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Ergonomic Interventions and Their Effects on Worker Performance: A Systematic Review

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Abstract: Despite robust evidence on the benefits of ergonomic interventions, their absence or suboptimal implementation in many workplaces continues to compromise workers' health and organizational productivity, with musculoskeletal disorders (MSDs) accounting for a substantial share of occupational health and safety problems. There is a need for a consolidated synthesis of how ergonomic interventions have evolved over time and how effectively they improve work performance. A systematic review was conducted of empirical studies published between 2001 and 2025 that evaluated ergonomic interventions and reported work performance outcomes. A comprehensive search was carried out in multiple scientific databases. Studies were included if they assessed workplace ergonomic interventions and provided quantitative or qualitative data on work performance indicators, including physical, biomechanical, and productivity-related outcomes. The evidence shows a shift from purely physical ergonomic approaches to multicomponent strategies that integrate technological and psychosocial elements. Consistent improvements were observed in physical and biomechanical indicators, including significant reductions in muscle activity and musculoskeletal pain. These changes were accompanied by modest but recurrent increases in productivity (approximately 2–3%). Critical implementation factors included worker participation, regular supervision, and continuous monitoring. Multicomponent interventions that combined physical ergonomic modifications, educational and behavioral components, technological support, and active involvement of workers tended to be more effective than single-component programs. Ergonomic interventions have evolved toward more sophisticated and personalized approaches that address both physical and psychosocial determinants of work. Their successful implementation, however, requires sustained organizational commitment and a systematic approach. This review synthesizes ergonomic intervention strategies over a 24-year period (2001–2025), outlines a structured approach to evaluating multicomponent ergonomic interventions, including in hybrid work settings, and summarizes evidence-based recommendations for implementing sustainable ergonomic programs across diverse organizational contexts.

Keywords: Ergonomics; Ergonomic interventions; Work performance; Musculoskeletal disorders; Occupational health; Organizational productivity.

人体工效学干预及其对员工绩效的影响：项系统综述

摘要：

尽管已有大量证据表明人体工效学干预具有显著效益，但在许多工作场所，此类干预的缺失或实施不到位仍持续损害劳动者健康并削弱组织生产力，其中肌肉骨骼疾病（musculoskeletal disorders, MSDs）占职业健康与安全问题的相当比例。当前亟需对人体工效学干预随时间演变的路径及其提升工作绩效的有效性进行系统整合与综合评估。为此，本研究开展了一项系统综述，纳入了2001-2025年间发表的、评估人体工效学干预并报告工作绩效结局的实证研究。研究通过多种科学文献数据库开展系统检索，纳入标准为：在工作场所情境中实施人体工效学干预，并提供关于工作绩效指标的定量或定性数据，包括躯体、生物力学以及生产率等相关指标。结果显示，人体工效学干预已由单一的物理干预逐步转向整合技术与心理社会要素的多组分策略。在躯体与生物力学指标方面观察到持续改善，包括肌肉活动度和肌肉骨骼疼痛的显著降低；同时，生产率也呈现幅度不大但反复出现的提高（约2%–3%）。关键实施因素包括劳动者参与、定期督导以及持续监测。相较于单一组分方案，集成物理工效学改造、教育与行为干预、技术支持以及劳动者积极参与的多组分干预往往表现出更高的有效性。总体而言，人体工效学干预正朝向更加复杂精细且个性化的方向发展，更加全面地兼顾工作中的躯体与心理社会决定因素；然而，其成功实施仍有赖于组织层面的持续投入与系统性推进。本综述在2001-2025年的24年时间跨度上综合了人体工效学干预策略，提出了用于评估多组分人体工效学干预（包括混合办公情境）的结构化分析路径，并总结了在多样化组织情境下实施可持续工效学方案的循证建议。

