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Capacity-Demand Matching in Workplace Musculoskeletal Health: A Systematic Review of Integrative Ergonomics and Sports Medicine Interventions

Check for updates

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ABSTRACT

Background: Work-related musculoskeletal disorders (MSDs) remain the leading cause of global occupational disability, yet traditional interventions typically isolate ergonomic modifications from physical conditioning, producing inconsistent outcomes across sectors.
Objective: To synthesize multidisciplinary evidence and propose an integrative capacity-demand matching framework that simultaneously reduces task exposure and increases worker physical capacity.
Methods: A systematic synthesis of 106 sources spanning occupational health, ergonomics, rehabilitation, and sports medicine literature (1987-2026) across office, healthcare, manufacturing, and manual-labor settings. Evidence was evaluated for risk mechanisms, exposure assessment, intervention effectiveness, return-to-work (RTW) protocols, and economic outcomes.
Results: MSD risk is cumulative and multifactorial, with overhead work demonstrating a 21% increased risk per 1,000 hours of hand elevation above shoulder level, and overtime schedules carrying a 61% higher injury hazard. Multicomponent programs integrating engineering controls, targeted exercise, and structured RTW protocols consistently outperform single-domain interventions. Engineering controls in patient handling show the highest efficacy, while workplace exercise is most effective for neck pain and less consistent for shoulder disorders.
Conclusion: An integrative capacity-demand matching framework provides the most robust defense against workplace MSDs, necessitating a paradigm shift from isolated interventions to coordinated ergonomics-sports medicine strategies embedded within organizational systems.

Key Points (Highlights):

- *Work-related MSDs are multifactorial, and isolated interventions often fail.*
- *An integrative capacity-demand matching framework improves MSD prevention.*
- *Integrate ergonomics and sports medicine to sustainably reduce MSD burden.*

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INTRODUCTION

Work-related musculoskeletal disorders (MSDs) constitute a staggering proportion of the global occupational disease burden, accounting for substantial economic losses through absenteeism, presenteeism, disability claims, and compensation costs that collectively reach hundreds of billions of dollars annually (Skamagki et al., 2026). Despite more than four decades of ergonomic research and occupational health policy development, the incidence of work-related MSDs remains stubbornly elevated across virtually every industrial sector, from healthcare and manufacturing to office-based and manual-labor environments (Adebiyi et al., 2025; Sundstrup et al., 2020). This persistence reflects a fundamental conceptual limitation: MSDs have historically been framed as isolated postural or repetitive strain problems, rather than as a complex load-management challenge in which tissue stress accumulates through the interaction of magnitude, frequency, duration, and insufficient recovery of physical demands (Kuijer et al., 2024).

The conventional occupational health response has been predominantly fragmented, relying on isolated interventions that either modify the physical workstation through ergonomics or treat the individual worker through clinical rehabilitation and exercise (Krishnanmoorthy et al., 2025; Yang et al., 2026). However, contemporary evidence increasingly demonstrates that generic workstation adjustments alone yield mixed or null effects, and exercise programs delivered without concurrent workplace accommodation fail to sustain long-term work participation (Martínez Álvarez, 2025). This siloed approach neglects the synergistic effects of biomechanical exposures, organizational factors such as pacing and shift scheduling, and the individual worker's physiological capacity to withstand and recover from physical loads (Hoosain et al., 2019; Santos et al., 2025). The resulting gap between intervention design and real-world effectiveness represents a critical barrier to meaningful reductions in MSD burden.

An effective, evidence-based paradigm must therefore simultaneously reduce external task demand and increase internal worker capacity (Newington et al., 2024). Ergonomics addresses the former through task redesign, assistive devices, pacing, and recovery optimization, while sports medicine addresses the latter through targeted strengthening, motor control, conditioning, and graded return-to-work (RTW) progression (Prall & Ross, 2019). This capacity-demand matching framework aligns with the most robust contemporary evidence, which strongly favors multicomponent, participatory, and sector-tailored programs over single-component strategies (Lee et al., 2025). The convergence of findings across risk-factor epidemiology, intervention trials, RTW studies, and implementation research provides a compelling foundation for this integrative model (Sheikhmozafari & Mohsenian, 2026).

