Medicina y Seguridad del Trabajo (Internet)
https://revistas.isciii.es/revistas.jsp?id=MST

E-ISSN: 1989-7790
NIPO: 156240044

doi: 10.4321/s0465-546x2025000400005
Original Article

Ergonomic risks in truck maintenance: task characterization and analysis with a normative and descriptive approach

Riesgos ergonómicos en la mantención de camiones: caracterización de tareas y análisis con enfoque normativo y descriptivo

Gabriela P. Urrejola-Contreras[1] 0000-0002-8370-4550
Miguel Pérez-Lizama[2] 0000-0002-7257-1713
Boris Gary-Zambra[3] 0000-0002-9809-3158
Daniela Pérez-Casanova [4] 0000-0001-6701-0578
[1]Universidad de Viña del Mar, Facultad de Ciencias de la Vida, Unidad de Ciencias Aplicadas, Viña del Mar, Chile
[2]Universidad de Viña del Mar, Facultad de Ciencias de la Vida, Carrera de Kinesiología, Viña del Mar, Chile
[3]Universidad de Viña del Mar, Facultad de Ingeniería, Negocios y Ciencias Agroambientales, Viña del Mar, Chile
[4]Investigador/a independiente, Santiago de Chile, Chile.

Correspondence

Gabriela Urrejola-Contreras
gabriela.urrejola@uvm.cl

Received: 01.10.2025
Accepted: 15.11.2025
Published: xx.12.2025

Authorship contribution

GU: Work design, data collection, drafting of the manuscript, and critical revision of its content. Final approval of the version to be published.
MP: Data analysis and interpretation, critical revision of its content. Final approval of the version to be published.
BG: Critical revision of its content. Final approval of the version to be published.
DP: Work design, data collection. Final approval of the version to be published.

Funding

This work did not receive any funding.

Conflict of interest

The authors declare no conflict of interest.

How to cite

Urrejola-Contreras GP, Pérez-Lizama M, Gary-Zambra B, Pérez-Casanova D. Ergonomic risks in truck maintenance: task characterization and analysis with a normative and descriptive approach. Med Segur Trab (Internet). 2025;71(281):253-265. doi: 10.4321/s0465-546x2025000400005

https://doi.org/10.4321/s0465-546x2025000400005

Abstract

Introduction: Physical ergonomic risks in the automotive sector contribute significantly to work-related musculoskeletal disorders, particularly low back pain. Evidence highlights high prevalence linked to manual load handling, awkward postures, and repetitive tasks. Research on heavy vehicle maintenance workers is scarce, underscoring the need to characterize risks and support preventive workplace interventions.

Method: This cross-sectional study in Santiago, Chile, assessed 256 male freight transport mechanics and cellar workers exposed to manual load handling. Evaluations included questionnaires, technical visits, and Chilean regulatory protocols: the MMH Guide and TS-WMSD Standard. These tools identified risks related to lifting, pushing, posture, repetition, and force, classifying them into levels requiring corrective measures. Data analysis employed descriptive statistics, prevalence, and percentages to characterize occupational risks and compare international methodologies.

Results: This study identified ergonomic risks among mechanics and cellar workers engaged in manual load handling. Lifting, lowering, and carrying tasks involved 206 workers, while 114 performed pushing and pulling. Mechanics predominated in the highest-risk categories (>60%), whereas cellar workers were more frequent in low/moderate levels. Main risks included vertical lifting position (70%), grip zone (56%), and trunk asymmetry (52%). According to the TS-WMSD protocol, repetitive movements and non-neutral postures reached 100% prevalence.

Conclusions: This study confirms significant ergonomic risks among mechanics and cellar workers. Mechanics face higher risks in lifting due to vertical positions, heavy loads, and postural asymmetry, while cellar staff encounter pushing/pulling hazards from poor grip zones. Limitations of the TS-WMSD protocol suggest complementing evaluations with REBA and NIOSH to enhance risk detection.

Keywords: Ergonomics; Workplace; Biomechanical Risk, Occupational health, Workload.

Resumen

Introducción: Los riesgos ergonómicos físicos en el sector automotriz contribuyen significativamente a los trastornos musculoesqueléticos laborales, especialmente dolor lumbar. La evidencia muestra alta prevalencia asociada a manipulación manual de cargas, posturas forzadas y tareas repetitivas. La investigación en mantenimiento de vehículos pesados es limitada, destacando la necesidad de caracterizar riesgos y apoyar intervenciones preventivas.

Método: Este estudio transversal en Santiago, Chile, evaluó a 256 hombres trabajadores mecánicos y de bodega expuestos a manipulación manual de cargas. La evaluación incluyó visitas técnicas, cuestionarios y protocolos chilenos: la Guía MMC y la Norma TMERT. Estas herramientas identificaron riesgos asociados a levantar, empujar, posturas, repetición y fuerza, clasificándolos en niveles que requieren medidas correctivas. El análisis usó estadísticas descriptivas, prevalencias y porcentajes, comparando metodologías internacionales de evaluación de riesgos laborales.

