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Ergonomic Assessment of Manual Loading and Unloading of Wood in Forestry Trucks

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Abstract

This evaluation aims to analyze and innovate the manual wood loading and unloading workstation in forestry trucks, as well as to highlight ergonomics as a tool within the business and small enterprise management field to achieve production outcomes and improve workers' quality of life. The methodology involves both quantitative and qualitative assessment. Results: The evaluation revealed manual handling of loads that requires prompt corrective actions. Interventions led to the acquisition of machinery, including a crane and a wood splitter. Additionally, an organizational-level intervention resulted in the hiring of two additional workers, allowing the company to maintain economic income throughout the year. Conclusion: This assessment analyzed the manual wood loading and unloading workstation in forestry trucks, successfully describing and evaluating both the job and the organization of the family-owned small business. Subsequently, the ergonomic intervention, which introduced technology into tasks that were previously performed solely manually, helped reduce musculoskeletal discomfort among workers. Processes were redesigned to improve performance and increase income. However, this evaluation did not address all subsystems in which there are health and safety risk factors for workers. Therefore, further assessments of the various workstations are necessary, along with the proposal of improvements—technological or organizational—for future research.

Keywords
Ergonomics, forestry, family SME, manual loading and unloading.

1. Introduction
Small and Medium Enterprises (SMEs) play a fundamental role in the economy. Many operate formally, while others work in informality as a means of daily survival. According to the Undersecretariat for International Economic Relations, SMEs are defined as those whose annual sales range between 2,400 and 100,000 UF (Biblioteca del Congreso Nacional de Chile, 2010). It is estimated that there are 1,299,147 small and medium-sized enterprises in the country, which face economic difficulties that, in turn, contribute to a high failure rate.

This particular SME is engaged in firewood production, which is used for heating—from industrial boilers to domestic stoves and combustion systems—as well as for the transportation of wood derivatives. However, for the purposes of this study, only the firewood loading and unloading workstation was analyzed. The company produces a maximum of 52 cubic meters per day, generally distributed between 20 and 32 cubic meters per truck. As a result, approximately 104 cubic meters are manually handled daily—during both loading and unloading—without the use of mechanical aids such as wheelbarrows, conveyor belts, cranes, or other assistive devices. This volume is not fixed and may vary depending on seasonal demand. Moreover, the company has limited financial resources, and workers have reported experiencing lower back pain, elbow tendinitis, and wrist tendinitis—symptoms that tend to worsen at the end of the high-demand season.

In this regard, "one of the most significant challenges is explaining how and why family-owned businesses behave and achieve outcomes differently from other types of organizations" (Benavides et al., 2011, p. 88). Therefore, the main objective of this job evaluation is to make visible a common occupation in southern Chile—that of home firewood delivery—and to determine how this work impacts workers' health, while also highlighting the challenges faced by small family-owned enterprises.

2. Objectives

2.1 General objective

- To analyze and innovate the manual wood loading and unloading workstation in forestry trucks.

2.2 Specific objectives

- To describe the manual wood loading and unloading workstation in forestry trucks.
- To assess the worker in their workstation and the family-owned business at the organizational and social interaction levels.
- To redesign the manual wood loading and unloading task.
- To highlight ergonomics as a strategic tool in business and SME management to improve production outcomes and enhance workers' quality of life.

3. Materials and Methods

The analysis was conducted in a family-owned SME consisting of three workers, all of whom participate in the entire production process to obtain the final product: 1-meter-long firewood. One worker was analyzed while performing the task of wood loading and unloading.

