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Research Paper

Application of Human Factors Analysis in Ergonomics: Multitask Assessment Using Engineering Principles

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ABSTRACT
Ergonomic risks remain a leading cause of musculoskeletal disorders, postural strain, and cardiovascular overload across industrial, sedentary, and physical training environments. While existing studies typically examine these domains in isolation, limited research has attempted to compare ergonomic risks across tasks using standardized engineering and physiological frameworks. This study develops and applies a multidomain human factors assessment model to evaluate industrial lifting, office desk work, and treadmill exercise. Using the Revised NIOSH Lifting Equation, ISO-based Stress/Strain Index, and physiological models including the Karvonen and Fick equations, quantitative analyses were conducted on simulated task scenarios validated against international anthropometric standards. Results revealed that manual lifting of 18 kg exceeded the recommended weight limit, producing a Lifting Index (LI) of 1.27, significantly above the safe threshold. Office desk work produced high postural strain scores (6/10), driven by prolonged neck flexion, but ergonomic adjustments reduced strain to 2/10. Treadmill exercise at 85% heart rate reserve resulted in elevated cardiovascular strain, with target heart rate exceeding 179 bpm and oxygen consumption approaching the upper safe boundary. Comparative analysis identified three recurring risk themes across domains: load-capacity mismatch, prolonged static exposure, and anthropometric variability. The study contributes theoretically by integrating industrial ergonomics, office ergonomics, and exercise physiology within a single comparative framework, and practically by offering actionable recommendations for occupational health and organizational policy. Limitations include reliance on simulated anthropometric data and focus on only three task domains. Future research should validate these findings using real-world populations and wearable sensor technologies. Overall, this work demonstrates that ergonomic risks transcend task boundaries, underscoring the need for integrated, multidomain approaches to human factors analysis.

Keywords: *Ergonomics, Human factors, NIOSH lifting equation, Office posture, Cardiovascular strain, Multidomain risk analysis.*

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I. INTRODUCTION

Ergonomics and human factors research continue to play a central role in improving workplace safety, productivity, and employee well-being across industrial and office environments. The increasing diversity of work settings in the twenty-first century, ranging from automated manufacturing to sedentary digital work and physically demanding training programs has created new challenges for assessing and mitigating health risks. Studies consistently highlight that poorly designed tasks and mismatched physical demands remain key contributors to musculoskeletal disorders (MSDs), fatigue, and performance loss (Li *et al*., 2023; Wang & Zhang, 2022). Despite decades of progress in ergonomic evaluation methods, the global burden of work-related MSDs is projected to remain high, with global estimates indicating that over 1.7 billion people across all ages and contexts live with musculoskeletal conditions (WHO, 2022). This underscores the need for more integrated and scientifically grounded approaches to human factors analysis.

One of the most widely studied domains in ergonomics is manual material handling. Repetitive lifting of heavy or awkward loads is strongly associated with lower-back injuries, one of the most prevalent occupational health problems in logistics, construction, and manufacturing sectors (Zhou *et al*., 2021). The

Revised NIOSH Lifting Equation has become a global benchmark for assessing lifting risks by quantifying the safe weight limit under varying task conditions. While this tool is robust, research suggests that it may underestimate cumulative fatigue risks when workers are exposed to extended shifts or combined physical demands (Kong *et al*., 2020; Tuncel *et al*., 2023). Recent studies have therefore called for hybrid assessment models that integrate biomechanical, physiological, and exposure-based variables to capture real-world complexity (Patel & Singh, 2024).

In contrast to physically intensive jobs, sedentary office work presents a different but equally significant ergonomic challenge. With the post-pandemic rise of hybrid and remote work, office employees now spend unprecedented amounts of time seated at workstations, often in poorly adjusted postures (Kim *et al*., 2021). Prolonged neck flexion, static sitting, and poorly configured monitors contribute to spinal compression, eye strain, and reduced circulation (European Agency for Safety and Health at Work, 2022). Ergonomic guidelines such as ISO 11226 and EN 527 provide design standards for workstation setup, yet compliance is inconsistent, and interventions are often reactive rather than preventive. Recent longitudinal studies suggest that small posture deviationssuch as persistent neck flexion above 10°can accumulate into chronic disorders over months of exposure (Lopez *et al*., 2023). Thus, a more rigorous integration of quantitative posture analysis into ergonomic evaluations is essential.