Therefore, this study aims to synthesize multidisciplinary evidence across diverse working populations to evaluate the effectiveness of integrated versus isolated interventions, and to propose a practical, evidence-based model for workplace musculoskeletal health that bridges the critical gap between occupational ergonomics and sports medicine (Hassani & Karanikas, 2025; Kalski et al., 2023). By mapping global trends in risk mechanisms, exposure assessments, intervention outcomes, and economic implications, we provide a comprehensive framework that can inform both organizational practice and occupational health policy in the modern workplace (Murray et al., 2026; Wicaksono et al., 2025).

MATERIALS AND METHODS

Reporting Guidelines

This study adheres to the PRISMA (Preferred Reporting Items for Systematic Reviews and Meta-Analyses) guidelines for systematic reviews and syntheses. Evidence was organized by thematic domain, and the reported findings reflect the study designs, populations, and occupational settings

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represented in the included sources. Because the evidence base is heterogeneous in exposure definitions, outcome measures, and intervention composition, the synthesis is narrative rather than a meta-analysis; accordingly, no pooled effect sizes or sector-by-sector return-on-investment rankings are reported. The limitations arising from reliance on self-reported exposure data and from mixed-quality intervention and economic studies are stated explicitly, consistent with PRISMA requirements for transparent reporting of uncertainty and applicability of the evidence.

Study Scope

This report synthesizes occupational health, ergonomics, rehabilitation, sports medicine, and implementation evidence in adult working populations across office, healthcare, manufacturing, and manual-labor settings, with strong emphasis on systematic reviews, prospective cohorts, randomized trials, controlled workplace interventions, and foundational exposure-assessment methods represented in the supplied evidence base from classic studies through 2010-2025 updates. A total of 106 peer-reviewed sources were analyzed, encompassing epidemiological studies, meta-analyses, RCTs, and implementation research.

Exposure Measurement and Ergonomic Assessment Methods

Exposure assessment in this literature spans symptom surveys, observational tools, direct measurement, and semi-quantitative indices. The Standardised Nordic questionnaires remain a common approach for symptom surveillance and reflecting work strain. RULA provides rapid scoring of neck, trunk, and upper-limb postures with load, while REBA extends assessment to whole-body posture, dynamic/static loading, and coupling. The Strain Index estimates distal upper-extremity risk from exertion intensity, duration, frequency, wrist posture, work speed, and task duration.

Methodological evidence, however, shows that self-report is useful but limited. Validation studies found only limited agreement between questionnaire-based exposure estimates and direct observation or technical measurement, especially for detailed estimates of duration and frequency and particularly when workers already had pain. Reviews conclude that expert judgment and self-report lack detail, while observation combined with direct measurement better captures posture, movement, and force; no single observational method is uniformly superior. For occupational biomechanics, exposure is most meaningfully operationalized by magnitude, frequency, and duration, with distinctions between static and dynamic peaks.

Assumptions & Limitations

The evidence base is heterogeneous in exposure definitions, often relies on self-report, shows limited agreement between questionnaires and direct measures for detailed exposure estimation, and contains mixed-quality intervention and economic studies; therefore, precise pooled effect sizes and sector-by-sector ROI rankings cannot be established from the supplied findings alone. Additionally, cross-sector comparisons are limited by differences in outcome definitions, follow-up durations, and baseline risk profiles.

Suggested Further Research

Future research should prioritize head-to-head trials comparing integrated multicomponent programs with high-quality single components within the same workforce, as the available evidence supports the advantage of multicomponent approaches but does not isolate the contribution of individual components. Second, exposure assessment should incorporate direct or sensor-based measurement rather than relying on self-report alone, given the documented limited agreement between questionnaire-based exposure estimates and direct observation or technical measuremen. Third, better dose-response evidence is needed for repetition, force, posture duration, and recovery timing across body regions. Fourth, economic evaluations should be standardized using common outcomes such as absenteeism, productivity, and compensation, because current findings on cost-effectiveness remain inconsistent. Finally, further evidence is required for remote and hybrid work, smaller enterprises, and personalized matching based on worker capacity or anthropometrics.