To carry out the evaluation, both quantitative and qualitative techniques were applied, including:
• Workday time study
• Individual and group interviews
• Ronald-Morris Questionnaire
• Manual Handling Assessment Charts (MAC) method

The following instruments were used:
• Stopwatch
• Scale
• Stadiometer
• Bluetooth-connected heart rate band
• HR Monitor mobile application
• Time study recording sheet
• Mobile phone camera
• Tripod
• Free Video to JPG Converter v.5.0.101 build 201
• Google Maps
•On-site MAC assessment recording sheet

4. Results and Discussion

Basic Description of the Process and Performed Tasks
The SME produces one-meter-long firewood, which is used for heating purposes—ranging from industrial boilers to household stoves and wood-burning systems. The company also transports wood byproducts; however, for the purposes of this study, only the manual loading and unloading of firewood was analyzed (Figure 1).

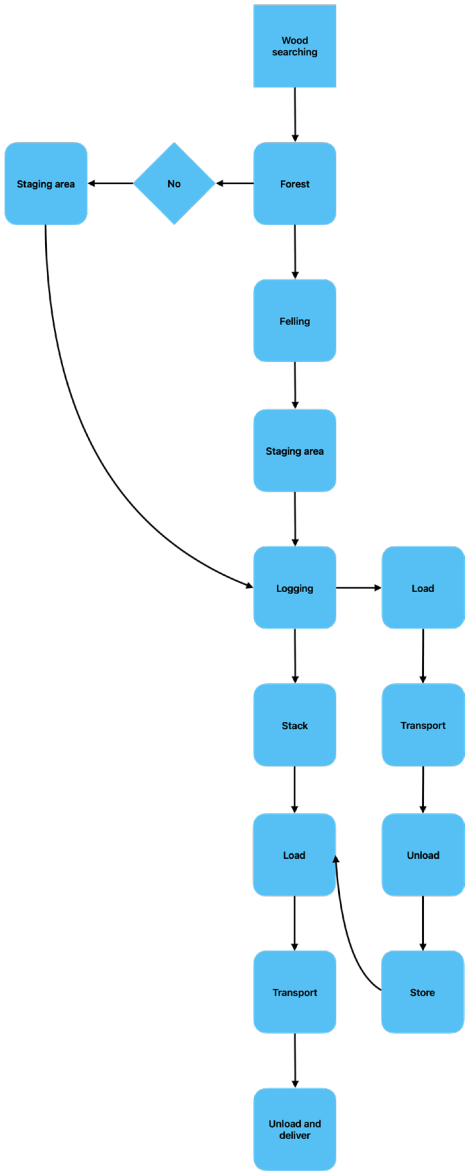

Figure 1. System Flowchart (Sequence of Activities)

4.1 Geographical Location of the Workstation

The time study was conducted 74 kilometers from the city of Valdivia, in the Los Ríos Region. It is important to note that the starting point was Valdivia, and the destination was the rural area of Iñipulli, located in the commune of San José de la Mariquina, with an approximate travel time of 1 hour and 18 minutes (Figure 2). Valdivia serves as the main point of sale for the firewood, which is transported from Iñipulli and other work sites in neighboring communes.

The point of sale in the commune of Valdivia is located in a residential area, specifically on a dead-end street. As a result, the owners of the SME had to engage in discussions with local residents due to the movement of trucks through the street, the noise generated by vehicles in the early morning hours, and the deterioration of the pavement caused by the weight of the trucks (Figure 2).