关键词： 人体工效学；工效学干预；工作绩效；肌肉骨骼疾病；职业健康；组织生产力

1. Introduction

Despite clear evidence for the benefits of ergonomic interventions, their absence or suboptimal implementation in many work environments continues to compromise both worker health and organizational productivity. Musculoskeletal disorders (MSDs) account for more than 40% of occupational safety and health risks, particularly among office workers [1]. Multiple barriers including inadequate ergonomic policies, low awareness, and insufficient training sustain a persistent gap between knowledge and practice: although a substantial proportion of workers report exposure to ergonomic information, fewer than 10% effectively integrate this knowledge into their daily tasks [2]. Empirical studies further indicate that, while ergonomic interventions are generally effective in reducing musculoskeletal symptoms, these health gains do not consistently translate into lower healthcare costs or robust productivity improvements across sectors [3, 4]. Economic benefits appear more evident in manufacturing and warehousing, whereas other sectors show more modest or inconclusive results [4]. Long-term effectiveness is also constrained when intervention design and implementation are driven primarily by managerial imperatives rather than participatory or researcher-led approaches, and by the scarcity of replication studies and rigorous economic evaluations [5, 6].

For the purposes of this review, ergonomic interventions in work environments are understood as integrated sets of physical and organizational strategies that aim to optimise the fit between workers, tasks, tools, and workspaces in order to promote health, safety, and performance [7]. These interventions may include engineering controls (e.g. workstation redesign, tools and equipment modification), administrative and organizational measures (e.g. work–rest schedules, task rotation, participatory ergonomics, training), and emerging forms of digital ergonomics that use information and communication technologies to monitor and adapt work conditions [7, 8, 19]. The design and implementation of ergonomic interventions have diversified across sectors from agricultural and construction workstations to hospital wards, manufacturing plants, and office environments reflecting heterogeneous task structures and risk profiles [8, 10, 11]. In the post-pandemic context, characterised by widespread hybrid and remote work arrangements, ergonomic risk management must increasingly address distributed workspaces and home-based workstations, adding complexity to traditional workplace-focused approaches [9].

Worker performance, in this review, is conceptualised as a multidimensional construct that encompasses task performance (e.g. accuracy, speed, error rates), productivity and presenteeism, safety-related performance (e.g. unsafe acts, near-misses), and self-rated work performance and engagement [16–18]. Methods for assessing performance outcomes in ergonomics research have become progressively more sophisticated, combining objective indicators with self-report instruments. Sensor-based systems, such as inertial measurement units and depth cameras, have been used to capture movement patterns and postures and to classify work activities in sectors such as construction and manufacturing with high accuracy, supporting the identification of ergonomic risks and the evaluation of intervention effects [12, 13]. Digital monitoring technologies, including systems based on wearable devices or radio-frequency identification, provide information on presence, interaction patterns, and workflow dynamics in office and industrial settings [14]. At the same time, standardized questionnaires such as the Individual Work Performance Questionnaire (IWPQ) enable the assessment of multiple dimensions of self-reported performance, while advanced analytical approaches, including Bayesian models, have been applied to predict engagement and performance in dynamic work environments [16, 17].

Despite this growing body of evidence, several important gaps remain in understanding the relationship between ergonomic interventions and worker performance. First, evidence is fragmented across sectors and intervention types, with substantial variation in how both interventions and performance outcomes are defined and measured. This heterogeneity complicates comparisons across studies and limits the ability to draw generalizable conclusions. Second, the persistent gap between ergonomic knowledge and its practical application especially in sectors such as healthcare, where limited ergonomics education contributes to high physical demands and declining performance suggests that contextual factors such as managerial support, organizational culture, and worker participation are critical to intervention success [2, 5, 17]. Participatory approaches that emphasise dialogue, social capital, and joint problem-solving, as in the Nordic model, have been proposed as mechanisms for embedding ergonomic practices into everyday work routines [5]. In technology-intensive environments, digital ergonomics is emerging as a promising avenue for aligning working conditions with workers' capabilities and limitations [19]. However, methodological challenges persist, particularly in the evaluation of complex, multifactorial programmes that involve concurrent changes in technology, organisation, and behaviour. Such interventions often require pragmatic, non-experimental designs to capture the complexity of real-world work systems, raising questions about internal validity, comparability, and the synthesis of findings across heterogeneous studies [20].