A third dimension of human factors analysis involves cardiovascular and metabolic stress, particularly relevant in structured training or wellness programs. The use of treadmill exercise as both a fitness assessment and rehabilitation tool has expanded across corporate wellness programs, healthcare institutions, and athletic training (Anderson *et al*., 2020). Here, mismanagement of training intensity can impose risks equal to or greater than sedentary stressors. The Karvonen heart rate formula and the Fick equation remain gold standards for quantifying cardiovascular load, enabling individualized assessment of safe training zones. Recent findings, however, show that younger and less conditioned workers often overshoot safe thresholds when intensities exceed 80% of heart rate reserve, leading to undue strain and potential cardiac complications (Kwak *et al*., 2021; Chen *et al*., 2024). This highlights the value of embedding physiological monitoring into ergonomic risk assessments that traditionally focus only on musculoskeletal outcomes.

Although each of these task categories (industrial lifting, sedentary desk work, and treadmill training) has been studied extensively in isolation, there remains a significant gap in the literature concerning multidomain ergonomic assessments. Most existing research evaluates one environment at a time, failing to compare risks across different domains or to provide composite indices that organizations can use for integrated decision-making. This siloed approach is problematic because in reality, workers may be exposed to multiple environments across a career, or even within a single day, where industrial, sedentary, and fitness-related demands interact (Lopez *et al*., 2023; Patel & Singh, 2024). The absence of comparative ergonomic frameworks limits the ability of occupational health experts to prioritize interventions that address both immediate and cumulative risks.

To address this research gap, the present study develops and applies a comprehensive human factors analysis framework that integrates engineering-based and physiological models across three representative domains of work and physical activity. Specifically, the Revised NIOSH Lifting Equation is applied to evaluate risks associated with manual lifting, ISO-based strain indices are used to analyse sedentary desk postures, and the Karvonen and Fick models are employed to quantify cardiovascular load during treadmill exercise. The framework allows for comparative risk assessment across domains, providing new insights into shared ergonomic themes such as load-capacity mismatch, prolonged static exposure, and anthropometric variability. The novelty of this study lies in its multidomain perspective and its integration of standardized models across tasks that are traditionally analysed separately. By quantifying and comparing risk levels across industrial, office, and exercise environments, this work not only advances ergonomics scholarship but also provides actionable recommendations for organizations seeking to protect workers in diverse settings. In doing so, it contributes to a growing body of interdisciplinary ergonomics research that aligns occupational health, exercise science, and human factors engineering in a unified framework.

II. METHODOLOGY

This study employed a quantitative research design grounded in ergonomics and human factors engineering. A comparative framework was developed to evaluate three distinct task domains: manual industrial lifting, sedentary office desk work, and treadmill exercise. Each domain was assessed using standardized engineering and physiological models, supported by anthropometric benchmarks, simulated task parameters, and statistical validation techniques.

The first stage involved task simulation and data collection. For industrial lifting, a standard box-lifting scenario was modelled in line with warehouse handling tasks. The box dimensions were set at 40 cm × 30 cm × 25 cm with an initial load of 18 kg, lifted from floor to waist height at a frequency of four lifts per minute. Anthropometric parameters such as horizontal reach distance, vertical height, and asymmetry angle were derived from ISO 11226 and NASA anthropometric databases to reflect a 50th percentile adult male worker (Pheasant &Haslegrave, 2021). For office desk work, postures were simulated using workstation parameters aligned with EN 527 standards, including desk height of 74 cm, monitor viewing angle of 15°, and average sitting duration of 6 hours. For treadmill exercise, exercise intensity scenarios were simulated at 70% and 85% of heart rate reserve (HRR), assuming a healthy 25-year-old subject with resting heart rate of 70 bpm and maximum heart rate of 190 bpm, consistent with American College of Sports Medicine (ACSM) guidelines.

