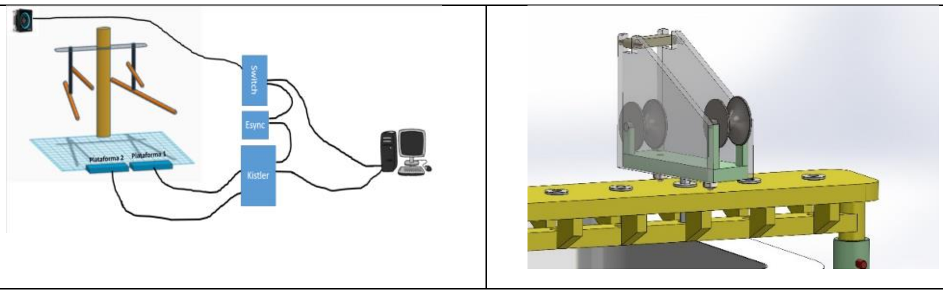

Figure 2: a) Schematically, synchronization procedure for the motion capture system and force platforms; b) Support prototype for hydraulic mower.

When carrying out the vegetation pruning operation with hydraulic motor pruning, the ELV begins by cutting the smaller branches in stages, “dividing” the branch into proximal and distal cutting zones, duly identified with markings on cardboard, 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.

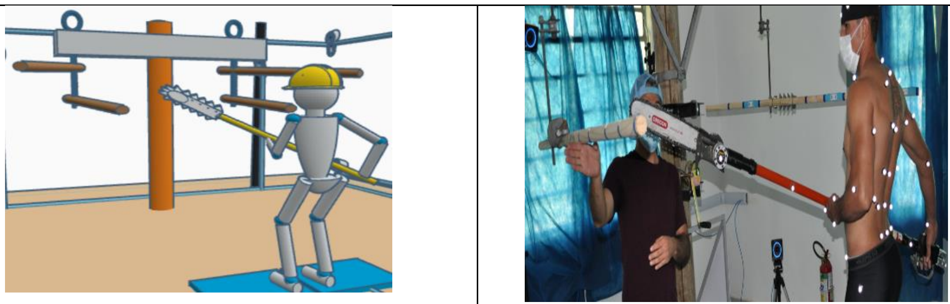

Figure 3: a) Schematic of how the ELV was positioned at the time of data collection between the left and right “branches”; b) ELV positioned before collection begins.

During collection, the ELV used a Greenlee® hydraulic mower measuring 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 movements of pruning vegetation by touching the branches of bottom to top and top to bottom in 10 pre-determined zones (15 cm) along the branch.

To collect 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 upper (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 from the Kistler model 9286B (1000hz). The kinematic data were 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; other processing was carried out in the Matlab® environment.

Results

The values shown refer to: a) variation in the displacement of the center of mass (CoM) of the ELV in the mediolateral [x], anteroposterior [y] and vertical [z] axes; b) Ground Reaction Force (FRS) referring to the two force platforms on the axes, medium 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 vegetation pruning on the left side, the CoM indicates greater postural balance using the support, presenting a trajectory with less variability, mainly in the [x] axis – Middle lateral and Anteroposterior [y] axis (Figure 4).