Against this backdrop, there is a clear need for an up-to-date, cross-sectoral synthesis of the effects of ergonomic interventions on worker performance that integrates evidence on both health-related and performance-related outcomes, and, where available, economic and implementation indicators. The present study addresses this need by conducting a systematic review of the scientific literature on ergonomic interventions and worker performance across diverse occupational sectors.

The review is conducted and reported in accordance with PRISMA guidelines and includes experimental, quasi-experimental, and observational studies that evaluate ergonomic interventions using objective and/or subjective measures of worker performance.

Specifically, this systematic review aims to characterise the types and components of ergonomic interventions implemented in different work contexts; synthesise evidence on their effects on multiple dimensions of worker performance; and examine how intervention design features and contextual factors, including organisational support and digital ergonomics, influence the magnitude and sustainability of performance-related outcomes. By doing so, the review seeks to provide a coherent and rigorous evidence base to help narrow the gap between ergonomic theory and the practical implementation of interventions aimed at improving work performance.

2. Methods and materials

The systematic review method followed the PRISMA (Preferred Reporting Items for Systematic Reviews and Meta-Analyses) guidelines [22]. It was registered in PROSPERO on July 10, 2025 (1101904).

2.1 Eligibility criteria

2.1.1. Types of studies

This review included only original studies, consisting of randomized and non-randomized controlled trials (RCTs, non-RCTs). Studies without intervention or studies with intervention but without data were excluded.

2.1.2. Types of participants

The studies included people of working age. Studies aimed primarily at students and retired people were excluded.

2.1.3. Context/environment

Any work environment in which an ergonomic intervention is carried out. Studies from any country were included.

2.1.4. Types of interventions

Ergonomic interventions involving implementation or evaluation of implementations were included, with the aim of improving any of the following aspects (among others): workplace assessment, proactive programs, training and coaching programs, health promotion workshops, progressive exercises for different parts of the body, use of applications to improve adherence to interventions, comparison of methods, pain prevention and management (as specified in section 2.1.5 below). Therefore, the interventions were mainly aimed at workers: posture, movements, and strength.

Interventions focused on evaluating individual and work-related factors associated with health-related productivity loss in office workers, not exclusively ergonomic interventions, were excluded. Studies that did not describe a specific ergonomic intervention implemented, the redesign of tools, workstations, or spaces, and those that also focused on the characteristics of change processes and their impact were excluded.

2.1.5. Comparator(s)/control

Since the objective of the review was to identify the effectiveness of ergonomic interventions on work performance, we did not define the comparator/control in advance. For the controlled trials identified, we described the interventions received by the control group. In studies where no alternative interventions were used for the control group, this was indicated.

2.1.6. Types of outcome measures

The studies evaluated outcomes such as reduced loss of productivity, significant reduction in musculoskeletal pain and discomfort and eye fatigue, improvements in work performance, significant improvements in the ergonomic level of workstations, improvements in physical capacity, reduced work absenteeism, and impact on overall well-being.

2.2. Search strategy

Two electronic databases (using MeSH and free-text search terms) were searched to find eligible studies included in Scopus and Web of Science from January 2001 to December 2025. The reference lists of the identified records and relevant reviews were reviewed (HB, EK). Studies published in different languages were included. The search strategy is shown in Figure 1.

2.3. Selection processes

Five reviewers independently carried out a study selection process, with any disagreements resolved with the help of a sixth reviewer.

The selection of articles was carried out in three phases, as shown in Figure 1:

1. Identification: Initially, 100 articles were identified (52 in Scopus and 48 in WoS). Using

Rayyan software, six duplicates were detected and eliminated, resulting in 94 unique articles for review.