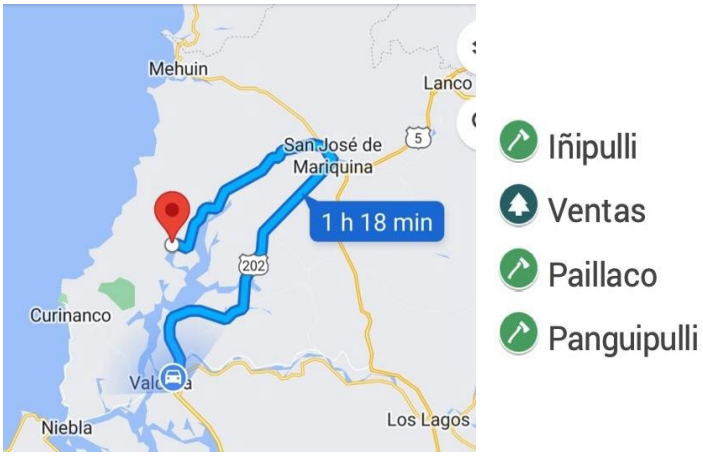

Figure 2. Distribution of work sites and route followed during the time study

4.2 Systems

Purpose of the Production System and Service
The SME produces firewood for both household and industrial use, as well as for the transportation of wood byproducts. On average, the daily volume handled is 52 cubic meters, distributed between 20 and 32 cubic meters per truck. Therefore, considering both loading and unloading, a total of 104 cubic meters is manually moved each day. It is important to note that this amount is not fixed and varies depending on demand, as one or two trucks may be used for transportation.

Subsystems and Number of Workers
•Subsystem 1: Forest and felling (1 chainsaw operator)
•Subsystem 2: Transport and staging area (1 ox team and 2 workers)
•Subsystem 3: Cutting into logs and stacking (1 chainsaw operator and 2 workers)
•Subsystem 4: Loading, transporting, and unloading (2 or 3 workers, of whom 1 or 2 also serve as drivers)

This SME employs three individuals who participate and rotate across the different activities. The evaluated worker participates in Subsystem 2 by staging the wood (acanchado), in Subsystem 3 by stacking the cut logs, and in Subsystem 4 by loading the firewood, driving the truck, and unloading it. It is important to note that the role of driver depends on the volume of firewood orders.

Components of the Subsystem Where the Evaluated Worker Operates
The evaluation focused on Subsystem 4, which involves the tasks of loading and unloading firewood, as well as driving the truck (when there is high demand for firewood deliveries).
Workers: There are 2 or 3 owner-workers who are responsible for loading and, in the case of the driver(s), unloading the truck. One of these workers was evaluated in this study; his role on this occasion consisted of loading and unloading firewood.

Technology: The work is performed manually. The business owns three trucks; for this assessment, they used the one with the largest capacity, which holds up to 32 cubic meters of firewood.
Work Structure: This is a family-run SME. The three workers are family members. There is no hierarchical distinction between the two business owners, as all are siblings and make decisions collectively with their immediate family. Additionally, they have the support of an accountant.

Personal Background and Training of the Evaluated Worker (Table 1-Table 6).

Table 1. Personal Background

Antecedentes personales	
Name	H.F.C
Sex	Male
Age	38 years
Height	1.73 m
Weight	100 kg
BMI	33. 54 (Class 1 Obesity)
Start of workday	07:27 Am
End of workday	17:21 pm
Total hours	09:54:21 hours

Table 2. Educational Background

Education and Training	
Eschooling	Completed high school (4th year), with a mid-level technical degree in agriculture.
Driver's License	Class B and A2

Time Study

Subsystem 4:

- Arrival
- Transport
- Loading
- Transport
- Unloading
- End of workday

The sequence begins with the worker's arrival at the parking area located at a gas station, in the sector where the firewood point of sale is located. The truck is kept at the gas station. They begin the trip to the firewood storage site, located in the rural area of Iñipulli, within the commune of San José de la Mariquina. The journey took approximately 1 hour and 28 minutes. Upon arrival, they start by placing wooden stakes and stacking the firewood onto the truck.

At the beginning, the worker reaches the base of the truck and arranges the wood. As the stack grows in height, the worker must throw the firewood upward to continue stacking. Then, a second worker climbs onto the truck to receive the firewood and stack it higher. This process is repeated on the other side of the truck, requiring the worker to reposition himself to load the remaining side. They measure the amount of wood loaded, and this task concludes.

The return trip begins in order to deliver the firewood, taking approximately another 1 hour and 28 minutes. Upon arrival, the evaluated worker gets out of the truck, locates the previously coordinated customers, and the unloading process begins. The driver climbs onto the back of the truck and begins handing the firewood to the other worker on the ground, who receives and arranges it. When the pile reaches a level that is easily accessible from the ground, the driver joins the unloading and helps stack the firewood.