Resultados: Este estudio identificó riesgos ergonómicos en mecánicos y trabajadores de bodega involucrados en manipulación manual de cargas. Las tareas de levantar, bajar y transportar incluyeron a 206 trabajadores, mientras 114 realizaron empuje y tracción. Los mecánicos predominaron en los niveles de mayor riesgo (>60%), en tanto los bodegueros se concentraron en niveles bajo/moderado. Los principales riesgos fueron levantamiento vertical (70%), zona de agarre (56%) y asimetría del tronco (52%). El protocolo TMERT evidenció 100% de prevalencia en posturas no neutrales y movimientos repetitivos.

Conclusiones: Este estudio confirma riesgos ergonómicos significativos en mecánicos y trabajadores de bodega. Los mecánicos enfrentan mayores riesgos en levantamiento por posturas verticales, cargas pesadas y asimetrías, mientras que los bodegueros presentan riesgos en empuje/arrastre por zonas de agarre deficientes. Las limitaciones del protocolo TMERT sugieren complementar con REBA y NIOSH para mejorar la detección.

Palabras clave: Ergonomía; Lugar de trabajo; Riesgo biomecánico; Salud ocupacional.

https://doi.org/10.4321/s0465-546x2025000400005

Introduction

Physical ergonomic risks are one of the main causes of work-related musculoskeletal disorders (WMSDs), and the automotive industry is no exception, showing a high prevalence of ailments particularly affecting the lower back, neck, and shoulders [(1)]. For instance, a study conducted in 50 Chinese automotive companies estimated a 32.8% prevalence of WMSDs among workers engaged in assembly and mechanical tasks [(2)]. Similarly, research involving 43 automotive repair workshops found that 80% of workers performing vehicle maintenance experienced lower back pain. The variables most strongly associated with this pain were inappropriate postures such as squatting and insufficient rest time between task-related postural changes [(3)].

The automotive sector employs a large workforce subjected to highly repetitive tasks, prolonged working hours, and considerable physical demands across manufacturing, assembly, maintenance, and repair activities [(4-6)]. However, the magnitude and nature of ergonomic risks can vary depending on the vehicle type and specific job tasks. For example, a study involving 496 small vehicle repair workshops identified different risk categories depending on the specific occupation of the mechanical worker. The highest postural risk was found among workers performing body repair tasks, while moderate risks were more prevalent in those involved in electronics and painting tasks [(7)]. Furthermore, research conducted at Scania's truck manufacturing plant found significant variations in risk patterns across different truck models, concluding that such differences stemmed from variations in workstations [(8)]. Consequently, results obtained in automated settings may not fully capture the ergonomic challenges inherent to manual truck maintenance work.

Although international studies have examined ergonomic risk factors in vehicle parts production and assembly systems, research specifically addressing the physical demands and ergonomic risks faced by heavy-duty vehicle maintenance and repair workers remains scarce. This is even more the case when considering studies focused on a population of workers performing specific tasks characterized by less standardized workspaces and minimal automation [(9)]. In this regard, the main comparative difference with highly automated manufacturing plants lies in the fact that heavy vehicle maintenance workshops involve manual, physically demanding operations in confined spaces and the use of awkward postures.

Manual load handling is an inherent component of most mechanical operations, involving the lifting and lowering of objects at inadequate heights, unhealthy horizontal distances when carrying loads with the hands far from the spine, and asymmetric or twisting when coupling a load whose manual grip area is uncomfortable. These activities pose an ergonomic risk, especially when performed with awkward postures and in a repetitive manner [(10–12)].

Some research has identified the types of manual handling activities performed by workers engaged in truck maintenance and repair, concluding that the most aggravating factors include asymmetric load handling over the back, the distance between the hands and the back during lifting, poor grip, and inadequate coupling between the hand and the object due to the irregular characteristics of the load [(13)].

Various tools and guidelines are available to assess ergonomic risks, with general technical guidelines are typically used as an initial approach for risk identification. In Chile, this assessment is carried out using protocols and standards focused on identifying and controlling risk factors related to manual handling of loads (such as load weight, frequency, lifting distance, grip zones, body posture, and the presence of asymmetry or twisting during handling), as well as those associated with work-related musculoskeletal disorders including non-neutral postures, repetitive movements, pace and workload, exposure time, environmental conditions, and vibration [(14)].

Despite this, research specifically targeting mechanical workers remains limited, representing a critical knowledge gap given the ergonomic demands of this sector. Understanding these risks is essential not only for worker health but also for reducing absenteeism, improving productivity, and informing workplace interventions. Therefore, the aim of this study was to characterize ergonomic risks among workers involved in manual load handling in the heavy transport mechanical sector.

Methods

This was a cross-sectional study conducted in Santiago, Chile, in a company within the freight transport mechanics sector during August 2025. The company employs 256 male dedicated to truck repair and maintenance tasks. From this population, two occupational groups were selected for evaluation: mechanics and cellar workers, based on the nature of their tasks involving manual load handling. The inclusion criteria were a full-time work schedule (44 hours per week) and a permanent employment contract.

The evaluation process comprised three stages. In the first stage, a technical visit was carried out to identify the workers' occupations and their main tasks. During this visit, workers were invited to participate, and they voluntarily agreed to take part.