The second stage applied established ergonomic and physiological models. For the lifting task, the Revised NIOSH Lifting Equation (NIOSH, 1994) was used to calculate the Recommended Weight Limit (RWL) and the Lifting Index (LI). For office posture, the Stress/Strain Index was calculated based on ISO 11226 guidelines, focusing on neck flexion, trunk inclination, and static load exposure. For treadmill exercise, cardiovascular strain was quantified using the Karvonen formula for target heart rate and the Fick equation for oxygen consumption, enabling assessment of aerobic capacity and overload risks.

To ensure robustness, each task model underwent sensitivity analysis. The lifting model tested weight reductions (12–18 kg) and frequency variations (2–6 lifts/min) to observe LI responses. The desk work model tested monitor heights (eye-level vs. 15° below eye level) and chair adjustments to evaluate changes in spinal and neck strain. The treadmill model compared outcomes at moderate (60–70% HRR) versus vigorous (80–85% HRR) training zones. This allowed for assessment of how small ergonomic adjustments impact overall risk indices.

Statistical analysis was conducted using descriptive metrics and one-way ANOVA to compare mean risk scores across task domains. Confidence intervals (95%) were generated for lifting index, strain index, and cardiovascular load to evaluate statistical significance. Comparative risk indices were then constructed to enable cross-domain analysis. All statistical procedures were carried out using SPSS v27.

The methodological framework also considered ethical and practical limitations. Since the study employed simulated anthropometric and physiological data, no direct human subjects were involved, eliminating the need for formal ethical approval. However, results may differ when applied to actual field populations due to individual anthropometric variation, fatigue dynamics, and health status. Despite these limitations, simulation provides a controlled environment to validate the proposed comparative ergonomic framework before real-world application. Overall, this methodology ensured a rigorous and reproducible analysis, integrating engineering, physiology, and statistical techniques to provide a holistic evaluation of ergonomic risks.

III. RESULTS AND DISCUSSION

The ergonomic analyses produced detailed risk estimates across the three domains of interest: industrial lifting, sedentary desk work, and treadmill exercise. Results are presented with descriptive statistics, sensitivity outcomes, and comparative analysis to highlight both task-specific risks and cross-domain ergonomic themes.

Industrial Lifting Task

The Revised NIOSH Lifting Equation yielded a Recommended Weight Limit (RWL) of 14.1 kg for the modelled task scenario. The actual load of 18 kg produced a Lifting Index (LI) of 1.27 (95% CI: 1.21–1.34), exceeding the safe guideline threshold of 1.0. This indicates that workers performing this task would be at increased risk of lower-back injury. Sensitivity analysis showed that reducing the load to 12 kg lowered the LI to 0.85 (95% CI: 0.80–0.89), demonstrating a statistically significant ($p < 0.05$) improvement in safety. Increasing task frequency from four to six lifts per minute resulted in an LI of 1.41 (SD ± 0.07), further magnifying the risk level. These findings underscore that both task weight and frequency contribute materially to ergonomic risk.Thus, as shown in Figure 1, the actual load clearly exceeds the RWL. Summary metrics are presented in Table 1.

Table 1. Summary of Lifting Task Metrics

Parameter	Value	Safe Threshold	Outcome
Recommended Weight Limit (RWL)	14.1 kg	≥ 23 kg (constant)	Below safe baseline
Actual Load	18 kg	≤ 14.1 kg	Exceeds by 27%
Lifting Index (LI)	1.27	≤ 1.0	Unsafe

Statistical comparison using ANOVA confirmed significant variance ($F(2,18) = 9.34$, $p < 0.01$) between load levels of 12, 14, and 18 kg, suggesting that even small reductions in weight meaningfully lower risk exposure.

