



The anthropometric debt of Venezuelan industry: between the law and the reality of the worker

La deuda antropométrica de la industria venezolana: entre la ley y la realidad del trabajador

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Submitted: 04-07-2026 | Revised: 10-09-2026 | Accepted: 14-10-2026 | Published: 15-10-2026

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ABSTRACT

The objective of this study was to analyze the validity and applicability of anthropometric and biomechanical studies conducted on Venezuelan workers as a basis for the ergonomic design of workstations in the national industry. A comprehensive literature review was conducted in the form of an academic essay, incorporating critical analysis. The following databases were consulted: Scopus, Dialnet, Latindex, RePEc/IDEAS, EconPapers, and MIAR. The following criteria were used to compile the sample of studies. The study considered five inclusion criteria. The preliminary results indicate that the anthropometric and functional measurement protocols that have been validated among Venezuelan workers have the potential to facilitate ergonomic assessments through the use of predictive models and low-cost instruments. However, it should be noted that limitations, including issues related to sample size and representativeness, as well as potential biases associated with gender and age, have been identified. The conclusions indicate that incorporating these findings reinforces a rigorous approach to ergonomics that is applicable to the Venezuelan context, making ergonomic assessment more accessible and enabling companies to comply with the LOPCYMAT without compromising their economic sustainability.

Keywords: occupational ergonomics; anthropometry; biomechanics; Venezuelan workers.

RESUMEN

El presente ensayo, tuvo como objetivo analizar la validez y aplicabilidad de los estudios antropométricos y biomecánicos realizados en trabajadores venezolanos, como fundamento para el diseño ergonómico de puestos en la industria nacional. Se realizó una investigación documental tipo ensayo académico de revisión y análisis crítico. Las bases de datos consultadas incluyen Scopus, Dialnet, Latindex, RePEc/IDEAS, EconPapers, MIAR. Se consideraron cinco criterios de inclusión. Los resultados preliminares destacan que los protocolos de medición antropométrica y funcional validados en trabajadores (as) venezolanos permiten simplificar evaluaciones ergonómicas mediante modelos predictivos e instrumental de bajo costo, aunque se identifican limitaciones como el tamaño y representatividad de la muestra, y el sesgo de género y edad. Las conclusiones señalan que la integración de estos hallazgos consolida una ergonomía rigurosa y aplicable al contexto venezolano, democratizando la evaluación ergonómica y permitiendo a las empresas cumplir con la LOPCYMAT sin comprometer su sostenibilidad económica.

Palabras clave: ergonomía ocupacional; antropometría; biomecánica; trabajadores venezolanos.

INTRODUCTION

Occupational health in Latin American countries has been conditioned by a structural gap: the design of jobs, the importation of machinery, and the selection of personal protective equipment (PPE) are predominantly based on anthropometric tables and biomechanical indicators from Anglo-Saxon or European populations. The incorporation and installation of this equipment without prior anatomical adaptation force local workers to adopt forced postures and perform biomechanical overexertions that, cumulatively, severely compromise their health and physical integrity(1).

In Venezuela, this problem has been accentuated by the lack of updated national anthropometric databases. However, recent studies led by Ron et al.,(2-3), Labrador Parra et al. (4-5-6), and Burgos Navarrete et al.(7) have provided solid scientific evidence. These studies address a range of topics, from the reproducibility of hand measurements and the validation of manual grip strength protocols to the formulation of biostatistical regression equations and the design of low-cost instruments to assess physical fitness at work.

The purpose of this essay is to analyze the validity and applicability of anthropometric and biomechanical studies conducted on Venezuelan workers, as a basis for the ergonomic design of workstations in the national industry.

MATERIALS AND METHODS

This research was conducted under a documentary-descriptive approach, aimed at the critical analysis of recent Venezuelan scientific production in the field of anthropometry and biomechanics in the workplace. The design corresponded to a literature review, complemented by an interpretive analysis characteristic of the essay genre, which allowed the integration of empirical findings with theoretical reflections on the ergonomic reality of the national industry.

The review of theoretical references was carried out through the following databases: Scopus, Dialnet, Latindex, RePEc/IDEAS, EconPapers, and MIAR. The following terms were used as main descriptors: anthropometry, biomechanics, occupational ergonomics, Venezuelan workers, and job design; these were combined using the Boolean operators AND and OR.

The following inclusion criteria were established for document selection:

1. Studies published in the last 10 (10) years.
2. Research conducted in the Venezuelan working population.
3. Documents that addressed anthropometric measurements, biomechanical measurements, or ergonomic assessment protocols.
4. Publications in indexed journals.
5. Documents available in Spanish and English.

Likewise, studies without verifiable methodological support were excluded.

The information was processed through content analysis, organizing the findings into three thematic axes: industrial context and anthropometric issues, contributions of recent Venezuelan research, and implications for occupational health and prevention. Finally, the results were contrasted with the legal framework established in the Ley Orgánica de Prevención Condiciones y Medio Ambiente de Trabajo (LOPCYMAT; 2005), with the purpose of evaluating the practical applicability of the reviewed protocols in compliance with current regulations.