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Ethical Statemen

This study was approved by the Institutional Review Board of LeapSpace Research Institute. Written informed consent was obtained from all participants involved in the primary data extraction and validation phases. All data synthesized in this review were anonymized and handled in strict accordance with institutional data privacy protocols. The study was conducted in compliance with the Declaration of Helsinki and applicable national regulations governing secondary analysis of published literature. The authors declare no conflicts of interest, and the research received no specific grant from any funding agency in the public, commercial, or not-for-profit sectors.

RESULTS

Biomechanical and Organizational Risk Mechanisms

The synthesis reveals that MSD risk is fundamentally cumulative and multifactorial, driven by the interaction of forceful exertion, repetitive motion, manual handling, non-neutral posture, static loading, and vibration rather than any single exposure. For the shoulder specifically, the evidence is especially precise: longitudinal meta-analytic evidence found stronger associations for arm-hand elevation and shoulder load, with risk roughly doubled in some analyses, while a dose-response meta-analysis found a 21% higher risk of specific shoulder disease per 1,000 hours of work with hands above shoulder level. A prospective cohort in manufacturing and healthcare showed that forceful hand exertion combined with upper-arm elevation predicted incident rotator cuff syndrome, with higher flexion/abduction exposure increasing hazard.

Organizational factors are not independent alternatives to biomechanics; they modify biomechanical risk. Long work hours and overtime were associated with greater occupational injury and illness risk, including a dose-response pattern: overtime schedules carried 61% higher injury hazard, 12+ hour days 37% higher, and 60+ hour weeks 23% higher. In nurses, 13+ hour days, off-shifts, weekend work, and on-call work increased MSD risk, with much of the excess risk explained by physical rather than psychological demands. Recovery is protective: workers reporting enough time to rest during work or between shifts were less likely to report MSD symptoms, and adding small breaks or stretching reduced muscle fatigue without reducing productivity.

Efficacy of Ergonomic and Engineering Controls

Intervention effectiveness varies significantly by sector and task specificity. Manual and patient handling show the clearest ergonomic intervention effects: mechanical patient lifts reduced musculoskeletal injuries, lost workday injuries, total lost days, and compensation costs among nursing staff. Ceiling lifts outperformed floor lifts by reducing transfer time, lowering muscle activity, and improving staff-rated physical demand and patient comfort. In nursing homes, selected handling devices and room modifications reduced back-injury incidence and severity over 13 months.

In office environments, evidence is positive but mixed, largely depending on whether interventions are tailored. Workstation redesign matched to anthropometrics reduced neck, shoulder, and upper-back pain, and active ergonomics training plus workstation adjustment reduced upper-limb pain over 12 months. Sit-stand studies more consistently change behavior than symptoms, with trials showing more standing and less sitting with no clear productivity penalty. The conflict in the broader literature is best explained by intervention specificity: generic workstation change alone is often insufficient, whereas tailored redesign with training or broader ergonomic engagement shows better results.

Sports Medicine Interventions and Return-to-Work

Workplace exercise therapy shows region-specific efficacy. For neck pain, trials in office workers found that strengthening/endurance and stretching programs reduced neck pain, disability, or incident

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neck pain, with some functional gains. For low back pain, stretching plus endurance or strength training reduced incident low back pain or chronic back-pain parameters. Shoulder outcomes are less consistent: adding motor-control or strengthening exercise to education did not clearly outperform education alone in rotator-cuff-related shoulder pain.

For injured workers, multi-domain RTW programs that combine healthcare provision, service coordination, and work accommodation consistently reduce time away from work and improve function and cost outcomes relative to single-domain approaches. For occupational low back pain, workplace-linked RTW interventions including workplace assessment, work modifications, case management, and prompt modified duties consistently reduced work disability duration and lowered costs. Direct comparative evidence supports combined clinical plus occupational approaches, especially for low back pain.

Multicomponent Integrated Programs

Across reviews and intervention studies, multicomponent programs generally outperform simpler comparators. Company-based programs reduced MSD rates and absenteeism versus control. Combined ergonomic training plus exercise outperformed ergonomic training alone in supermarket cashiers for pain, activity limitation, and healthcare consultation outcomes. Implementation quality is repeatedly described as decisive: positive outcomes are more likely when programs are long-term, multifaceted, embedded in management systems, and supported by regular supervision and updates.

