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Prefacio

Para la Sociedad de Ergonomistas de México A.C. (SEMAC); la ergonomía se ha distinguido por ser una ciencia cada vez más comprometida con el bienestar humano, ampliando sus intereses y alcances en el estudio de las capacidades y limitaciones del hombre. Las reglamentaciones y normativas existentes en torno a la Ergonomía y Salud Ocupacional existentes en México y que se fraguan en Latinoamérica deben cubrirse por las organizaciones al desarrollar ambientes y espacios laborales confortables y saludables. Pero la Ergonomía debería incluirse en la búsqueda de la mejora en la productividad donde la inversión realizada es retornada para empresas con ergónomos comprometidos.

La Ergonomía también debe aplicarse en la informalidad laboral, donde también se tienen condiciones riesgosas y peligros laborales que vulneran la calidad de vida de quienes los realizan. Así, en México uno de cada dos trabajadores subsiste en la informalidad laboral y esta proporción parece estar aumentando en los últimos años, por lo que representa un desafío complejo con diversas perspectivas, económicas, sociales, ambientales, tecnológicas y de sostenibilidad que amerita un esfuerzo multidisciplinario para atender, reducir y mitigar sus efectos en la población laboral.

Los editores, árbitros y comité académico, a nombre de la Sociedad de Ergonomistas de México, A.C., agradecemos a los autores de los trabajos por compartir investigación en este libro que busca recapitular nuevos conocimientos y aplicaciones creativas. Reconociendo a los autores en su esfuerzo, compromiso y sacrificio al impulsar la ergonomía en su propio entorno social y sector de trabajo específico. Donde su valiosa aportación estamos seguros impulsa y contribuye en el avance de la ergonomía a nivel nacional y mundial en la mejora de entornos de trabajo, el aumento de la productividad organizacional y hacia el interior de las Instituciones de Educación Superior.

Considero que este nuevo libro editado por la SEMAC ha conseguido la meta de difundir y dar acceso libre a estos trabajos que buscan el bienestar de los miembros de empresas y organizaciones. Los invito a leerlos, compartirlos y difundirlos para que sean de utilidad a aquellos estudiosos y practicantes de la ergonomía en México y el mundo y así se consiga el objetivo y lema de SEMAC "TRABAJO PARA OPTIMIZAR EL TRABAJO"

Dr. Carlos Raúl Navarro González
Presidente SEMAC 2024-2026

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Comparison Using Electromyography in the Use of an Exoskeleton for Lifting Loads

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Resumen: El levantamiento de cargas, una actividad prevalente en múltiples industrias está asociado a un alto riesgo de trastornos musculoesqueléticos, particularmente en la región lumbar y las extremidades inferiores. Los exoesqueletos han sido propuestos como una solución innovadora para mitigar estos riesgos al proporcionar soporte estructural y reducir la carga física en tareas exigentes. Este estudio evalúa la efectividad de un exoesqueleto en la reducción de la carga muscular mediante electromiografía (EMG). Los resultados demuestran una reducción significativa en la activación muscular, lo que sugiere que el uso de exoesqueletos puede disminuir el riesgo de lesiones musculoesqueléticas y mejorar la ergonomía en entornos industriales.

Palabras clave: Exoesqueleto, EMG, Ergonomía, Levantamiento de cargas,

Relevancia para la ergonomía: Este artículo hace una contribución significativa a la ergonomía al proporcionar evidencia empírica sobre la efectividad de los exoesqueletos para reducir la carga muscular durante las tareas de levantamiento de carga, una actividad común y físicamente exigente en diversos sectores industriales. El estudio destaca el potencial de los exoesqueletos para mejorar la seguridad y la salud en el lugar de trabajo al mitigar una de las principales causas de trastornos musculoesqueléticos (TME) entre los trabajadores: el levantamiento de objetos pesados de forma repetitiva. Al demostrar una reducción sustancial en la activación muscular, particularmente en los cuádriceps, la investigación subraya los beneficios prácticos de la integración de exoesqueletos en entornos industriales como intervención ergonómica preventiva. El uso de electromiografía (EMG) para medir la actividad muscular ofrece una evaluación precisa y objetiva, lo que hace que los hallazgos sean muy relevantes para investigadores y profesionales. Los resultados del estudio también podrían informar directrices y mejores prácticas para el despliegue de exoesqueletos, contribuyendo a entornos de trabajo más seguros y sostenibles.