It is important to note that the quantity of firewood delivered depends on the customer's needs, meaning it varies from day to day. Finally, they return to the parking area at the gas station, where the workday ends.

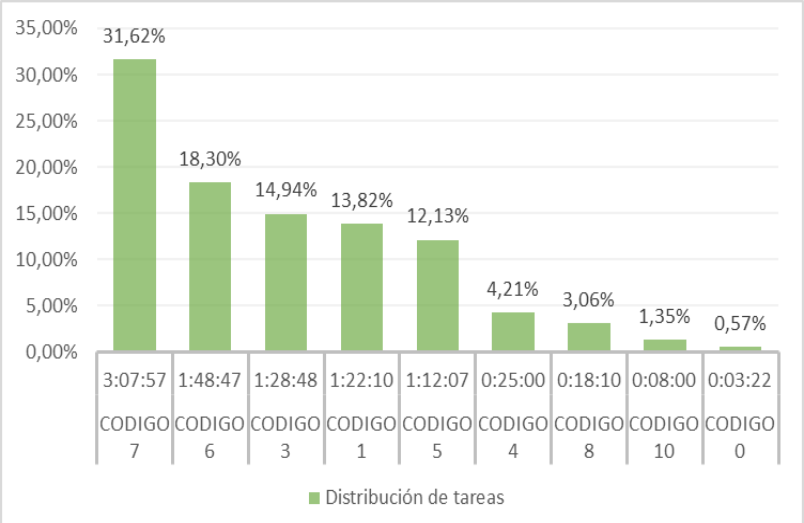

Figure 3. Time Distribution by Activity

The main activity, which involves stacking, throwing, and receiving firewood, accounts for 47.96% of the workday (Figure 3), which totals 9:54:21 hours. The secondary activity refers to transportation, and finally, placing the wooden stakes represents 37.67%. Together, the primary and secondary activities make up 85.63% of the total workday (Table 3).

Table 3. Percentage of Time Spent by Activity

Type of activity	Time (hrs)	Percentage of total time
Main	4:45:04	47,96 %
Secondary	3:43:45	37,67 %
Breaks	0:03:22	0,57 %
Waiting	1:22:10	13,825 %
Total	9:54:21	100 %

Manual Handling of Loads
MAC Method
The MAC (Manual Handling Assessment Charts) method was applied to the tasks of lifting, lowering, and carrying, all performed by a single individual. The following are the results of the evaluations.

Table 4. Lifting Task Performed by a Single Person

Risk factors		Color	Score
A	Load weight and frequency	Green	0
B	Horizontal distance from hands to lumbar region	Orange	3
C	Vertical lifting and lowering region	Red	3
D	Trunk twisting and lateral bending	Red	2
E	Postural constraints	Orange	1
F	Hand–object coupling	Red	2
G	Working surface	Red	2
H	Environmental factors	Red	2
Total score			15
Action category			3

In the lifting task performed by a single person, a total score of 15 was obtained, resulting in an action category of 3. This indicates that corrective actions are required soon. In the carrying task performed by a single person, a total score of 9 was obtained, corresponding to action category 2, indicating that corrective actions are needed.

Table 5. Carrying Task (Walking with Load)

Risk factors		Color	Score
A	Load weight and frequency	Green	0
B	Horizontal distance from hands to lumbar region	Orange	3
C	Asymmetrical load on the back	Orange	1
D	Postural constraints	Green	0
E	Hand–object coupling	Red	2
F	Walking surface	Orange	1
G	Environmental factors	Red	2
H	Carrying distance	Green	0
I	Obstacles	Green	0
Total score			9
Action category			2

In the lowering task performed by a single person, a total score of 14 was obtained, resulting in an action category of 3. This indicates that corrective actions are required soon.