Regarding the tasks, those involving lifting, lowering, and carrying loads were performed by 206 individuals, while tasks involving pushing and pulling were carried out by 114 workers. Sixty-four workers performed both types of tasks; therefore, they were counted twice to identify the risk associated with each group of tasks performed. Figure 1.

In the second stage, the researcher administered a questionnaire on personal and work-related background to the workers to carry out a later characterization. In a third phase, the presence of work-related risks was assessed using two instruments currently in force under Chilean regulations: a) the Technical Guide for the Evaluation and Control of Risks Associated with Manual Handling of Loads (MMH), and b) the Technical Standard for the Identification and Evaluation of Risk Factors for Work-Related Musculoskeletal Disorders (TS-WMSD).

Description of the protocols

Chilean Technical Guide for the Evaluation and Control of Risks Associated with Manual Material Handling (MMH)

Is a preventive protocol applicable to all companies handling loads over 3 kg. It has four stages—identification, evaluation, control, and assurance of risk mitigation. The process starts with key questions about lifting, pushing, or repetitive tasks to detect risks, classifying them as acceptable, critical, or non-critical. If risk is found, evaluation tools such as NIOSH, MAC, RAPP, or KIM are used to assign a risk score based on load weight, posture, frequency, and environment. Critical risks require immediate correction, and companies must periodically verify the effectiveness of control measures.

Technical Standard for the Identification and Evaluation of Risk Factors for Work-Related Musculoskeletal Disorders (TS-WMSD).

Is a mandatory protocol focused on upper-limb musculoskeletal disorders. It uses a four-stage checklist covering task repetitiveness, posture, force, and recovery time through direct observation. Risk is classified using a color-coded system: green (acceptable), yellow (moderate), and red (critical). The standard also considers physical, environmental, organizational, and psychosocial factors, requiring specific validated methods if critical risks persist, thus supporting preventive actions and continuous improvement in occupational health.

Analysis and Statistics

All the data obtained were compiled in an Excel spreadsheet for subsequent analysis. For the analysis, descriptive statistics, measures of central tendency, and measures of dispersion were used. Percentage distributions and prevalence calculations were included to compare levels and patterns of risk, types of tasks, and occupations.

https://doi.org/10.4321/s0465-546x2025000400005

Ethical Considerations

The study considered the necessary ethical safeguards and obtained informed consent from the workers, which specified the voluntary nature of participation, the anonymity of the data, and its use exclusively for research purposes.

Figure 1: Examples of tasks performed in each workshop occupation.

A–B. Lifting, carrying, and lowering tasks, as well as pushing and pulling tasks, performed by a mechanic, respectively. C–D. Lifting, carrying, and lowering tasks, as well as pushing and pulling tasks, performed by a cellar worker, respectively.

Results

The largest number of workers were engaged in activities involving lifting, lowering, and carrying loads (206) in comparison to pushing and pulling activities (114). Some workers performed both types of tasks. For both activities, the age of workers was between 18 and 45 years of age. Regarding task occupation, the workers involved in lifting, lowering, and transporting loads, correspond to mechanic (128) and cellar worker (78) (Table 1).

Table 1. Descriptive characteristics of the workers by demographics and working conditions.

	Total	
	n	%
Workstation		
Mechanics	162	63.2%
Cell workers	84	32.7%
Painter	5	2.0%
Dent removal workers	5	2.0%
Task distribution		
Lifting, lowering, and transporting	206	80.5%
Pushing and pulling	114	44.5%
Weekly working hours		
Half time (22 hrs per week)	0	0%
33 hrs per week	0	0%
Full time (44 hrs per week)	256	100%
Age (yr)		
<18	0	0%
18-45	252	98.4%
>45	4	1.6%

Distribution of workers according to their risk level

Figure 2 displays the percentage distribution of workers across risk levels (low, moderate, and high) for lifting, lowering, and carrying activities. The lowest risk group has the lowest proportion of workers, while the highest risk group has the highest proportion (Fig. 2A). In addition, the cellar workers are more represented in the low and moderate risk levels compared to mechanics. However, at the highest risk level, most workers are mechanics, with a percentage over 60%, while cellar workers have a lower proportion in this category (Fig. 2B).

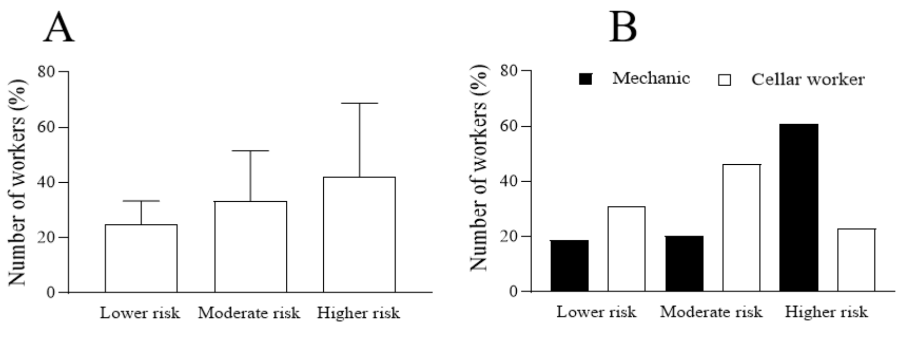

Figure 2. Percentage distribution of workers according to their risk level (low, moderate, and high) engaged in activities involving lifting, lowering, and carrying loads under MMH protocol.