Abstract: Load lifting, a prevalent activity in various industries, is associated with a high risk of musculoskeletal disorders, particularly in the lumbar region and lower extremities. Exoskeletons have been proposed as an innovative solution to mitigate these risks by providing structural support and reducing physical load in demanding tasks. This study evaluates the effectiveness of an exoskeleton in reducing muscle load using electromyography (EMG). The results demonstrate a significant reduction in muscle activation, suggesting that exoskeleton use may decrease the risk of musculoskeletal injuries and improve ergonomics in industrial settings.

Keywords: Exoskeleton, EMG, Ergonomics, Load Lifting

Relevance to Ergonomics: This article makes a significant contribution to ergonomics by providing empirical evidence on the effectiveness of exoskeletons in reducing muscle load during load-lifting tasks, a common and physically demanding activity in various industrial sectors. The study highlights the potential of exoskeletons to enhance workplace safety and health by mitigating one of the leading causes of musculoskeletal disorders (MSDs) among workers—repetitive heavy lifting. By demonstrating a substantial reduction in muscle activation, particularly in the quadriceps, the research underscores the practical benefits of integrating exoskeletons into industrial settings as a preventive ergonomic intervention. The use of electromyography (EMG) to measure muscle activity offers a precise and objective assessment, making the findings highly relevant for researchers and practitioners. The study's results could also inform guidelines and best practices for exoskeleton deployment, contributing to safer and more sustainable work environments.

1. INTRODUCTION

Load lifting is a fundamental and frequent activity across various industries, including but not limited to manufacturing, construction, and logistics. In these sectors, workers are routinely exposed to substantial physical loads, which, over time, can lead to the development of a range of musculoskeletal disorders (Botti & Melloni, 2024; Irawan et al., 2019; Pacifico et al., 2022). These disorders, such as lower back pain, shoulder strain, and joint injuries, are prevalent among workers who engage in repetitive and strenuous lifting tasks (Kinge et al., 2015; Mohd Nur et al., 2018; Theurel & Desbrosses, 2019a). The implications of these disorders are far-reaching, extending beyond the immediate discomfort and health issues faced by workers. They have a significant economic impact on both the individuals and the industries they serve, manifesting in decreased productivity, an increase in the number of sick days, and the subsequent costs associated with medical treatments and workers' compensation claims (Bevan, 2015; Fournier Daniel E. AND Yung, 2023; Haumaru Mahi, 2024).

In response to these challenges, the adoption of innovative technologies has become a focal point of interest. Among these, exoskeletons have been identified as a promising solution to mitigate the risks associated with heavy lifting (Alemi et al., 2019; Botti & Melloni, 2024; Li et al., 2021; Tadepalli et al., 2019). Exoskeletons are sophisticated, wearable devices designed to provide structural support to the body, thereby alleviating the physical strain experienced during demanding tasks. By redistributing the load and reducing the direct impact on key muscle groups, exoskeletons have the potential to enhance worker safety and well-being (Bao et al., 2019; Howard et al., 2020; Mohd Nur et al., 2018; Theurel & Desbrosses, 2019b),

However, despite the promising nature of these devices, their widespread adoption in the workplace requires rigorous, objective, and quantitative evaluations of their effectiveness. This is where electromyography (EMG) becomes invaluable. EMG is a crucial tool that measures the electrical activity of muscles during physical exertion, offering detailed insights into the muscle load and fatigue experienced by workers using exoskeletons (Lyu et al., 2019; Phinyomark et al., 2012; Raez et al., 2006). By leveraging EMG data, researchers can obtain a clear, evidence-based understanding of how exoskeletons impact muscle activity, enabling them to assess whether these devices genuinely reduce the risk of musculoskeletal disorders (Blanco et al., 2019). This study is therefore centered on exploring the effects of exoskeleton use on muscle load during load lifting activities, employing EMG measurements to ensure a thorough and scientifically robust evaluation.

2. OBJECTIVES

2.1 Evaluate the reduction of muscle load in workers using an exoskeleton during load lifting.

This objective focuses on measuring how the use of the exoskeleton influences muscle activity during load-lifting tasks. It is expected that the exoskeleton will provide significant support resulting in lower muscle activation, thereby reducing the risk of fatigue and injury.

2.2 Compare the levels of muscle activity, measured by EMG, in workers with and without the use of the exoskeleton.

Comparing EMG measurements under conditions with and without an exoskeleton will allow the establishment of quantitative differences in muscle load. This comparative analysis is crucial for understanding the extent of the exoskeleton's impact and validating its effectiveness as an ergonomic tool.