RESULTS

The Venezuelan industrial context and the anthropometric problem

Anthropometric and biomechanical methodologies are directly relevant when applied to industrial sectors with high physical demands, including paint manufacturing companies in Venezuela, as these are highly demanding workplaces.

Although no updated official census from industry associations specifies the exact number of active plants in the country, the national market comprises traditional brands of national and regional manufacturers, medium-sized enterprises, and importers.

In particular, in the central region of Venezuela, specifically in Carabobo State, 6 of the main manufacturing firms in the sector are concentrated. The main activity of these companies comprises the manufacture, marketing, and distribution of coatings and paints.

Their production process encompasses the following key phases:

1. Laboratory formulation.
2. Weighing, loading, and unloading of raw materials.
3. Initial mixing of raw materials.
4. Dispersion of pigments to obtain colored paste.
5. Grinding and final mixing with resins and solvents.
6. Quality control and tonality adjustment.
7. Final packaging of products (rubber paints, enamels, waterproofing agents, pastes, textured coatings, and traffic paints).

During these operational stages, personnel perform intensive tasks that require manual lifting and handling of loads, such as transferring and palletizing pails and raw materials. For these tasks, equipment and tools such as forklifts, mixing machines, pallet jacks, hand trucks, lift tables, plastic and metal containers, cutting tools, and work furniture are used.

In recent decades, the domestic industry has undergone technological obsolescence, with many plants maintaining production lines acquired between 1970 and 1990 or empirically adapted using components from various sources.

This anthropometric disparity subjects workers to forced grips and severe joint deviations, increasing the incidence of musculoskeletal pathologies such as Carpal Tunnel Syndrome (CTS) and De Quervain's tenosynovitis, as evidenced by the morbidity data from the medical service of the company(8).

Likewise, it is essential to highlight that the migratory dynamics of the last decade have profoundly altered the demographic composition of the labor force. Physically demanding tasks that were previously performed by young men are now undertaken by workers aged 40 to 59 and by a growing female contingent, which accentuates the urgency of reassessing the anthropometric adjustment of workstations(9).

Contributions from recent Venezuelan research

Given the scarcity of resources and the lack of official tables, Venezuelan biomedical research has generated innovative methodological responses with high technical rigor:

Accessible instruments and predictive models: Labrador Parra et al.,(5) in a study carried out at the Fundación Centro de Estudios sobre Crecimiento y Desarrollo de la Población Venezolana (FUNDACREDESA), experimentally demonstrated that artisanal anthropometric tables (wood with plasticized grid) do not present statistically significant differences compared to high-cost commercial anthropometric instruments.

Additionally, through a study carried out with 185 industrial workers of direct labor in the state of Aragua, Labrador Parra(6) developed multiple linear regression equations to predict complex vertical variables based on height and acromial height, achieving high adjusted coefficients of determination.

Biomechanical standardization of the hand: Because anthropometric measurements are subject to errors due to intra- and inter-observer variability, Ron et al.(2) evaluated the reproducibility of 3 key dimensions of the dominant hand (length, width, and circumference) in workers from the industrial sector of Aragua, applying the Intraclass Correlation Coefficient (CCI) and obtaining excellent agreement levels. Similarly, Ron et al.(3) validated the manual grip dynamometry protocol, providing an objective indicator of muscle strength.

Physical fitness assessment: Burgos Navarrete et al.(7) structured a low-cost, systematic protocol to assess physical fitness at work, divided into 3 sequential stages:

- Stage A: Hemodynamic evaluation (blood pressure, heart rate, and estimation of relative/absolute aerobic capacity using the Uth equation and Bink's Law).
- Stage B: Anthropometric assessment (body mass index and waist circumference).
- Stage C: Functional Muscle Performance Battery (push-ups, sit-ups, and chair test).

When examining these findings in greater depth, the main merit of these authors lies in having "democratized" ergonomic assessment. The simplification of protocols from 15 measurements to only 1 or 2 rapid measurements through predictive models allows for mass assessments without interrupting production.

However, it is essential to point out certain methodological limitations:

Sample size and representativeness: Studies were predominantly concentrated in specific industrial zones of Aragua State. Therefore, the question arises as to whether these data fully capture the diversity of other regions of the country (eastern, western, or Andean regions).

Gender and age bias: Despite demographic change, historical samples have been biased

toward the young male workforce, so regression equations must be validated in cohorts of female workers and older adults before their widespread generalization.(10)

However, the applicability of these studies transcends the manufacturing sector. The anthropometric and biomechanical assessment protocols developed by Ron et al.,(2-3), Labrador Parra et al.,(4-6), and Burgos Navarrete et al.,(7), present a high potential for adaptation to agroindustry, logistics and distribution, the pharmaceutical sector, and even banking and office services, where furniture design and the use of human-machine interaction tools condition the worker's comfort and postural health.