A. An increase in the percentage of workers is observed as the risk level increases. B. Cellar workers are more represented in the low and moderate risk levels compared to mechanics. While, at the highest risk level, most workers are mechanics, with a percentage over 60%, while cellar workers have a lower proportion in this category.

Figure 3, shows the percentage of distribution workers according to their risk level (low, moderate, and high) engaged in activities involving pushing and pulling. workers with low and high risk have similar proportions, both close to 50%, while there is no representation in the moderate-risk category (Fig. 3A). Cellar workers are more represented in the low risk levels compared to mechanics. with a percentage over 60%, while they also predominate over mechanics in the lower-risk category. In contrast, mechanical workers have the greatest representation in the highest risk category, with a percentage close to 70%, while cellar workers have a lower percentage in this category (Fig. 3B).

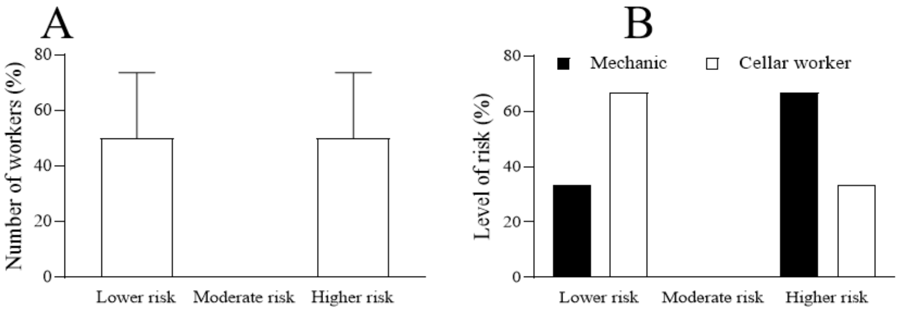

Figure 3. Percentage distribution of workers according to their risk level (low, moderate, and high) engaged in activities involving pushing and pulling under MMH protocol .

A. workers with low and high risk have similar proportions, both close to 50%, while there is no representation in the moderate-risk category. B. Cellar workers are more represented in the low risk levels compared to mechanics. with a percentage over 60%, while they also predominate over mechanics in the lower-risk category. In contrast, mechanical workers have the greatest representation in the highest-risk category, with a percentage close to 70%, while cellar workers have a lower percentage in this category.

Table 2 shows the cases and prevalence of main risks of lifting and lowering (206 workers evaluated) and push and pull (114 workers evaluated). The of loads over 10 kg is the most prevalent risk, at 60%. Both the weight of the load and the horizontal distance between the hands and the load have a prevalence of 44% each. Both the characteristic of the load and the asymmetry, rotation or inclination of the trunk have a prevalence of 52% each and the vertical lifting position have a prevalence of 70%. The grip zone is the main risk detected in push and pull with a prevalence of 56%.

Table 2. Prevalence of ergonomic risk factors according to the MMH protocol

Main risks detected in lifting and lowering	Cases (n)	Prevalence (%)
Loads exceeding 10 kg	124	60
Load characteristics	107	52
Weight of the load	91	44
Vertical lifting position	144	70
Horizontal distance between hands and load	91	44
Asymmetry, rotation or inclination of the trunk	107	52
Main risks detected in push and pull	**Cases (n)**	**Prevalence (%)**
Grip zone	64	56

According to the TS-WMSD protocol assessment, most workers were classified in the low-risk category (20%), although with great variability reflected in the error bar (standard deviation, Figure 4A). In contrast, the moderate and high-risk levels have considerably lower percentages, both below 5%, with little variability in the data (Fig. 4A). The figure 4B, shown the percentage distribution of workers according to their risk level (low, moderate, and high) for four occupational groups: dent removal workers, mechanics, cellar workers, and painters. Low risk: Mechanics represent the largest proportion in this category, with a percentage close to 60%, while the other groups have significantly lower values. Moderate and high risk: The distribution is more balanced among the four groups, with low percentages and no marked differences between them. It is observed that most mechanics are concentrated in the low-risk group, while the other groups have a more homogeneous distribution across the different risk levels (Fig. 4B).

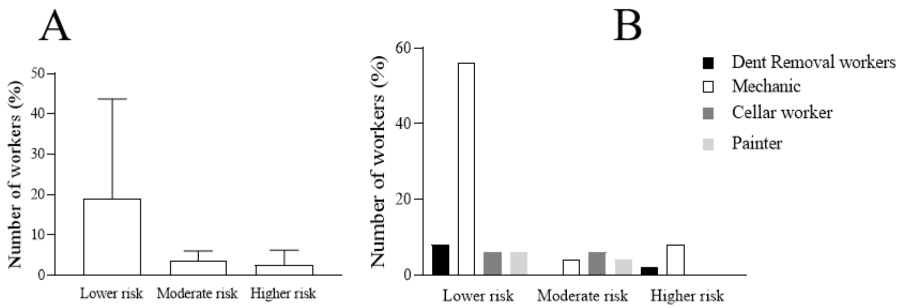

Figure 4. Percentage distribution of workers according to their risk level under TS-WMSD protocol.