2.3 Determine the effectiveness of the exoskeleton in preventing musculoskeletal injuries in the long term.

While the focus of this study is on short-term muscle load analysis, it is important to consider the long-term implications of exoskeleton use. This objective involves a discussion of how the reduction in muscle load could translate into a decrease in the incidence of chronic musculoskeletal injuries.

3. METHODOLOGY

3.1 Participant Selection:

For this study, 3 workers from a manufacturing industry were recruited based on their experience in load-lifting tasks. Participants were informed about the study's purpose and provided with the necessary instructions for the tests. Inclusion and exclusion criteria were established to ensure group homogeneity and minimize external variables that could affect the results.

3.2 Instrumentation:

EMG data collection was carried out using surface electrodes placed on key muscles involved in load lifting, including the quadriceps and the gluteus maximus, and. These muscles were selected due to their relevance in the biomechanics of load lifting. EMG data were recorded using a high-precision data acquisition system, ensuring accurate capture of muscle electrical activity.

3.3 Procedure:

In this experiment, participants performed a series of standardized load-lifting tasks, both with and without the use of the exoskeleton. The lifting protocol was designed to replicate common workplace tasks where a load of 25 kg is lifting, ensuring the practical relevance of the results. The activity consisted of four repetitions of lifting and four repetitions of lowering a previously calculated weight, corresponding to each participant’s maximum load. Before each lifting session, a warm-up period was conducted to prevent injuries and ensure consistency in the measurements. Electromyography (EMG) sensors were placed on the participants' key muscles, recording electrical activity during each repetition, allowing for a detailed analysis of muscle response under maximum load conditions. The order in which participants performed tasks with and without the exoskeleton was randomized to control for potential learning or fatigue effects, thus ensuring the validity of the results obtained regarding muscle efficiency and effort during intense physical activities.

4. RESULTS

The results of the EMG analysis indicate a significant reduction in muscle activity among participants who used the exoskeleton, particularly in the quadriceps. This reduction is more pronounced during liftings, as it is in this phase where the quadriceps are primarily activated and maintain their activity throughout the execution of the cycles (Figure 1). Without the exoskeleton, the average maximum activation of the quadriceps during the lowering ranges from 544 to 652, whereas with the exoskeleton these values decrease to a range between 564 and 613, representing an average reduction of 9%. During the lifting, without the exoskeleton, activation values ranged from 542 to 641, but with the exoskeleton, they decrease to a range between 550 and 589, with a more significant reduction of 20%. The maximum values of the different muscles are shown in Table 1. These findings suggest that the exoskeleton provides effective support in situations of high physical demand, particularly during lifting, where muscle activation is more intense.

Figure 1 illustrates an example of the EMG signals from the quadriceps for a participant during load lifting with and without the exoskeleton, showing a clear decrease in the amplitude of the EMG signal when using the exoskeleton, confirming the observed reduction in muscle activation. The reduction in biomechanical load, especially during lifting, is consistent with the hypothesis that the exoskeleton decreases the muscular effort required to perform the task, which could have positive implications for reducing muscle fatigue and preventing injuries during repetitive or prolonged tasks. Although these results are promising, further studies are recommended to confirm these effects in the long term and to explore in greater depth the relationship between the reduction in muscle activity and the prevention of injuries. This analysis demonstrates that the exoskeleton is effective in reducing quadriceps muscle activation during load lifting, which could have positive implications for improving work efficiency and preserving musculoskeletal health.

Table 1. Maximum activation without and with the exoskeleton

Maximum activation					
Without exoskeleton		M1	M2	M3	M4
Lowering	Participant 1	697	717	545	541
	Participant 2	630	616	555	531
	Participant 3	605	623	562	561
	Average	644	652	554	544
Lifting	Participant 1	731	737	554	542
	Participant 2	573	576	544	527
	Participant 3	596	611	549	556
	Average	634	641	549	542
Maximum activation					
With exoskeleton		M1	M2	M3	M4
Lowering	Participant 1	630	616	555	531
	Participant 2	605	623	562	561

	Participant 3	605	601	601	601
	Average	613	613	573	564
Lifting	Participant 1	573	576	544	527
	Participant 2	596	611	549	556
	Participant 3	596	568	568	568
	Average	589	585	554	550

M1: left quadriceps, M2: right quadriceps, M3: left gluteus maximus, m4: right gluteus maximus. Muscle activation are showed in millivolts.