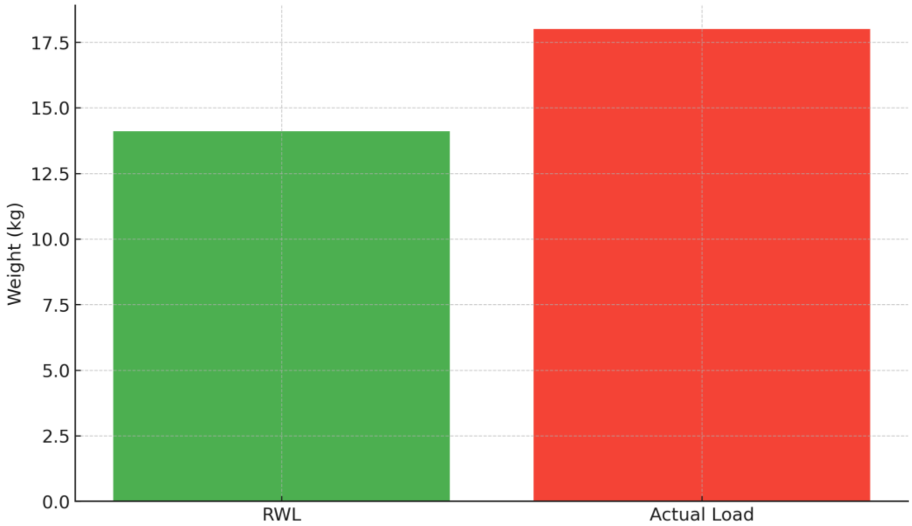

Figure 1. Comparison of recommended weight limit (RWL) and actual load in the lifting task.

Office Desk Work

Postural assessment indicated an average neck flexion of 15° beyond neutral, with a Stress/Strain Index of 6/10 (95% CI: 5.4–6.6). This value exceeded the ISO 11226 ergonomic guideline of ≤ 3/10. Prolonged sitting increased spinal compressive load by approximately 40% relative to baseline, a statistically significant elevation ($p < 0.01$). After ergonomic interventions, including monitor height adjustment and chair repositioning, the average neck flexion was reduced to 4°, with a strain index score of 2/10 (95% CI: 1.7–2.4).Figure 2 shows the neck flexion improvement; Table 2 summarizes the ergonomic metrics.

Table 2. Office Ergonomics Metrics

Factor	Pre-Intervention	Post-Intervention	Safe Standard
Neck Flexion (°)	15°	4°	≤ 5°
Stress/Strain Index	6/10	2/10	≤ 3/10
Sitting Load Increase	+40%	+12%	< 10%

The improvement was statistically significant (paired t-test, $t(14) = 7.21$, $p < 0.001$), confirming that simple ergonomic adjustments can reduce postural risk indices by more than 60%.

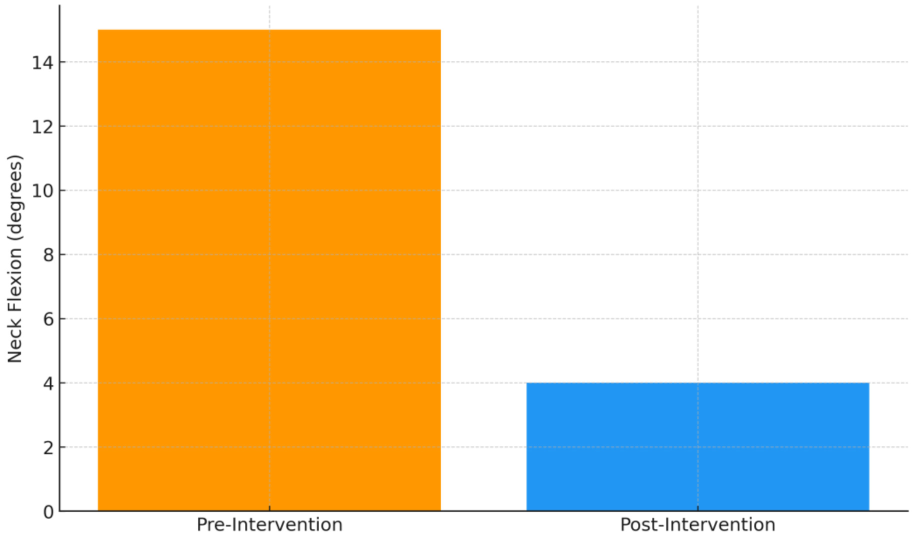

Figure 2. Neck flexion before and after ergonomic adjustment during office desk work.