A. *Most workers are in the low-risk category (~20%) with high variability; moderate and high-risk levels are both below 5%.* B.*Mechanics show the highest proportion of low-risk workers (~60%), while other groups have lower values. Moderate and high-risk levels are evenly distributed across all occupations, with generally low percentages.*

Main risks detected in workplaces according to the TS-WMSD protocol (Table 3). The presence of repetitive movements, the use of non-neutral postures and movements, cold exposure, lots of work for working hours and work pace imposed by other people have a prevalence of 100%, while use of vibrating tools and impact have a prevalence of 20%.

Table 3. Prevalence of ergonomic risk factors according to the TS-WMSD protocol

Main risks detected in jobs	Cases (n)	Prevalence (%)
Presence of repetitive movements	114	100
Use of non-neutral postures and movements	114	100
Cold exposure	114	100
Use of vibrating tools and impact	23	20
Lots of work for working hours	114	100
Work pace imposed by other people	114	100

https://doi.org/10.4321/s0465-546x2025000400005

Discussion

The study confirms the presence of ergonomic risk in the tasks performed by mechanics and cellar operators. Mechanics show a higher risk during vertical lifting tasks, while cellar operators are more exposed during pushing and pulling tasks due to poor grip zones, similar to findings reported in other studies [15,16]. Musculoskeletal disorders are mainly associated with forced work rhythms, non-neutral postures, and cold conditions.

A first analysis arises from differentiating the risk level in the activities performed by mechanics and cellar operators. The higher proportion of workers with high risk in lifting and lowering tasks is mainly determined by the vertical lifting position, loads exceeding 10 kg, load characteristics, and postural asymmetries—factors that increase physical effort [17,18]. The implication is clear: a greater vertical distance traveled with a load makes the task more demanding and physically taxing for the spinal muscles [19,20]. Likewise, design limitations restrict grip or handling when objects are not sufficiently ergonomic—whether due to their size, shape, or handle type—affecting the horizontal distance between the hands and spine and overloading the lumbar area and limbs during material handling [21-23].

In pushing and pulling tasks, mechanics again show the highest proportion of high-risk levels, mainly due to poor grip zones related to handle design, which interferes with the applied effort [24].

A second point relates to the application of the TS-WMSD protocol, where data appeared somewhat contradictory. Although most mechanics were classified as low risk, they simultaneously reported a high prevalence of risk factors such as non-neutral postures and repetitiveness [25]. This discrepancy may be due to limitations of the instrument, such as the low sensitivity of the protocol to discriminate and detect risk in specific manual tasks, leading to an overestimation of risk across all exposures.

Therefore, it may have difficulties in sufficiently weighting the combination of repetitiveness and awkward posture if other variables such as intensity, duration, or exposure dose are not met [26]. In other words, the instrument combines risk factors in low, moderate, and high magnitudes, and if the force or exposure time score is low, it could shift the result toward a low-risk condition, even when awkward postures have been observed. Conversely, and following this reasoning, if awkward postures occur over short periods of time, they may be assigned a low score, even when they are repetitive.

Therefore, the TS-WMSD protocol may struggle to adequately weight the combination of repetitiveness and awkward postures when other variables—such as intensity, duration, or exposure dose—are not met [26]. In other words, the instrument combines risk factors in low, moderate, and high magnitudes, and if the force or exposure time score is low, the result could shift toward a low-risk condition even when awkward postures are observed. Conversely, following this logic, if awkward postures occur over short periods, they may be assigned a low score even when they are repetitive.

Furthermore, if this worker population had been evaluated using the REBA method (widely used to assess posture-related risk), a higher risk classification would likely have been observed even in tasks that the MMH considered moderate risk, since REBA is more sensitive to forced or repetitive postures, even when assessing light loads [27]. In this sense, workers who experience trunk rotation, inclination, and excessive vertical postures during lifting could receive a higher risk weighting. Similarly, if the assessment had been conducted using the NIOSH equation for jobs involving lifting and lowering loads, postural risks in repetitive tasks might have been underestimated, as this method prioritizes load weight, distance, height, and lifting frequency—possibly resulting in a Lifting Index (LI) > 1, particularly due to load size [28].

Therefore, this comparison suggests that the evaluation carried out with Chilean regulatory protocols could be complemented with the REBA method to detect posture-related risks, while the NIOSH equation would primarily address the effects of weight, distance, and lifting frequency—minimizing bias and reducing the likelihood of overestimation or underestimation (29-31). This highlights that the recognition of ergonomic risk is heterogeneous and that workers' occupation, task nature, exposure time, and the sensitivity of assessment instruments must all be considered [32,34].