2. Screening: The titles and abstracts of the 94 articles were reviewed, of which 73 met the initial eligibility criteria and 21 were excluded. Four articles could not be located in full text, leaving 69 articles for detailed evaluation.
3. Eligibility: The 69 articles were read in full and evaluated thoroughly. The inclusion criteria were rigorously applied, specifically evaluating:

- The presence and description of ergonomic interventions
- The use of methods or tools to measure the impact on work performance
- The inclusion of the adult working population

As a result of this evaluation, seven articles were excluded for partially meeting the established criteria, leaving a final sample of 62 articles for analysis.

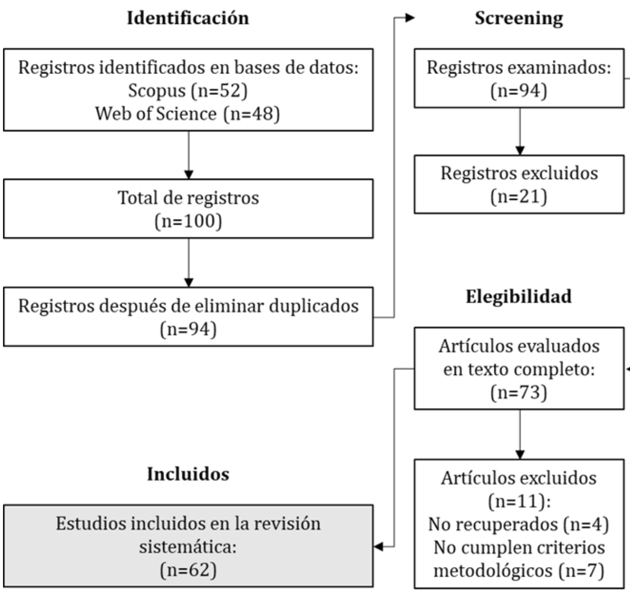

Figure 1. Flow chart of article selection for the study - PRISMA process
Source: own elaboration

2.4. Selection Criteria and Theoretical Framework

The selection of research objects was guided by three primary considerations:

1. Methodological rigor of intervention studies, requiring clear documentation of protocols and outcomes.
2. Relevance to contemporary work environments, particularly focusing on interventions adaptable to both traditional and remote work settings; and,
3. Longitudinal impact assessment, prioritizing studies with follow-up periods of at least 6 months. These criteria were established to ensure practical applicability and theoretical contribution to the field of ergonomic intervention research.

2.5. Data extraction

Data extraction was performed independently by three reviewers and agreement was reached through discussion (i.e., reviewers checked the data extraction table and discussed any inconsistencies to reach consensus; this was necessary if the data were not particularly clear).

Details about study characteristics (authors, year, country, industry sector), type of ergonomic intervention, duration of intervention, implementation methodology, specific tools and metrics for measuring impact on work performance, and main results were extracted from each study.

The methodological characteristics of all studies were evaluated using the Newcastle-Ottawa Scale (NOS) (23), considering three main domains:

1. Population selection methods: The representativeness of the sample and the participant selection criteria were evaluated.
2. Comparability between groups: The methodology used to ensure comparable groups and control for bias was analyzed.
3. Measurement of exposure and outcome: The tools and methods used to measure the impact of ergonomic interventions were evaluated.

The data were extracted independently and verified to ensure the accuracy and completeness of the information.

2.6. Risk of bias

Three reviewers independently assessed the retrieved articles and discussed any disagreements. The risk of bias was assessed using the Cochrane Handbook classification [54] for all included articles. The risk of selection, performance, detection, attrition, and reporting bias was assessed. The risk of bias for non-RCT studies was assessed as high for categories that could not be satisfied in such designs.