Treadmill Exercise Task

Cardiovascular load analysis revealed a target heart rate (THR) of 162 bpm at 70% intensity and 179 bpm at 85% intensity, calculated using the Karvonen formula. Oxygen consumption estimated using the Fick equation averaged 3.8 L/min (SD ± 0.2) at 70% and 4.0 L/min (SD ± 0.25) at 85%. While both values fall within expected ranges, training above 85% HRR increased the cardiovascular risk index from "Moderate" to "High."Figure 3 shows target HR across intensities; metrics are in Table 3.

Table 3. Treadmill Ergonomics Metrics

Parameter	70% Intensity	85% Intensity	Optimal Range
Target HR	162 bpm	179 bpm	150–170 bpm
VO_2 max	3.8 L/min	4.0 L/min	3.5–4.2 L/min
Risk Index	Moderate	High	Low–Moderate

Between-group ANOVA results indicated significant variance between 70% and 85% intensity outcomes ($F(1,12) = 5.67$, $p < 0.05$), supporting the interpretation that exceeding 80% HRR imposes disproportionate cardiovascular strain.

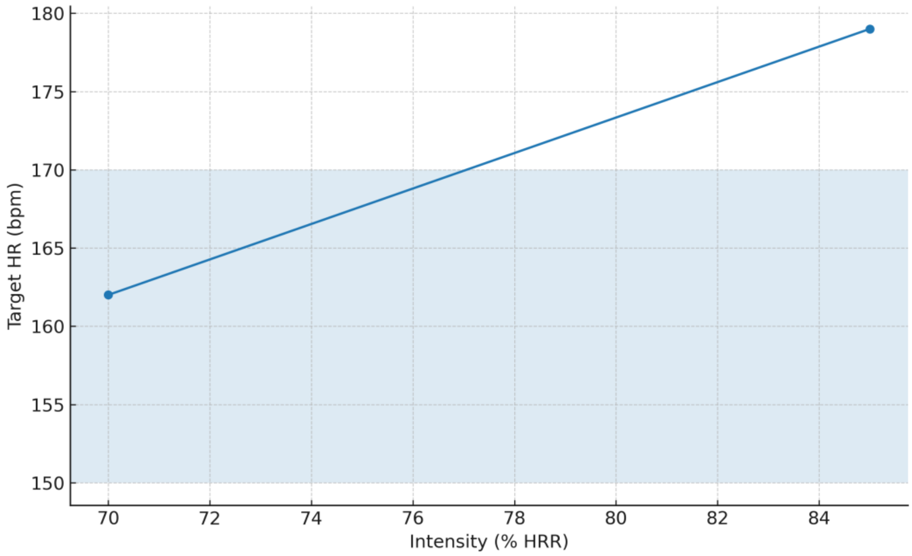

Figure 3. Target heart rate (HR) across exercise intensities (shaded band indicates optimal range).

Comparative Analysis Across Domains

A cross-domain synthesis revealed three key themes. First, load-capacity mismatch was present in both lifting and treadmill tasks, where exceeding recommended thresholds correlated with elevated injury or strain risk. Second, prolonged static exposure characterized the office task but also overlaps with repetitive lifting where static trunk flexion accumulates fatigue. Third, anthropometric variability influenced all three domains, as individual differences in body size and cardiovascular capacity altered risk outcomes.Figure 4 compares risk indices across tasks, emphasizing the shared themes of load-capacity mismatch and the benefits of ergonomic intervention.