Considering the methodology used in Chilean regulatory protocols and other internationally recognized standard tools or methods, such as the NIOSH lifting equation and the REBA method, it is important to emphasize that the main methodological differences lie in their focus, technical depth, and applicability. The Technical Guide for Manual Material Handling (MMH) proposes a progressive approach, starting with a basic identification stage and advancing toward a more in-depth evaluation that incorporates complementary methods such as the NIOSH equation and REBA. Specifically, the NIOSH lifting equation uses a numerical, precise, and quantitative approach that requires biomechanical knowledge and highly specialized technical training for its application. The REBA method, on the other hand, assigns scores based on observed postures, introducing a subjective dimension.

The TS-WMSD protocol, in addition to detecting biomechanical risks, integrates ergonomic analysis with clinical criteria and addresses them through a continuous medical surveillance program aimed at risk mitigation. Therefore, this tool can be applied in a mixed context involving both ergonomics and occupational health (Appendix 1).

Finally, ergonomic risks are widespread among mechanics and cellar operators in freight transport workshops. Mechanics are particularly affected by vertical lifting tasks and poorly designed workstations, while cellar operators are more exposed to pushing and pulling risks linked to inadequate grip zones. These findings underscore the need for occupation-specific ergonomic assessments and preventive strategies to reduce musculoskeletal disorders and improve workplace safety.

Limitations

The main limitations of this study include the exclusive use of Chilean regulatory protocols (MMH and TS-WMSD), whose sensitivity to detect certain postural or repetitive risk factors may be limited, potentially leading to an over- or underestimation of actual risk. Additionally, the cross-sectional design prevents establishing causal relationships between ergonomic exposure and musculoskeletal disorders, suggesting that future studies should incorporate international tools and longitudinal follow-up for a more comprehensive assessment.

Bibliografía

1. Zare M, Bodin J, Sagot J, Roquelaure Y. Quantification of exposure to risk postures in truck assembly operators: neck, back, arms and wrists. Int J Environ Res Salud Pública. 2020;17(7):6062. DOI: https://doi.org/10.3390/ijerph17176062

2. Zhang H, Deng H, Jia N, Chen F, Li X, Cao L, et al. Epidemiological study of work-related musculoskeletal disorders and related risk factors among automobile maintenance workers. Work. 2023;76(3):1219–31. DOI: https://doi.org/10.3233/WOR-220412

3. Shern T, Subramaniam A, Purushothaman V. Prevalence of low back pain and associated risk factors among car mechanics in Malacca, Malaysia. Inti Journal [Internet]. 2020;37. Available in: https://intijournal.intimal.edu.my/

4. Spallek, M., Kuhn, W., Uibel, S. *et al.* Trastornos musculoesqueléticos relacionados con el trabajo en la industria automotriz debido al trabajo repetitivo: implicaciones para la rehabilitación. *J Occup Med Toxicol. 2010;* 5 ,6. DOI: https://doi.org/10.1186/1745-6673-5-6

5. Sirzai H, Dundar EA. A cross-sectional study determining the prevalence of musculoskeletal diseases in automotive factory workers: Occupational musculoskeletal diseases. J Surg Med. 2022;6(10):868-72. DOI: https://doi.org/10.28982/josam.1050531

6. Hosseini, Z.S.J., Mokhtarinia, H.R., Vahedi, M. *et al.* Prevalence and multivariate analysis of risk factors associated with musculoskeletal disorders among automotive assembly workers: a cross-sectional study. *BMC Public Health. 2025;* 25, 2710. DOI: https://doi.org/10.1186/s12889-025-23987-4

7. Adesope W, Onawumi A, Adeyanju S, Ajayeoba A, Oyetunji O, Fajobi M, et al. Effects of ergonomic intervention approach on Ssome occupational hazards in automobile workshop in south western Nigeria. Arid Zone Journal of Engineering, Technology and Environment [Internet]. 2024;20(4):936–46. Available in: mhttps://www.azojete.com.ng/index.php/azojete/article/view/996

8. Zare M, Malingue A, Hoglund R, Biau S, Roquelaure Y. Evaluation of ergonomic physical risk factors in a truck manufacturing plant: case study in SCANIA Production Angers. Ind Health. 2016;54(2):163–76. DOI: 10.2486/indhealth.2015-0055.

9. Cardoso M, Fulton F, McKinnon C, Callaghan, J. P., Johnson, M. J., & Albert, W. Ergonomic evaluation of a new truck seat design: a field study. International journal of occupational safety and ergonomics: JOSE, 2019; 25(3), 331–343. DOI: https://doi.org/10.1080/10803548.2017.1348056

10. Tamene A, Mulugeta H, Ashenafi T, Thygerson S. Musculoskeletal disorders and associated factors among vehicle repair workers in Hawassa City, Southern Ethiopia. Journal of Environmental and Public Health. 2020;1:9472357. DOI: https://doi.org/10.1155/2020/9472357

11. Liaqat S, Jawad M, Rauf W, Zahra M. Frequency of work-related low back pain and disability among automobile mechanics in Lahore: low back pain and disability in automobile mechanics. Pakistan Journal of Physical Therapy (PJPT). 2020;3(3):20–3. DOI: https://doi.org/10.52229/pjpt.v3i3.906

12. Kamarudzaman M, Rahman M, Zaki N. Risk assessment of pushing and pulling (RAPP) among mechanics at tyre service center. En Singapore: Springer; 2024. p. 675–85. DOI: https://doi.org/10.1007/978-981-97-0169-8_56

13. Morales-Perrazo L, Ramón-Díaz L, Collantes-Vaca S, Aldas-Salazar D. Riesgo ergonómico por levantamiento de cargas: caso de estudio "Talleres de mantenimiento vehicular de maquinaria pesada". Revista Científica y Tecnológica UPSE (RCTU). 2019;6(1):17–26. DOI: https://doi.org/10.26423/rctu.v6i1.328.