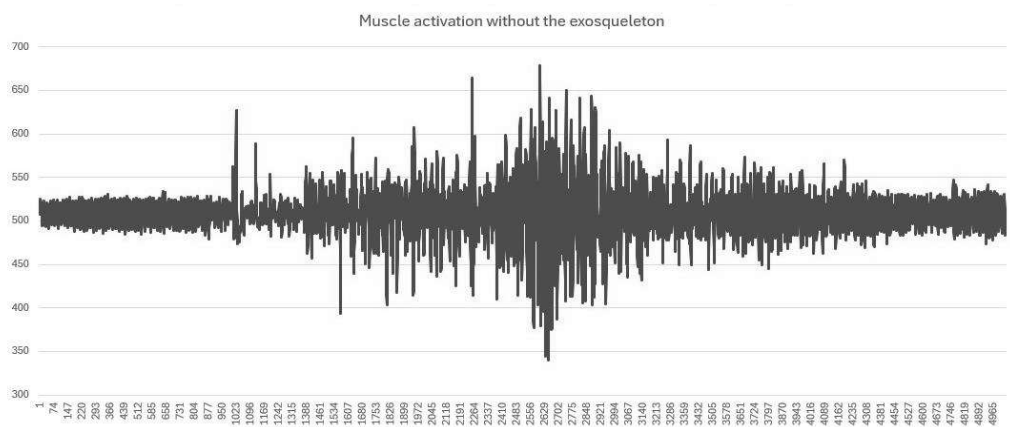

Figure 1. Muscle activation without the exoskeleton

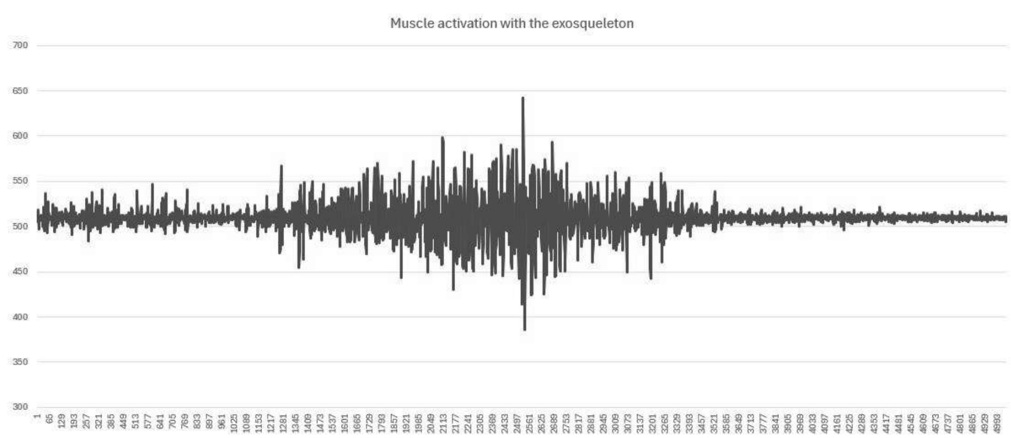

Figure 2. Muscle activation with the exoskeleton

5. DISCUSSION AND CONCLUSION

The findings of this study clearly demonstrate that the use of exoskeletons in load-lifting activities significantly reduces muscle activation, particularly in the quadriceps, as evidenced by EMG measurements. The observed reduction in muscle activity during both the lifting and lowering phases suggests that exoskeletons can effectively alleviate physical strain on workers, which is particularly beneficial in industries where repetitive lifting tasks are common. This reduction in muscle load not only enhances ergonomics but also potentially lowers the risk of musculoskeletal injuries over time, contributing to improved occupational health and safety.

The reduction in muscle activation by 9% during the lowering and up to 20% during the lifting highlights the exoskeleton's effectiveness in providing substantial support during physically demanding tasks. These results align with previous research suggesting that exoskeletons can redistribute load and reduce the direct impact on critical muscle groups, thereby mitigating the risk of fatigue and injury. The significant decrease in EMG signal amplitude when using the exoskeleton, as illustrated in Figure 1, further confirms its role in reducing the biomechanical load during load-lifting tasks.

However, this study is not without limitations. The small sample size of participants may limit the generalizability of the results. Additionally, the study focused on a specific type of exoskeleton and a limited range of load-lifting tasks, which may not fully represent the variety of conditions found in different industrial settings. Therefore, future research should include larger, more diverse participant groups and explore the effectiveness of different exoskeleton models across various industrial applications.

Moreover, while this study provides valuable insights into the short-term benefits of exoskeleton use, the long-term effects on muscle fatigue and overall occupational health remain to be fully understood. Future studies should investigate the impact of prolonged exoskeleton use, considering factors such as user comfort, adaptability to different tasks, and the potential for long-term reduction in injury rates

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