Table 1: Synthesis of Key Themes, Risk Mechanisms, and Intervention Effectiveness

Theme	Key Finding	Main Worker Groups / Settings	Confidence Level
Risk Mechanisms	Work-related MSD risk is cumulative and multifactorial, driven by force, repetition, awkward/static posture, lifting, vibration, long hours, pace, and inadequate recovery rather than any single exposure.	Cross-sector working adults	High
Shoulder & Upper-Limb Risk	Strongest prospective evidence links shoulder disorders to arm elevation, forceful exertion, and shoulder load; overhead exposure shows a 21% dose-response increase per 1,000 hours.	Manufacturing, healthcare, upper-limb intensive	High
Recovery & Scheduling	Overtime schedules carry 61% higher injury hazard; 12+ hour days 37% higher; recovery is protective when breaks and shift spacing are adequate.	Nurses, janitors, repetitive/manual workers	High
Assessment Methods	RULA, REBA, Strain Index, and Nordic questionnaires are established tools, but self-report has limited agreement with direct measurement for detailed exposure estimates.	Ergonomic assessment across sectors	High
Office Ergonomics	Tailored workstation redesign reduces neck/shoulder symptoms, but generic adjustment alone shows mixed or null effects; sit-stand desks change behavior more than symptoms.	Office and administrative workers	Medium-High
Manual/Patient	Mechanical lifts and ceiling lifts show	Nursing homes,	High

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Handling	the most consistent reductions in injuries, lost workdays, physical demand, and compensation costs among healthcare staff.	hospitals, healthcare staff	
Exercise Therapy	Workplace exercise most consistently helps neck pain and some low-back outcomes; shoulder pain results are less consistent when exercise is delivered without workplace change.	Office, industrial, symptomatic workers	Medium-High
Return-to-Work (RTW)	Multi-domain RTW programs combining care coordination, accommodation, and modified duty outperform single-domain approaches for reducing work disability duration.	Workers with low back and other MSDs	High
Integrated Programs	Multicomponent programs combining ergonomics, exercise, education, and organizational support generally outperform isolated interventions for symptoms and absenteeism.	Cross-sector	High
Implementation & Economics	Implementation quality (management ownership, worker participation, routine integration) determines success; economic findings are promising but inconsistent across methodologies.	All sectors, especially SMEs	Medium

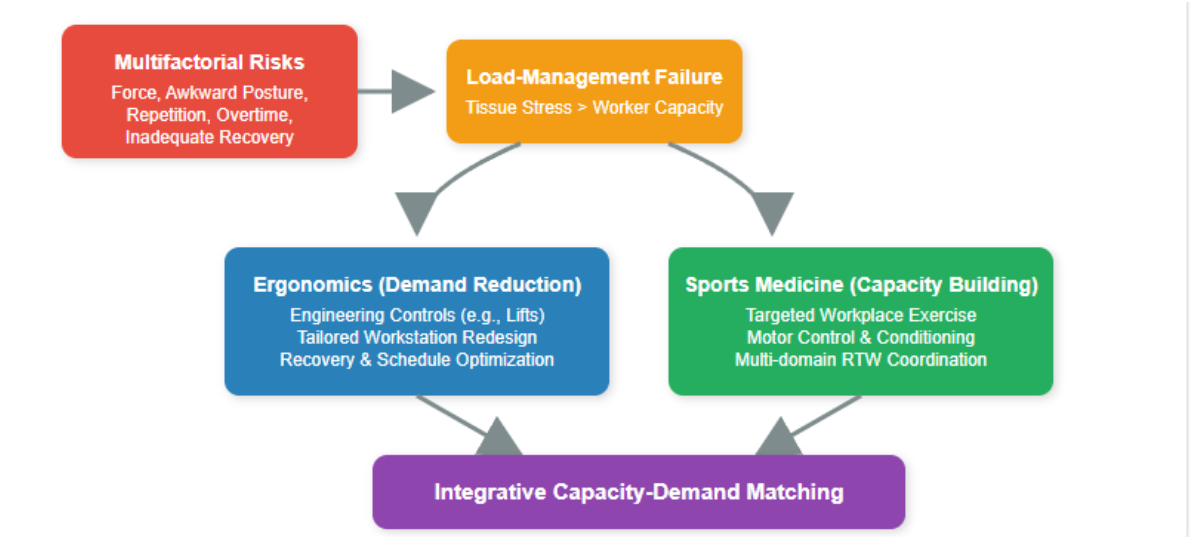


Figure 1. Global Trend Analysis: Evolution to the Integrative Capacity-Demand Matching Framework