Table 6. Lowering Task Performed by a Single Person

Risk factors		Color	Score
A	Load weight and frequency	Green	0
B	Horizontal distance from hands to lumbar region	Orange	3
C	Vertical lifting and lowering region	Red	3
D	Trunk twisting and lateral bending	Red	2
E	Postural constraints	Orange	1
F	Hand–object coupling	Red	2
G	Working surface	Orange	1
H	Environmental factors	Red	2
Total score			14
Action category			3

Health Status and Health Perception During the interview regarding his health status and perception, the evaluated worker reported experiencing musculoskeletal pain, which has led to visits to emergency care centers due to acute low back pain. These episodes have caused work stoppages lasting approximately seven days. Another important factor to consider is the absence of preventive medical check-ups for adults, due to lack of time, which results in undiagnosed or unmonitored preventable health conditions and delays in initiating appropriate treatment. He also reported having suffered workplace accidents, such as falls from height, being struck, and being caught or pinched by pieces of wood. When asked whether he believes he could continue performing this job for several more years, he responded that it is his main source of income and a family project. Regarding his perception of quality of life in old age, he stated that this type of work will have an impact on his future well-being. As an example, he referred to his father's health, noting that he spent his entire life doing the same work. He also mentioned that in recent years he developed a lumbar hernia, which currently affects his gait and negatively impacts his emotional state.

Nutrition
During the interview, the worker described his eating habits during the week and on weekends. On weekdays, he typically eats three meals a day, including bread twice daily. Upon returning home at the end of the workday, he eats homemade meals. When asked why he eats mainly bread instead of bringing food to the work site, he explained that they lack a proper place to sit and eat. As a result, they eat bread while driving the truck, which allows them to save time, complete deliveries more quickly, and return home earlier for a full meal.

Clothing and Personal Protective Equipment
On the day of the evaluation, the weather was cold and rainy. The evaluated worker was wearing a sweatshirt and no waterproof clothing. When asked about this, he explained that they rarely wear waterproof garments because sweat tends to condense inside, leaving them wet throughout the day. For this reason, he prefers clothing that allows sweat to evaporate, helping to stay dry during the workday. When asked about footwear, the worker mentioned that they purchase safety shoes twice a year, as toe injuries and foot entrapments are common accidents. The most commonly used footwear is rubber boots, as they keep the feet warmer and are worn with socks and wool stockings. The interview continued with questions about clothing during the summer season. The worker stated that they continue to wear the same long-sleeved clothing to avoid sunburn. He also noted that they do not use sunscreen, as sweating causes it to drip into their eyes, resulting in a strong stinging sensation. For this reason, they avoid using it altogether.

Organization of the SME
During the meetings, the workers were asked whether they had experienced any issues related to hierarchy or organization within the SME. Anecdotally, they shared that on numerous occasions, they had sold a load of firewood to different customers at the same time. When it came time to decide to whom they would actually deliver, it created conflicts, especially because they were just starting out and needed to build customer loyalty. Failing to fulfill an order gave a negative impression of their family-run home firewood delivery business. Another issue mentioned by the owners—who are brothers—is that people often confuse them, leading to duplicate orders for the same customer. As a result, they sometimes load more firewood into the truck than the customer actually needs. Regarding decision-making, it is carried out as a family, either during family meetings or at mealtimes (breakfast or lunch). All family members contribute their opinions when it comes to making investments or planning future steps.

Production and Performance
Firewood production takes place during the season with better weather, beginning in October and ending in March. Production is based on customer demand. During the high season, they work from Monday to Sunday, as they need to generate sufficient income to sustain themselves during the low season (March to September). Additional challenges include limited access to forest lands and the lack of a covered storage facility to stock firewood with low moisture content. Planning is done on a six-month basis, meaning there are no long-term projections—only short- and medium-term goals. The main objective is to survive from one season to the next.