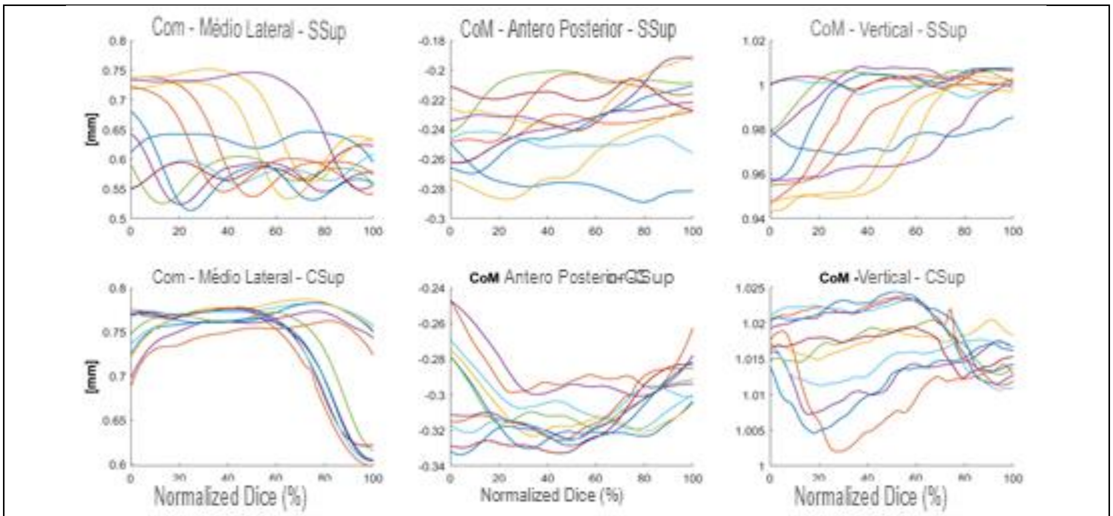

Figure 4: Distribution of values referring to the variation in the displacement of the center of mass of the ELV, during pruning in zone E3, in situations without support (SSup) and with support (CSup), in the mid-lateral axes [x]; anterior posterior [y]; vertical [z].

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

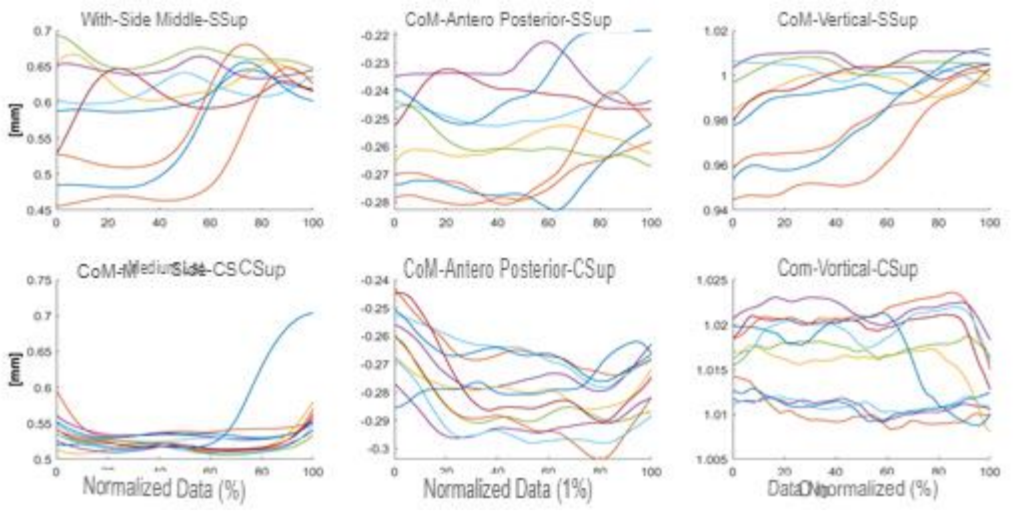

Figure 5: Distribution of values referring to the variation in the displacement of the center of mass of the ELV, during the pruning simulation in zone D3, in situations without support (SSup) and with support (CSup), in the mid-lateral axes [x]; anteroposterior [y]; vertical [z].

b) Ground Reaction Force (FRS)