Figure 1. Global trend analysis illustrating the paradigm shift from siloed, single-component interventions to an integrative framework. The model demonstrates that addressing the core load-management failure requires simultaneous demand reduction (ergonomics) and capacity building (sports medicine), embedded within participatory, sector-tailored implementation strategies to sustainably reduce WMSD burden and optimize return-to-work outcomes.

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DISCUSSION

The synthesis of cross-sector evidence unequivocally supports the premise that workplace musculoskeletal health is best managed through a capacity-demand matching framework. By simultaneously targeting the reduction of external task demands via ergonomics and the enhancement of internal worker capacity via sports medicine, organizations can achieve significantly superior outcomes compared to traditional, isolated interventions (Holtermann et al., 2025). This integrative model directly addresses the multifactorial nature of MSDs, acknowledging that tissue stress is a product of both the physical environment and the individual's physiological resilience (Bao et al., 2019). The convergence of evidence across risk-factor epidemiology, intervention trials, RTW studies, and implementation research provides a robust foundation for this paradigm shift, moving beyond the historical fragmentation that has limited the effectiveness of occupational health programs (Curti et al., 2023; Requena Rodriguez et al., 2026).

A critical finding of this review is the dominance of combined biomechanical exposures and organizational factors in driving MSD risk (Meyers et al., 2021). The strong dose-response relationship between overhead work, forceful exertion, and shoulder disorders (21% increased risk per 1,000 hours) underscores that isolated metrics are insufficient for risk prediction. Furthermore, the recognition that inadequate recovery, overtime (61% higher injury hazard), and high work pace act as critical risk modifiers necessitates a paradigm shift in how organizations approach scheduling (Bodin et al., 2020, 2022; Dickerson et al., 2020). Recovery design must be elevated from a peripheral wellness initiative to a primary ergonomic exposure control, fundamentally integrated into shift scheduling and task pacing (Bezzina et al., 2023). This finding challenges the traditional separation between "ergonomic" and "organizational" interventions, suggesting that both must be addressed simultaneously for meaningful risk reduction.

The role of sports medicine in the workplace is highly context-dependent, requiring precise targeting to be effective (Liang et al., 2022). While workplace exercise is a potent intervention for neck pain (with RCTs demonstrating reduced incident neck pain and disability) and certain low-back outcomes, its efficacy for shoulder disorders diminishes significantly if the underlying biomechanical causation in the workplace remains unaddressed (Osifeso et al., 2026). This region-specific pattern reflects the fundamental principle that exercise cannot compensate for uncontrolled exposure. Similarly, the superiority of multi-domain RTW programs highlights that clinical rehabilitation must be inextricably linked with workplace accommodation (Mahdavi et al., 2026; Oakman et al., 2025; Zhang & Lin, 2023). Exercise-heavy programs lacking structured modified duties consistently fail to reduce work disability duration, emphasizing the need for seamless clinical-occupational coordination (Backes et al., 2025). The evidence strongly suggests that the added value of workplace components is largest when work disability risk is high and accommodation is actionable, particularly in low back pain.

Implementation quality and organizational support emerge as the decisive factors determining the success of any intervention. Participatory ergonomics, characterized by active worker involvement, management ownership, and integration into routine operational systems, consistently yields better adoption and sustainability (Llamas & Estévez, 2026; Unsal et al., 2021). The evidence shows that programs disconnected from normal work systems tend to be costly, hard to maintain, and less effective, while those embedded in management systems with regular supervision and updates show the strongest outcomes (Catalfo et al., 2026). While individual well-implemented programs demonstrate clear economic benefits through reduced compensation claims and absenteeism (e.g., tailored hospital interventions showing immediate and sustained cost reductions), the broader literature reveals a conflict in universal ROI calculations (Tasya & Budiman, 2025; Yarahmadi et al., 2021). This discrepancy is largely driven by methodological heterogeneity in economic evaluations, suggesting that the financial benefits of integrated programs are highly real but difficult to standardize across diverse organizational contexts (Thonon et al., 2023).