2.7. Synthesis method

The studies were summarized narratively, which is recognized as an appropriate approach for evaluating data from heterogeneous study designs [55]. We present a narrative synthesis of the results of the included studies, structured around the type of intervention, the characteristics of the target population, the type of outcome, and the content of the intervention.

3. Results

3.1. Study characteristics and design

The systematic review included 62 studies with diverse methodological designs: randomized controlled trials (RCTs; n = 43), quasi-randomized controlled studies (n = 4), prospective controlled studies (n = 4), crossover designs (n = 4), and randomized clinical trials (n = 3). All studies examined ergonomic interventions targeting improvements in well-being, performance, and/or work-related outcomes. Comparison groups included workplace assessment (n = 5), reduction of perceived physical effort and musculoskeletal risks (n = 31), use of devices that facilitate postural changes (n = 4), and implementation of models to prevent work absenteeism (n = 3).

3.2. Sample characteristics

The total study population comprised 6,670 participants across various occupational sectors. Sample sizes ranged from 14 to 4,784 participants, with the largest sample from the IMF and World Bank study [24] including 4,784 participants (1,500 intervention, 3,284 control) and the smallest from an agricultural worker's study with 14 apple pickers [25]. All studies included working-age adults; where specified, age ranges were 18 to 60 years.

Occupational sector distribution was office workers (n = 29, 47%), healthcare workers (n = 5, 8%), construction workers (n = 4, 6%), industrial workers (n = 4, 6%), workers with pre-existing conditions (n = 4, 6%), and multi-sector studies (n = 7, 11%). Additional sectors included agricultural, childcare, precision manual tasks, slaughterhouse, metalworking, and home care workers.

Geographical distribution showed 13% of studies from the Netherlands (n = 8, 2003-2017), 11% from Iran (n = 7, 2020-2024), 10% each from Denmark (n = 6, 2010-2024) and the United States (n = 6, 2005-2020), 8% each from Finland (n = 5, 2001-2022) and Thailand (n = 5, 2001-2025). Brazil was the only Latin American country represented (n = 1).

3.3. Intervention types

Studies were categorized by intervention type, with 33 studies implementing multiple intervention types.

3.3.1. Ergonomic implementations

(n = 47 studies): Devices to reduce muscle strain and improve posture (n = 17) [24-40], progressive exercise programs (n = 16) [31, 41-55], replacement of materials/devices to reduce hazards (n = 6) [56-61], risk factor identification (n = 6) [62-67], healthy lifestyle promotion (n = 4) [34, 68-70], and personalized ergonomic adjustments (n = 5) [24, 47, 50, 53, 71].

3.3.2. Ergonomic workstation assessment

(n = 23 studies): Evaluation and recommendation of modifications (n = 4) [41, 55, 67, 72], personalized evaluations (n = 7) [19, 24, 50, 53, 64, 71, 73], and development/adoption of improvements (n = 15) [30, 31, 40, 49, 55, 59, 61, 66, 68, 73-78].

3.3.3. Educational interventions

(n = 19 studies): Group health promotion workshops (n = 5) [19, 41, 50, 55, 79], risk identification and solution development workshops (n = 8) [32, 61, 64, 74, 77, 80-82], and ergonomic principles education (n = 10) [24, 34, 36, 44, 59, 71, 73, 80, 81, 83].

3.4. Assessment methods

Multiple assessment tools were employed across studies, predominantly self-report questionnaires:

3.4.1. Productivity and performance

WPAI-SHP [41, 50, 74, 84], WLQ [30], WPAI-GH [48], HPQ [19, 42, 61], JCQ [30, 83], PATH methodology [25].

3.4.2. Work stress

Likert scale (0-10) [41, 74], RA-WIS [30], JSI [50].

3.4.3. Musculoskeletal disorders

CMDQ [42, 80], NPRS [49, 53, 59], NSR scale [32, 50], VAS [26, 28, 44, 45, 47, 60, 75], Borg Scale [51, 54, 57, 43], Nordic Musculoskeletal Health Questionnaire [54].