14. Villanueva C, Cornejo P, Olivares F, Pisón M, Verasay N. Visión sobre las normas relacionadas a la detección y control de los factores de riesgo de TMERT y MMC desde la ergonomía: ¿son un aporte para la intervención ergonómica y la transformación del trabajo?: ergonomía, vigilancia y calificación de los TME. Atacama Journal of Health Sciences [Internet]. 1 (Supl 2):P7-C04. Available in: https://www.researchgate.net/profile/Carlos-Ibarra-Villanueva/publication/363349729_Vision_sobre_las_normas_relacionadas_a_la_deteccion_y_control_de_los_factores_de_riesgo_de_TMERT_y_MMC_desde_la_ergonomia_son_un_aporte_para_la_intervencion_ergonomica_y_la_trasformacion_del_trabajo/links/6318d5cd071ea12e36162f58/Vision-sobre-las-normas-relacionadas-a-la-deteccion-y-control-de-los-factores-de-riesgo-de-TMERT-y-MMC-desde-la-ergonomia-son-un-aporte-para-la-intervencion-ergonomica-y-la-trasformacion-del-trabajo.pdf

15. Eynipour A, Arjmand N, Dianat I, Soltanian A, Heidarimoghadam R. Assessing musculoskeletal disorder risks in an automobile part manufacturing factory: a comparison study of biomechanical and ergonomic tools. Health Scope. 2024;13(2):e139610. DOI: https://doi.org/10.5812/healthscope-139610 .

16. Nazemi H, Salmani M, Sabokroozroozbahani F, Ebadi Y, Fathallah F, Parnianpour M. Musculoskeletal injury risk assessment and intervention at a car manufacturer using various ergonomics and biomechanical tools. Scientia Iranica. 2025;1–29. DOI: 10.24200/sci.2025.64576.9028

17. Orgianus Y, Achiraeniwati E, Rausan M, Oemar H. Optimizing ergonomic work facilities in distribution logistics to prevent manual lifting injuries. Acta Logistica (AL). 2024;11(4):615–25. DOI: https://doi.org/10.22306c/al.vlli5.559

18. Flores-Guillén R, Palomino-Baldeón J. Cambio del nivel de riesgo ergonómico en posturas forzadas y movimiento repetitivo por rediseño de máquina sopladora de botellas de plástico. Rev Asoc Esp Espec Med Trab [Internet]. 2023;32(4):330–44. Available in: http://scielo.isciii.es/scielo.php?script=sci_arttext&pid=S3020116020230004000 07&lng=es.

19. Lim S. Exposures to select risk factors can be estimated from a continuous stream of inertial sensor measurements during a variety of lifting-lowering tasks. Ergonomics. 2024;67(11):1596–611. DOI: https://doi.org/10.1080/00140139.2024.2343949

20. Fang N, Zhang C, Lv J. Effects of vertical lifting distance on upper-body muscle fatigue. Int J Environ Res Salud Pública. 2021;18(10):5468. DOI: https://doi.org/10.3390/ijerph18105468

21. Donisi L, Cesarelli G, Capodaglio E, Panigazzi M, D'Addio G, Cesarelli M, et al. A logistic regression model for biomechanical risk classification in lifting tasks. Diagnostics. 2022;12(11):2624. DOI: https://doi.org/10.3390/diagnostics12112624

22. Dewantari N, Taqdisillah C, Mangaranap R, Mariawatti A, Herlina L. Optimizing worker safety: A case study on lifting load and body posture in rice cellar operations. Journal Industrial Servicess. 2024;10(1):63–8. DOI: http://dx.doi.org/10.62870/jiss.v10i1.24479

23. Kumar R, Banga H, Kumar R, Singh S, Singh S, Scutaru M, et al. Ergonomic evaluation of workstation design using taguchi experimental approach: a case of an automotive. Int J Interact Des Manuf. 15:481–98. DOI: https://doi.org/10.1007/s12008-021-00776-y

24. Wang, M. J., Chung, H. C., & Chen, H. C. The effect of handle angle on MAWL, wrist posture, RPE, and heart rate. Human factors. 2020; *42*(4), 553–565. DOI: https://doi.org/10.1518/001872000779698079

25. Hafez K. Occupational discomfort and injuries among automotive technicians in Jeddah, Saudi Arabia: A cross-sectional study. Work. 2022;73(4):1203–16. DOI: https://doi.org/10.3233/WOR-210522