"Our results suggest that older family businesses are more reluctant to grow compared to younger family businesses. Interestingly, this effect does not occur in non-family firms. This finding may be attributed to more entrepreneurial behavior during the early stages of the family business lifecycle." (Moreno & Casillas, 2021)

Organizational Goals or Expected Performance
Their current goal is to secure access to a forest in order to begin producing firewood for the upcoming year, in addition to selling the stock they currently have in storage.

Their long-term goal is to save enough money and sell one of their trucks in order to purchase a crane, with the aim of making their production process more efficient and ultimately improving their quality of life.

Evaluated Worker's Response to the Imposed Goals
The worker reported being able to meet the productivity goals set; however, he noted experiencing significant physical strain, particularly at the end of the high season, which runs from September to March. He also mentioned that the workload intensity decreases during the winter months, as the daily volume of firewood handled is lower.

Worker's Perception of Workload Demand in Relation to Their Capacity
The worker explained that workload demand depends on the season. During the high season, production exceeds their physical capacity, which is reflected in joint pain, tendinitis, and lower back pain by the end of the period. He acknowledged that this pace will take a toll on their bodies over time, but emphasized the need to produce in order to get through the winter and support their households. They are currently saving money to purchase a crane, which they believe would change their lives completely—allowing them to significantly increase productivity with minimal physical effort. As they age, they recognize that they won't be able to maintain the current work pace indefinitely, and must plan for how they will sustain themselves economically in the coming years. This is why acquiring a crane has become their main aspiration.

Intervention
Interventions were carried out at the end of 2021 and throughout 2022 with the aim of improving the quality of life of the workers in this family-run SME. During the intervention period, the world was experiencing the Covid-19 pandemic, and travel restrictions were in place. However, since the SME operated in the transport sector, it was allowed to continue moving without restriction, which enabled them to keep working and delivering firewood.

The family business was introduced to the intervention as an opportunity for change and improvement in their processes. This would lead to transformations in the way they work and organize themselves—ultimately representing a chance to enhance their quality of life.

Meetings were held to assess economic aspects. Due to the pandemic context, the government, in collaboration with Banco Estado, offered interest-free loans. The SME evaluated this option and applied for a loan in the amount of CLP $20,000,000 (twenty million Chilean pesos).

Linking Ergonomics with Business Strategy and Commercial Outcomes
The budget was invested in the purchase of a crane, a wood splitter, and mechanical repairs for the trucks. The installation of the crane faced several setbacks, as the owners of the family-run SME opted for informal mechanics instead of a specialized crane installation workshop. Regarding the purchase of the wood splitter, the worker was the primary beneficiary, as it led to a reduction in musculoskeletal symptoms such as epicondylitis and carpal tunnel syndrome. Tasks that were previously performed manually using a wedge and sledgehammer are now carried out by the wood splitter, resulting in an increase in daily production.

Organizational Strategies
Several meetings were held to discuss how to avoid going through the winter season without income, due to weather conditions that prevented access to the forest properties where the firewood was stored, as the roads were in poor condition. Additionally, the SME did not have a covered storage facility, which meant that during winter, the firewood had a high moisture content and was therefore not suitable for sale.

Linking Ergonomics with Organizational Strategy and Outcomes
The SME reorganized its operations by advancing firewood production with the support of an additional work pair dedicated to tree felling and field staging (volteo and acanchado). As a result, during the high season, they were able to fulfill deliveries without any shortages in firewood supply to meet customer demand. During the winter season—which tends to be the most economically challenging—the owners decided to undertake agricultural work on a farm in the Iñipulli area, while the additional work pair continued with felling and staging activities.

This allowed the overall process to continue without interruption. Currently, the workers are engaged in agricultural tasks during the week, while on weekends they continue with home firewood deliveries. It is important to recognize

that family businesses do not perceive or pursue growth in the same way as non-family businesses. In this regard, "the results indicate that family firms experience lower sales growth but higher employment growth compared to non-family firms" (Moreno & Casillas, 2021, p. 2). Therefore, it should be considered that growth in a family business is often reflected in the number of employees rather than in revenue. Some authors emphasize this point:
"We propose that family firms will grow less than non-family firms in terms of sales, but not in terms of number of employees. The second set of hypotheses introduces the firm's age as a predictor of the relationship between family ownership and business growth" (Moreno & Casillas, 2021, p. 2).