3.4.4. Disability assessment

RMDQ [27, 62], QuickDASH [79], DASH and NPDS-I [47], NDI [27, 41, 49, 62], WAI [28, 44, 55, 60, 84, 85], WOMAC [46].

3.4.5. Quality of life

EQ-5D [41, 62, 60], Walton's 35-item questionnaire [42].

3.4.6. Psychosocial assessment

Workstyle questionnaire [49], Start Back Tool [60], CES-D [66], GHQ-28 [61], ERIQ [66], QWC [66].

3.4.7. Risk exposure

RSI QuickScan [64], ManTRA tool [78], QEC, PLIBEL, ErgoSAM [56]

3.5. Intervention outcomes

Studies demonstrated the following measurable effects:

3.5.1. Productivity improvements:

Significant decrease in productivity loss proportion and magnitude [72], overall productivity increase [24], reduced work time loss in personalized assessment groups [19, 38, 48, 50, 61].

3.5.2. Physical well-being:

Improved working postures in head/neck and torso positions, reduced musculoskeletal pain in neck, shoulders, hands/wrists, and lower back [24, 42, 48, 59, 75, 73]. Ergonomic risk reduction and improved comfort/efficiency [28, 56]. Pain reduction reported in multiple studies [26, 28, 34, 35, 43, 45-47, 54, 57, 68], with associated work capacity improvements [28, 43].

3.5.3. Psychosocial outcomes:

Increased social and peer support, reduced physical work demands [42], decreased depression symptoms [62], improvements in growth opportunities, social integration, and work relevance [42].

3.6. Success rate

Table 1 presents intervention success rates by outcome measure:

Table 1. Success rate of interventions in improving results

Results	No. of Studies Reporting Improvements	No. of Studies Reporting the Result	Success Rate (% Reporting at Least Some Improvement)	No. of RCTs*		
				RCT +	RCT -	RCT =
Reduction in productivity loss	19	3	6.8%	17	0	2
Ergonomic improvements and their impact on physical well-being	19	2	78%	16	0	3
Pain reduction	3	40	43%	38	0	5
Reducing work-related stress	2	0	--	2	0	0
Improvements in quality of life	4	0	--	3	0	1

*RCT: Randomized Controlled Trial (RCT+ indicates positive results, RCT- indicates negative results, RCT= indicates no significant results)

3.7. Non-significant findings

Eleven studies reported no positive changes in any outcome measure. These included: one workstation assessment only [75], five ergonomic implementations only [25, 29, 45, 57, 62], two combined workstation assessment and implementation [53, 60], one combined workstation assessment with education [73], and two studies with all three intervention types [24, 55].

Two studies [41, 84] were protocols and did not report results.

3.8. Methodological quality

Newcastle-Ottawa Scale assessment revealed 74% of studies (n = 46) demonstrated excellent methodological quality (9/10 score), while 26% (n = 16) scored between 6-10. Initial inter-rater agreement was 97.7%. Studies achieving highest scores [19, 28, 31, 32, 35, 36, 39, 41, 44, 46, 48, 50, 62, 65, 67, 70, 74, 75, 77, 78] showed robust designs, comprehensive objective measurements, and structured follow-ups.

4. Discussion

4.1 Evolution of ergonomic interventions

The systematic analysis reveals a clear progression in ergonomic intervention approaches over the 2001-2025 period. The early phase (2001-2010) was characterized by single-component physical modifications, with studies [26, 35] demonstrating that simple interventions like arm supports and lighting improvements produced measurable reductions in muscle activity and visual discomfort. The introduction of dynamic elements such as evaluated break software [38] signaled the beginning of more sophisticated intervention strategies.

The middle period (2011-2020) marked a paradigm shift toward integrated approaches. The combination of physical and organizational elements [37, 70] proved more effective than isolated interventions. Participatory ergonomics emerged as a significant trend [40], emphasizing worker involvement in problem identification and solution development. This evolution reflects growing recognition that workplace ergonomics extends beyond physical modifications to encompass organizational and psychosocial factors.