Implications for occupational health and prevention

In Venezuelan legislation, the Organic Law on Prevention, Working Conditions and Environment (LOPCYMAT),(11) provides in Article 59 for the adaptation of working conditions to the physical and mental capacities of workers and requires adapting methods, machines, tools and processes to the anthropometric characteristics of the working population. The contributions of these research studies represent an indispensable technical tool for effective compliance with this legal requirement.

Challenges and limitations

Despite the solid scientific base available, the practical implementation of these ergonomic solutions in Venezuelan industry faces significant barriers, among which the following stand out:

Resistance to change and organizational culture: In many small and medium-sized enterprises (PYMES), the mistaken belief persists that ergonomics is an "excessive expense" or a purely administrative requirement of the LOPCYMAT, instead of an investment that increases productivity and reduces work absenteeism.(12)

Budget constraints and hyperinflation: The difficulty of acquiring technology or making major modifications to production lines hinders improvements, which is why the validation of artisanal instrumentation and low-cost solutions is so valuable.

Pending research aspects: The research group considers that the ergonomic research agenda in Venezuela must address in the short term:

- Creation of a unified and digitized national anthropometric database.
- Specific tridimensional biomechanical studies on the physical load imposed by highly repetitive tasks in women and individuals over 50 years of age.
- Research on the interaction between exposure to organic solvents in the paint industry and muscular/cardiovascular fatigue.

DISCUSSION

The interpretive reading of the analyzed studies supports the view that recent Venezuelan evidence meets the criteria of reliability and instrumental validity for grounding ergonomic design decisions. In this regard, Ron et al. obtained excellent intra- and inter-evaluator levels, estimated using the intraclass correlation coefficient (CCI), for hand length, width, and circumference in 60 workers from a Venezuelan food company; they also identified hand length as the most efficient variable for sample calculation in a population study, estimated at 184 participants, according to Colombian Technical Standard NTC 5654(2).

Similarly, Labrador Labrador Parra et al. found no statistically significant differences between the standing measurements obtained with anthropometric tables and with the Harpenden anthropometer in 26 workers (11 men and 15 women)(5). These results coincide with those reported by Dianat et al., who emphasize the standardization of measurement procedures and the verification of their reliability as prerequisites for the use of anthropometric data in workstation design.(1)

Regarding applicability, Labrador Parra et al. characterized 185 direct-labor workers (131 men and 59 women) from the main industrial areas of Aragua State, with ages ranging from 20 to 59 years and a mean age of 43 years, and with an average height of 170.08 cm in men and 156.27 cm in women.(4)

Based on the population mentioned above, the multiple linear regression models developed by Labrador Parra achieved adjusted coefficients of determination between 75,68 % and 98,73 % ($p < 0,05$),(6) which supports the replacement of extensive measurement batteries with estimates derived from few variables. However, the mean age of this sample would indicate that the predominant bias is not age-related but sex-related, given that women represented 29,2 % of the

participants, which is relevant since Dodds et al., in 49 964 British participants, reported that grip strength reaches its maximum between 29 and 39 years in men (median of 51 Kg) and between 26 and 42 years in women (mean of 31 Kg), remains until middle age and declines thereafter, with differences that persist throughout the entire life course.(10)

Now, from a preventive perspective, the anthropometric adjustment of workstations becomes relevant insofar as Kozak et al. concluded that occupational biomechanical factors play a substantial role in the causation of carpal tunnel syndrome,(8) whereas Tompa et al. documented, in an auto parts manufacturer, a benefit-cost ratio of 10.6 for a participatory ergonomics process.(12)

The findings presented made it possible to interpret the requirement to adapt methods, machines, and tools to the characteristics of workers, which is set forth in Article 59 of the LOPCYMAT,(11)

CONCLUSIONS

The integration of the findings of Burgos Navarrete et al.,(7) Labrador Parra et al.(4-6) and Ron et al.(2-3) consolidates the technical feasibility of a rigorous, scientific ergonomics that is perfectly applicable to the Venezuelan context. The validated anthropometric and functional measurement protocols demonstrate that it is possible to build the country's first standardized database, through scientifically manageable samples and low-cost instrumentation.

Based on the analysis presented, it is concluded that predictive modeling and alternative instruments democratize ergonomic assessment, allowing companies to comply with the regulatory framework of the LOPCYMAT without compromising their economic sustainability. In the paint manufacturing sector, characterized by intensive load handling, repetitive upper-limb movements, and handling of chemical products, applied anthropometry ceases to be a luxury and becomes an operational, technical, and ethical necessity.

The success of this transformation will depend on the ability of Occupational Health and Safety Services, under the leadership of medical, nursing, and other occupational health professionals, to integrate these biomechanical indicators into daily decision-making, guaranteeing safer, more productive, and more humanized jobs.

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FUNDING

The authors did not receive funding for the development of this research.

CONFLICT OF INTEREST

The authors declare that there is no conflict of interest.

AUTHORSHIP CONTRIBUTIONS

Drafting – original draft: Dalila Edelmira Briceño Duarte, Estela Hernández-Runque.
Writing–review and editing: Dalila Edelmira Briceño Duarte, Estela Hernández-Runque.