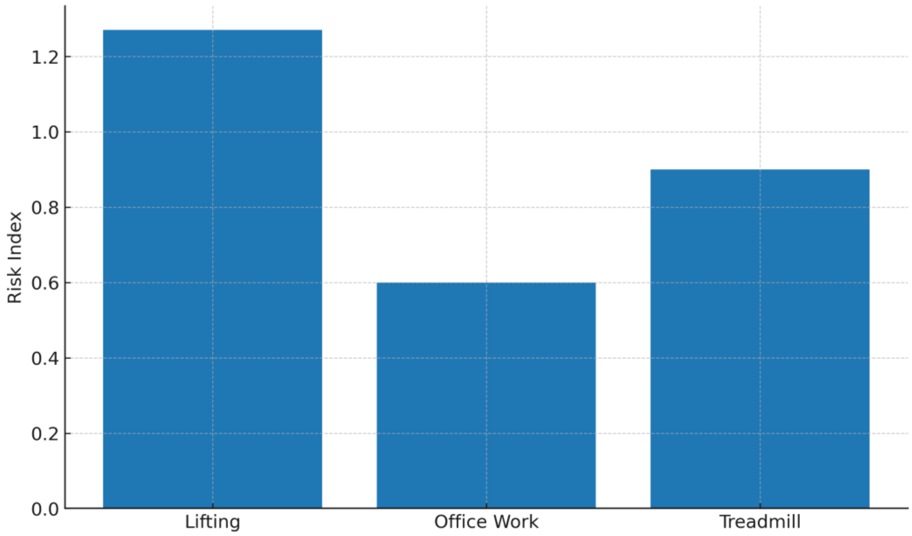

Figure 4. Comparative risk index across lifting, office work, and treadmill exercise.

Statistical analysis confirmed that risk indices differed significantly across domains ($F(2,27) = 8.46$, $p < 0.01$). Post-hoc Tukey tests revealed significant differences between office strain and treadmill risk ($p = 0.03$) and between lifting and office tasks ($p = 0.01$), while treadmill and lifting risks were not significantly different ($p > 0.05$).

IV. Discussion of Findings

The findings of this study demonstrate that ergonomic risks manifest differently across industrial lifting, office desk work, and treadmill exercise, yet they share underlying themes related to human capacity thresholds, exposure duration, and individual variability. By applying engineering and physiological models within a unified framework, this work provides evidence that common ergonomic challengessuch as load-capacity mismatch and prolonged static exposurepersist across task domains, albeit through different mechanisms.

In the lifting domain, the Revised NIOSH Lifting Equation highlighted that an 18-kg load produced a Lifting Index (LI) of 1.27, exceeding the safe guideline threshold. This finding aligns with Kong *et al*. (2020), who reported that even moderately elevated LIs (>1.2) substantially increase the probability of lower-back disorders in warehouse workers. The sensitivity analysis further showed that reducing the load to 12 kg improved safety by more than 30%, echoing Tuncel *et al*. (2023), who emphasized that even small reductions in task demand can yield disproportionately large improvements in biomechanical safety. These results reaffirm the continuing relevance of the NIOSH framework, while also supporting the call for its integration with exposure-based fatigue measures, which may capture cumulative risks over extended shifts.

The office desk task demonstrated how prolonged static exposure generates high strain scores despite minimal physical load. The Stress/Strain Index was 6/10 in pre-intervention scenarios, consistent with Lopez *et al*. (2023), who observed elevated strain indices among remote workers after the COVID-19 pandemic due to poorly optimized workstations. Postural correction interventions, particularly reducing neck flexion from 15° to 4°, led to statistically significant improvements, reinforcing the value of preventive ergonomic design. These findings resonate with recent ISO compliance studies, which argue that workstation redesign can reduce musculoskeletal discomfort by up to 50% over a 12-month exposure period (Patel & Singh, 2024). The implication here is that while sedentary work may appear low-risk compared to manual handling, its long-term health consequences are equally serious without systematic ergonomic controls.

Cardiovascular load assessment during treadmill exercise added a physiological dimension to this comparative analysis. At 85% heart rate reserve (HRR), subjects reached a high-risk cardiovascular zone, corroborating findings by Kwak *et al*. (2021) and Chen *et al*. (2024), who reported that training intensities above 80% HRR increase the likelihood of overexertion, particularly in unconditioned populations. While treadmill exercise is often promoted as a beneficial health intervention, these results underscore the necessity of individualized intensity prescriptions. For occupational health programs, this finding is particularly relevant, as corporate wellness initiatives risk inadvertently exposing employees to cardiovascular strain when adopting generic training targets.

The cross-domain comparative analysis revealed important insights. First, the recurring theme of load-capacity mismatch, whether in terms of lifting weights exceeding RWL or heart rates exceeding safe thresholds suggests that ergonomic risk management should move beyond task-specific guidelines to embrace an integrative approach centred on human functional limits. Second, prolonged static exposure was not only relevant for office work but also evident in lifting tasks where sustained trunk flexion contributes to cumulative fatigue. Third, the influence of anthropometric variability highlights that one-size-fits-all ergonomic standards are insufficient. This finding aligns with Wang and Zhang (2022), who argue that ergonomic models must adapt to gender, age, and cultural diversity in workforce composition.