Determining the Direction of the SME and Family Succession
During the meetings, the topic of developing protocols for operational processes was addressed, including the creation of a family succession protocol. This suggestion took the family business owners by surprise, as they had not previously considered long-term planning. Until that point, their outlook was limited to six-month periods, continuously reassessing the survival of the family enterprise. As such, the idea of a family succession plan seemed overly ambitious to them, since they do not envision the long-term continuity of the SME.

They also noted that this type of work has led to a decline in their quality of life. They do not believe they will be able to maintain the current pace of work in five or ten years. Additionally, within their potential family succession line, there is currently no one of appropriate age to assume responsibility for the business. Furthermore, they expressed a strong desire for their children to pursue professional careers and not continue in this type of physically demanding labor.

The discussions revealed that succession was a topic the owners had not previously considered, but it provided an opportunity for them to reflect on the future of the company. It is well established that the likelihood of success in family businesses tends to decrease as they pass from one generation to the next.

4.3 Discussion

The SME evaluated required not only an understanding of the tasks performed by the worker, but also of the family itself. It was essential to grasp how decisions are made, how the SME, the family, and the owners interact, and to learn about their life history in order to understand the purpose behind their work. This deeper understanding allowed me to integrate into their family environment and offer recommendations that would be meaningful and more likely to be adopted. The intervention had positive effects, as reported by the evaluated worker and the other team members, particularly in terms of the reduction of musculoskeletal symptoms. However, what had not been anticipated was the owners' decision to have the crane installed at a workshop that lacked the necessary expertise for such installation. Over time, as I spent more time with the owners and observed how they engaged with their surroundings, it became clear that they are responsible for maintaining their own trucks and have close relationships with local mechanics. They prefer taking their vehicles to workshops run by trusted community members rather than formal service centers, where they feel less confident and connected.

This highlights the importance for ergonomists of getting to know not only the workers, but also the owners and families that make up a family-run SME. Only by doing so can we truly understand how such enterprises operate and how decisions are made.

Ergonomics still has much to explore in this area: each family business represents a unique world. We must humanize ergonomics—moving beyond processes, services, methods, and equations. As ergonomists, we need to understand the person behind the work in order to better comprehend the worker and the inner workings of the family business.

5. Conclusions

This evaluation analyzed the manual wood loading and unloading workstation in forestry trucks, successfully describing and assessing both the job position and the organizational structure of the family-run SME. Following the ergonomic intervention, which introduced technology into tasks that were previously performed entirely manually, a reduction in the worker's musculoskeletal discomfort was achieved.

Work processes were redesigned to improve productivity and increase the SME's income, resulting in outcomes such as the hiring of two additional workers and the generation of year-round income, while consistently meeting home firewood delivery demands. Furthermore, the role of ergonomics is highlighted as a strategic tool in the management

of small enterprises.

However, it is important to note that due to the small sample size, the findings cannot be generalized. Nevertheless, this study offers a valuable perspective on a common yet underexplored activity in certain regions from an ergonomic standpoint, and may serve as a starting point for future research with broader scope.

This evaluation did not cover all subsystems in which there are health and safety risk factors for workers. Therefore, further evaluations should be conducted across the various job positions, with the aim of proposing both technological and organizational improvements in future studies

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Biography

Morelia Frías Cárcamo holds a Bachelor's Degree in Kinesiology (2021) and a Master's Degree in Ergonomics (2023). She works in highly rural areas, where she applies ergonomic principles in real-world contexts to improve occupational health. She is currently an independent researcher, focusing on the study of manual labor in underserved territories. Her research interests include rural ergonomics, occupational health, musculoskeletal disorders, and participatory intervention strategies in small and family-owned enterprises.