The most recent period (2021-2025) demonstrates unprecedented sophistication with technology integration. Camera systems [57] and mobile applications [69] exemplify successful technological adoption, while personalized, data-driven interventions [80] and hybrid programs combining in-person and virtual elements [84] represent the current frontier of ergonomic practice.

4.2. Effectiveness patterns and mechanisms

The high success rate for productivity loss reduction (86.8%) suggests that ergonomic interventions consistently address fundamental barriers to work performance. The modest but consistent productivity increases of 2-3% [24] may seem limited but represent substantial economic benefits when scaled across organizations. The differential success rates between outcomes with productivity and quality of life showing higher success rates than pain reduction (43%) indicate that some work-related parameters respond more readily to ergonomic interventions than others.

The finding that personalized assessments yielded superior results [19, 38, 48, 50, 61] aligns with contemporary understanding of individual variability in ergonomic needs. This suggests that one-size-fits-all approaches may be less effective than tailored interventions, despite their higher implementation costs.

4.3. Factors influencing intervention success

The analysis reveals several determinants of intervention effectiveness. Active worker participation [78] emerges as essential, consistent with participatory ergonomics principles. Regular supervision and follow-up [28] significantly enhanced outcomes, suggesting that initial implementation alone is insufficient without sustained support. The importance of adherence, particularly evident in the study [55] where benefits were limited to participants with ≥70% adherence, highlights implementation challenges in real-world settings.

The limited long-term effectiveness observed in several studies [53, 60] raises questions about intervention sustainability. The inconsistency between short-term improvements and long-term outcomes suggests potential Hawthorne effects or the need for ongoing reinforcement strategies.

4.4. Methodological considerations

The high methodological quality of included studies (74% scoring 9/10) strengthens confidence in the findings. However, certain limitations persist. The predominance of self-report measures, while practical, may introduce response bias. The geographical distribution, with limited representation from Latin America (one study from Brazil), suggests potential gaps in understanding ergonomic interventions across diverse cultural and economic contexts.

The variation in assessment tools, while providing comprehensive outcome measurement, complicates direct comparison between studies. Future research would benefit from standardized outcome measures to facilitate meta-analytic approaches.

4.5. Implications for practice

Organizations should adopt multi-component approaches integrating physical modifications, technological support, and behavioral elements rather than relying on single interventions. The evidence for personalized assessments supports investment in individual ergonomic evaluations despite higher initial costs. The importance of sustained follow-up suggests that ergonomic programs require ongoing resource allocation rather than one-time implementations.

For practitioners, sector-specific adaptation emerges as essential, with interventions requiring modification based on occupational demands and worker characteristics. The success of participatory approaches indicates that ergonomists should function as facilitators rather than prescriptive experts.

4.6. Future directions

Based on the temporal analysis revealing evolution from simple to complex interventions, future research should investigate optimal combinations of intervention components for specific occupational contexts. The limited evidence for long-term effectiveness necessitates longitudinal studies examining intervention sustainability and identifying reinforcement strategies.

The technological integration observed in recent studies suggests potential for artificial intelligence and machine learning in personalizing ergonomic interventions. Additionally, the predominance of studies from developed countries indicates need for research in diverse economic contexts, particularly examining cost-effective solutions for resource-limited settings.

The emergence of hybrid work environments post-2020 presents new challenges requiring investigation of ergonomic interventions for remote and flexible work arrangements. Development of standardized assessment protocols would facilitate comparison across studies and enable more robust evidence synthesis.

5. Conclusion

This systematic review advances the field of ergonomic intervention research in several novel ways. It introduces a comprehensive temporal analysis of intervention effectiveness, revealing the evolution from single-component to integrated approaches. The study's original contribution lies in identifying the synergistic effects of combining physical, technological, and psychosocial elements in ergonomic interventions, particularly in emerging hybrid work environments. This work also establishes a new framework for evaluating intervention success that considers both immediate physical impacts and long-term organizational outcomes.