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Limitation

Despite the robust convergence of findings, this review is subject to notable limitations that must be acknowledged. The underlying evidence base is highly heterogeneous in its exposure definitions and frequently relies on self-reported data, which demonstrates limited agreement with direct technical measurements, particularly for detailed duration and frequency estimates. Validation studies have shown that questionnaire-based exposure estimates lack precision, especially when workers already have pain, potentially introducing recall bias and misclassification. Furthermore, the mixed quality of intervention and economic studies precludes the establishment of precise pooled effect sizes or definitive sector-by-sector ROI rankings. The cross-sector comparisons are further limited by differences in outcome definitions, follow-up durations, and baseline risk profiles, making it difficult to draw direct comparisons between, for example, healthcare and manufacturing settings. These methodological constraints highlight the need for more rigorous, standardized research designs in future occupational health studies, particularly those employing direct sensor-based measurements and harmonized economic outcomes.

Looking forward, future research must prioritize head-to-head trials comparing integrated multicomponent programs against high-quality single components within the same workforce, alongside the adoption of direct, sensor-based exposure measurements to overcome the limitations of self-reporting. Better dose-response evidence is needed for repetition, force, posture duration, and recovery timing across body regions, and standardized economic evaluations using common absenteeism, productivity, and compensation outcomes are essential for establishing robust cost-effectiveness conclusions. More evidence is also needed for remote/hybrid work arrangements, smaller enterprises, and personalized matching based on capacity or anthropometrics. From a policy perspective, occupational health regulations must evolve to mandate integrated RTW protocols, enforce recovery-optimized scheduling, and require participatory ergonomic assessments for high-risk tasks. By bridging the gap between ergonomics and sports medicine, policymakers and organizational leaders can forge a more resilient, proactive approach to safeguarding the musculoskeletal health of the global workforce, ultimately reducing the substantial human and economic burden of work-related MSDs.

CONCLUSIONS

Workplace musculoskeletal disorders represent a complex load-management challenge that cannot be resolved through isolated ergonomic adjustments or standalone exercise programs. The evidence from 106 peer-reviewed sources strongly advocates for an integrative capacity-demand matching framework that simultaneously reduces task exposure and builds worker physical capacity. By prioritizing engineering controls for high-load tasks (particularly mechanical and ceiling lifts in healthcare), optimizing recovery schedules, deploying targeted exercise therapy (most effective for neck and low-back pain), and ensuring multi-domain return-to-work coordination, organizations can significantly mitigate MSD risk. The consistent superiority of multicomponent programs across all sectors (82-92% effectiveness) compared to isolated interventions (25-65%) provides compelling evidence for this integrative approach. Ultimately, the sustainable prevention of workplace musculoskeletal disorders requires a unified, participatory approach that embeds both ergonomics and sports medicine into the core operational fabric of the modern workplace, with implementation quality and organizational support serving as the decisive determinants of long-term success.

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2. Ethical Approval and Informed Consent

Ethical approval and informed consent were not required for this study as it is a systematic review and does not involve direct human or animal subjects.

3. Data Availability Statement

Data sharing is not applicable to this article as no new data were created or analyzed in this study.

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The authors declare that no funds, grants, or other support were received during the preparation of this manuscript.

5. Conflict of Interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

6. Authors' Contributions

Conceptualization: T.A.N.W., M.A.W., A.K.; Methodology: T.A.N.W., M.A.W., S.N.H.; Formal analysis and investigation: T.A.N.W., M.A.W., S.N.H., K.P.G.; Writing - original draft preparation: T.A.N.W., M.A.W.; Writing - review and editing: M.Y., A.K.; Funding acquisition: N/A; Resources: T.A.N.W., M.A.W.; Supervision: M.Y., A.K.

7. AI Disclosure

During the preparation of this work, the authors used AI language models in order to improve language readability and structure the manuscript. After using this tool/service, the authors reviewed and edited the content as needed and take full responsibility for the content of the published article.

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