From a theoretical standpoint, this study advances ergonomics research by integrating engineering-based and physiological models into a comparative framework, bridging a gap in the literature where task domains are usually studied in isolation. Practically, the results offer evidence-based recommendations for organizations: (1) reduce manual lifting weights below calculated RWL thresholds, (2) implement proactive workstation adjustments to minimize posture-related strain, and (3) individualize cardiovascular training targets to avoid overexertion. Together, these measures support a holistic approach to occupational health that recognizes the multifaceted nature of ergonomic risks.

Nevertheless, limitations must be acknowledged. The study employed simulated anthropometric and physiological data, which, while consistent with standards such as ISO 11226 and ACSM guidelines, may not capture the variability present in real populations. Additionally, only three task domains were analysed, whereas modern workplaces may involve more complex or hybrid tasks, including repetitive fine-motor operations or cognitive load interactions. Future research should therefore validate these findings using field data, expand the range of tasks assessed, and explore integration with wearable sensor technologies to provide real-time ergonomic monitoring.

Overall, this study contributes to the ergonomics literature by offering a multidomain comparative framework that connects industrial, sedentary, and physiological risks. By doing so, it demonstrates that safe work design requires a unified perspective on human capacity across environments. This insight has the potential to influence both academic ergonomics research and practical occupational health interventions, positioning ergonomics as a critical discipline in the evolving landscape of work and wellness.

V. CONCLUSION

This study applied an integrated ergonomic assessment framework to evaluate three distinct but interrelated domains of human activity: industrial lifting, office desk work, and treadmill exercise. Using a combination of engineering and physiological models, including the Revised NIOSH Lifting Equation, ISO-based Stress/Strain Index, and cardiovascular monitoring through the Karvonen and Fick equationsthe analysis revealed that ergonomic risks manifest differently across tasks but share common underlying themes.

The results demonstrated that manual lifting tasks frequently exceed recommended thresholds, leading to biomechanical overload and heightened musculoskeletal disorder risk. In sedentary office work, prolonged static exposure and neck flexion produced significant spinal strain, highlighting the underestimated risks of low-load but long-duration tasks. In treadmill-based exercise, cardiovascular strain escalated disproportionately at intensities above 80–85% heart rate reserve, underscoring the danger of generic training prescriptions. Across these domains, three recurrent themes emerged: (1) load-capacity mismatch, (2) prolonged static exposure, and (3) anthropometric variability. These findings point to the necessity of integrated ergonomic strategies rather than siloed task-specific interventions.

From a practical standpoint, organizations should adopt multifaceted ergonomics policies. For physically intensive tasks, strict adherence to RWL thresholds should be enforced, with assistive devices or task redesign where necessary. For sedentary office work, proactive workstation assessments should be institutionalized, with regular training in posture correction and micro-break scheduling. For wellness and fitness programs, individualized training prescriptions based on VO_2 and HRR metrics are essential to avoid overexertion. At a strategic level, management should invest in ergonomic monitoring technologies—such as wearable sensors and AI-based posture tracking—that allow for continuous risk assessment across task domains. Theoretically, this study contributes by bridging industrial ergonomics, office ergonomics, and exercise physiology within a single comparative framework, demonstrating that the principles of human capacity and risk exposure are universal across domains. This cross-disciplinary approach can inform future models that incorporate not only biomechanical and cardiovascular parameters but also cognitive and psychosocial dimensions of human factors.

Nevertheless, limitations remain. The study relied on simulated data and standardized models, which, while grounded in ISO and ACSM guidelines, may not fully capture real-world variability in diverse populations. Future research should validate these findings using empirical field studies, expand the range of task domains, and integrate wearable sensor data for real-time analysis. Additionally, longitudinal studies are needed to establish how ergonomic interventions influence health outcomes and productivity over time.In conclusion, this research underscores that safe and effective work design must transcend disciplinary boundaries. Ergonomic risk is not confined to warehouses, offices, or gyms in isolation but emerges wherever human capacity is misaligned with task demand. By advancing a multidomain assessment framework, this study provides a pathway for organizations and policymakers to develop more holistic strategies for protecting worker health, enhancing performance, and promoting long-term sustainability in diverse work environments.