Occupational ergonomics has undergone a remarkable evolution over the past two and a half decades, transforming from purely physical interventions to a multidisciplinary field that integrates technology, psychosocial factors, and participatory approaches. This systematic review analyzes the evolution of ergonomic interventions and their impact on work performance during the period 2001-2025, providing a comprehensive overview of their effectiveness and development over time.

The early years of this period (2001–2010) were characterized by interventions focused on specific physical modifications. Pioneering studies [26] and [35] demonstrated that relatively simple interventions, such as the implementation of arm supports and lighting improvements, could have significant effects on reducing muscle activity and visual discomfort. The introduction of more dynamic elements, such as active breaks and evaluated break software [38], marked the beginning of a transition toward more sophisticated interventions.

The second decade (2011–2020) saw a significant shift toward more integrated approaches. Studies by

[37, 70] demonstrated the effectiveness of combining physical and organizational elements. Participatory ergonomics gained prominence, as demonstrated by the work [40] that emphasized the importance of actively involving workers in the process of identifying and solving ergonomic problems.

The latest trends (2021-2025) reflect unprecedented sophistication in ergonomic interventions. The implementation of camera systems [57] and mobile applications [69] exemplify the successful integration of advanced technologies. Other studies [80] have demonstrated the value of personalized, data-driven interventions, while validating the effectiveness of hybrid programs that combine in-person and virtual elements [84].

The impact on work performance has been significant and multifaceted. The physical and biomechanical effects have been consistently positive, with notable reductions in muscle activity and postural improvements [26, 57]. Productivity has shown modest but consistent increases, typically in the range of 2-3 % [24], with significant reductions in pain-related productivity losses [50]. Psychosocial aspects have also improved, with significant increases in social support and job control [66], as well as improvements in work life quality [83].

Critical factors for the success of interventions have emerged clearly through studies. Active worker participation [78] has proven to be essential, while regular supervision and follow-up [28] significantly improve results. The sustainability of interventions has emerged as a decisive factor, with long-term studies demonstrating more lasting results [35].

The practical implications of this review are substantial. For organizations, the evidence suggests the need to adopt multi-component approaches that integrate physical modifications, training, and technological support. The cost-benefit ratio [74] indicates that initial investments in ergonomics can generate significant long-term benefits. For professionals, tailoring interventions to the specific characteristics of the work sector and the risk profile of workers has proven to be essential.

Based on our findings, we recommend:

1. Implementing integrated intervention approaches that combine physical modifications with technological support and behavioral components.
2. Establishing standardized protocols for measuring intervention effectiveness across different organizational contexts; and
3. Developing adaptive intervention models for hybrid work environments. Future research should focus on: investigating the long-term sustainability of ergonomic interventions in remote work settings; examining the role of artificial intelligence in personalizing ergonomic interventions; and developing cost-effective solutions for small and medium-sized enterprises.

Declarations

Author Contributions

The following statements should be used:

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No new data were generated or analysed in this study. Data sharing is therefore not applicable to this article.

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Informed Consent Statement

Not applicable. This study did not involve human participants, animals, or the use of identifiable personal data.

Conflicts of Interest

The authors declare that there are no conflicts of interest related to the publication of this manuscript. All ethical standards of scholarly publishing including the avoidance of plagiarism, informed consent where applicable, research misconduct, data fabrication and/or falsification, duplicate publication and/or submission, and redundant publication have been fully observed.

Use of Artificial Intelligence Tools

ChatGPT was used solely to assist with language editing and stylistic refinement of the manuscript. No AI tools were used to generate, alter, or analyse data or to draw scientific conclusions. The authors carefully reviewed and edited all AI-assisted text and accept full responsibility for the content of the final manuscript.

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