26. Grooten, W.J.A., & Johansson, E. Observational methods for assessing ergonomic risks of work-related musculoskeletal disorders: A scoping review. Journal of Health Sciences. 2018; 16 (Special), 8–38. DOI: https://doi.org/10.12804/revistas.urosario.edu.co/revsalud/a.6840

27. Tanase M, Chivu O, Tapirdea A, Nitoi D, Petrescu V. Research regarding works ergonomics in automotive repair shop. IOP Conf. Ser. Mater. Sci. Eng. 2021; 1182 012078; DOI: doi:10.1088/1757-899X/1182/1/012078

28. Kamarudzaman M, Rahman M, Zaki N. Manual Handling Risk Assessment using NIOSH Lifting Equation among Mechanics at Tyre Service Centre. Human Factors and Ergonomics Journal (HFEJ) 2022; 7 (2): 20 – 27. Available in: https://hfej.hfem.org/wp-content/uploads/2022/12/Paper-3-MAZLINA_HFEJ_2022_niosh-lifting-equation-revised.pdf

29. Asadi N, Sadeghi M. Investigating the relationship between environmental and cognitive ergonomics with work-related musculoskeletal disorders: A case study in an automobile industry. Work. 2025;80(2):514–27. DOI: https://doi.org/10.3233/WOR-240275

30. Mahboobi M, Taghipour M, Ali Azadeh M. Assessing ergonomic risk factors using combined data envelopment analysis and conventional methods for an auto parts manufacturer. Work. 2020;67(1):113–28. DOI: https://doi.org/10.3233/WOR-203257

31. Oktavera R, Sarifudin M, Cahyono W, Fais M, Deviyanti I. Evaluating and mitigating musculoskeletal risks among the operators: a case study in a small-scale automotive repair workshop. Jurnal Penelitian Pendidikan IPA. 2025;11(4):372–81. DOI: 10.29303/jppipa.v11i4.10682

32. Oliver-Hernández C, Li S, Aguado-Benedí M, Mateo-Rodríguez I. New challenges regarding the intervention of musculoskeletal risk in truck service garages. Sustainability. 2021;14(21):181. DOI: https://doi.org/10.3390/su1401018

33. Rodríguez Diez-Caballero B, Alfonso-Beltrán J, Bautista I, Barrios C. Occupational risk factors for shoulder chronic tendinous pathology in the Spanish automotive manufacturing sector: a case-control study. BMC Musculoskelet Disord. 2020;21(818). DOI: https://doi.org/10.1186/s12891-020-03801-5

34. Chintada A, Umasankar V. Improvement of productivity by implementing occupational ergonomics. Journal of Industrial and Production Engineering. 2022;39(1):59–72. DOI: https://doi.org/10.1080/21681015.2021.1958936

https://doi.org/10.4321/s0465-546x2025000400005

Appendix 1

Comparative Table:

Chilean Technical Guide vs NIOSH vs REBA vs TS-WMSD Protocol

Criterion	Chilean Technical Guide* (MMH)	NIOSH Lifting Equation	REBA (Rapid Entire Body Assessment)	TS-WMSD Protocol
Main focus	Prevention and control of risks in manual handling of loads or people	Quantitative risk assessment for lifting tasks	Overall postural assessment (whole body)	Surveillance of work-related musculoskeletal disorders in upper limbs
Type of tasks assessed	Lifting, lowering, carrying, pushing, and pulling	Vertical lifting of inanimate loads	Tasks involving awkward or sustained postures	Activities with repetitive movements, force, sustained postures
Applicability	Chile, with legal support (Law 20.001 and Supreme Decree No. 63)	International, especially USA	International, particularly for quick field assessments	Chile, mandatory in contexts with biomechanical exposure
Variables considered	Weight, frequency, posture, duration, load characteristics, environment	Load weight, initial/final height, horizontal distance, frequency, twisting, asymmetry, grip	Angles of body segments, load, dynamic and static activity	Frequency, force, posture, recovery, symptoms, clinical results
Methodology	Identification (basic and advanced) + technical evaluation using different methods (MAC, KIM, NIOSH)	Mathematical formula with multipliers and Recommended Weight Limit (RWL)	Scoring based on observed posture + force + repetitiveness	Exposure assessment + periodic clinical surveillance + risk classification
Level of expertise required	Low for identification; medium-high for evaluation	High (requires specific calculations)	Medium (requires observation and basic ergonomics knowledge)	Medium-high (requires health and ergonomics professionals)
Final outcome	Determines acceptable, critical, or evaluation-needed condition	Lifting Index (LI), risk if LI > 1	Risk level (very low to very high) with recommended actions	Risk classification (low, medium, high) and referral for medical surveillance
Advantages	Legally enforceable in Chile and detailed	Accurate and scientifically validated for lifting	Quick, practical, comprehensive; useful for prioritizing interventions	Integrates occupational health with risk management; clinical and preventive approach
Limitations	Focused on national context; less useful outside Chile	Limited to symmetrical lifting and standard tasks	Subjectivity in observation; less detailed for force and frequency	Limited to upper limbs; requires specific conditions for application

* Chilean regulation: Technical guide for the evaluation and control of risks associated with manual load handling.

** Chilean regulation: Surveillance protocol for work-related musculoskeletal disorders.