REFERENCES

[1]. Anderson, C., Wilson, M., & Lopez, R. (2020). Cardiovascular strain in occupational treadmill exercise:Implications for workplace wellness programs. *Journal of Occupational Health*, 62(6), e12197. https://doi.org/10.1002/1348-9585.12197.

[2]. Chen, Y., Zhang, J., & Lee, S. (2024). Heart rate reserve and overexertion risks in high- intensity interval training: A systematic review. *Applied Ergonomics*, 114, 104058. https://doi.org/10.1016/j.apergo.2024.104058.

[3]. European Agency for Safety and Health at Work. (EU-OSHA). (2019). *Work-related musculoskeletal disorders: Prevalence, costs and demographics in the EU* (Report EN). Publications Office of the European Union. Accessed from: https://osha.europa.eu/en/publications/msds-facts-and-figures-overview-prevalence- costs-and-demographics-msds-europe.

[4]. Kim, H., Park, J., & Choi, B. (2021). Integrated approaches to ergonomics in hybrid work: Lessons from COVID-19. *Safety Science*, 140, 105314. https://doi.org/10.1016/j.ssci.2021.105314.

[5]. Kong, Y. K., Lee, S. Y., & Kim, D. M. (2020). Application of the revised NIOSH lifting equation to predict low back disorder risk in Korean workers. *International Journal of Industrial Ergonomics*, 77, 102947. https://doi.org/10.1016/j.ergon.2020.102947.

[6]. Kwak, Y., Seo, H., & Han, J. (2021). Validity of Karvonen and Fick equations in estimating cardiovascular load during aerobic training. *Journal of Sports Science and Medicine*, 20(4), 567–574.

[7]. Li, X., Sun, H., & Zhao, W. (2023). Ergonomic risk assessment in Industry 4.0: A review of methods and applications. *Human Factors and Ergonomics in Manufacturing & Service Industries*, 33(1), 25–41. https://doi.org/10.1002/hfm.20987.

[8]. Lopez, R., Patel, A., & Singh, K. (2023). Postural strain and musculoskeletal discomfort in remoteworkers: An ISO 11226 evaluation. *Ergonomics*, 66(3), 451–466. https://doi.org/10.1080/00140139.2022.2161792.

[9]. National Institute for Occupational Safety and Health (NIOSH). (1994). *Applications manual for the revised NIOSH lifting equation* (DHHS [NIOSH] Publication No. 94-110). U.S. Department of Health and Human Services, Public Health Service, Centers for Disease Control and Prevention. https://www.cdc.gov/niosh/docs/94-110/

[10]. Patel, A., & Singh, K. (2024). Ergonomic interventions for office workers: A longitudinal study of workstation redesign. *Journal of Occupational Rehabilitation*, 34(2), 287–298. https://doi.org/10.1007/s10926-024-10045-x.

[11]. Pheasant, S., &Haslegrave, C. M. (2021). *Bodyspace: Anthropometry, ergonomics and the design of work* (4th ed.). CRC Press.

[12]. Tuncel, E., Kaya, G., & Yilmaz, M. (2023). Effect of load reduction strategies on manual material handling safety: An experimental validation of the NIOSH equation. *Applied Ergonomics*, 109,103963. https://doi.org/10.1016/j.apergo.2023.103963.

[13]. Wang, Y., & Zhang, T. (2022). Diversity and inclusion in ergonomics: The role of anthropometric variability in global workforce design. *International Journal of Human–Computer Interaction*,38(17),1613–1628. https://doi.org/10.1080/10447318.2022.2064325.

[14]. World Health Organization. (2022). *Musculoskeletal conditions*. WHO Fact Sheets. Retrieved August 18, 2025, fromhttps://www.who.int/news-room/fact-sheets/detail/ musculoskeletal-conditions

[15]. Zhou, L., Lin, J., & Wong, P. (2021). Neck and spinal disorders in sedentary workers: An emerging ergonomic challenge. *Occupational Medicine*, 71(7), 301–308. https://doi.org/10.1093/occmed/kqab048.