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

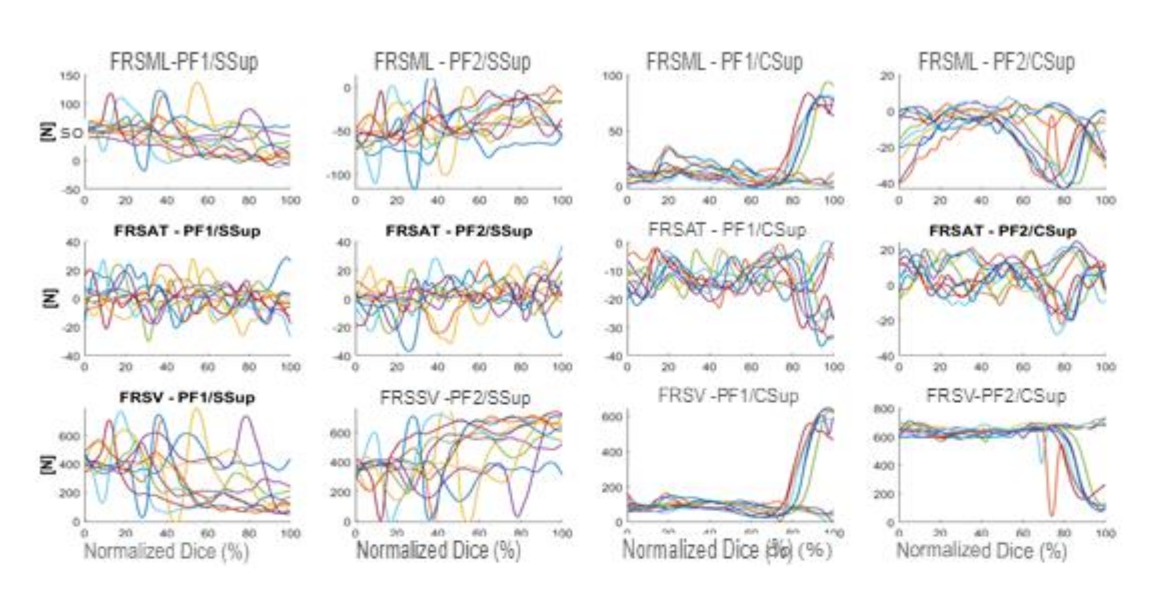

Figure 6: Ground Reaction Force (FRS) referring to the two force platforms (PF1 – left foot and PF2 – right foot) in the axes, mediolateral [x] - FRSML; anteroposterior [y] - FRSAT; vertical [z] – FRSV during vegetation pruning in zone E3 without support (SSup) and with support (CSup).

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

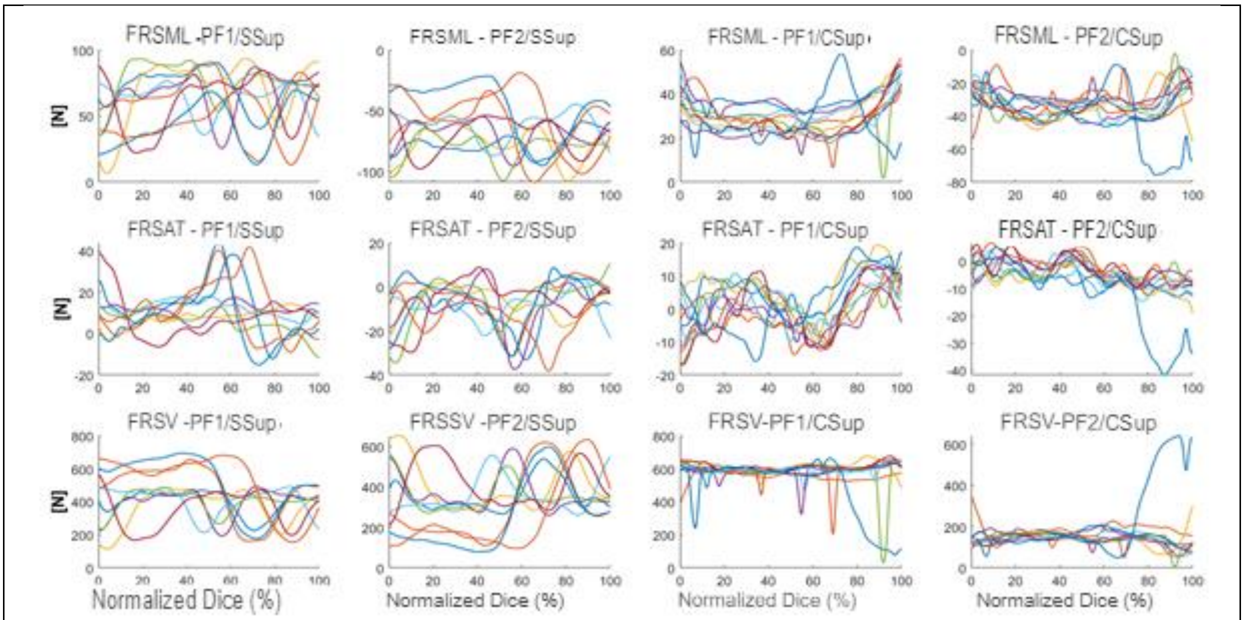

Figure 7: Ground Reaction Force (FRS) referring to the two force platforms (PF1 – left foot and PF2 – right foot) in the axes, mediolateral [x] - FRSML; anteroposterior [y] - FRSAT; vertical [z] – FRSV during vegetation pruning simulation in zone D3 without support (SSup) and with support (CSup).

Conclusion

Starting from an analysis of ELV fieldwork, based on the ergonomics of the activity, which highlighted the activity of pruning vegetation as a priority and allowed us to understand its intricacies, this research aimed to verify the behavior of the ELV's lower limbs without the use of a support prototype and the use of the support prototype for hydraulic motor pruning during the laboratory simulation of vegetation pruning based on kinematic and kinetic variables. This simulation of the activity in a laboratory environment tried to come 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 ergonomists in the field, with the exception of exposure to the elements. 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 medial lateral axis. The reaction forces helped to understand and corroborate the kinematic data showing that the ELV tends to suffer less wear when using the support.

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