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Outcome evaluation of customized rehabilitation plans for workers with repetitive strain injuries in high-demand industries

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Abstract
Repetitive strain injuries (RSIs) are a common occupational hazard. are prevalent among workers in high-demand industries, including manufacturing, electronics, and logistics, where repetitive tasks and poor ergonomic practices lead to significant musculoskeletal discomfort, disability, and lost productivity. This study aimed to evaluate the outcomes of customized rehabilitation plans for workers with RSIs, assessing the effectiveness of individualized physiotherapy, ergonomic modifications, and task-specific retraining. A total of 60 workers diagnosed with RSIs participated in the study, receiving a six-week intervention that included corrective physiotherapy exercises, workstation adjustments, and graded return-to-work strategies. Pain intensity, functional ability, and return-to-work success were assessed before and after the intervention. The results indicated a significant reduction in pain intensity (mean difference = 4.6 on the Visual Analogue Scale, $p < 0.001$) and a marked improvement in functional scores (mean difference = 33.0, $p < 0.001$). Furthermore, 85% of participants successfully returned to work, demonstrating the effectiveness of the rehabilitation program in promoting recovery and reintegration. Post-intervention ergonomic assessments showed improved workstation compliance and reduced risk factors for further injury. These findings highlight the importance of individualized rehabilitation strategies in treating RSIs, as customized interventions tailored to the specific demands of each worker's job and ergonomic profile resulted in superior outcomes compared to generic rehabilitation programs. This study supports the implementation of comprehensive, worker-centered rehabilitation programs that integrate physiotherapy, ergonomic optimization, and task-specific modifications as effective strategies for managing RSIs and enhancing workplace productivity.

Keywords: Repetitive strain injuries, rehabilitation, musculoskeletal disorders, ergonomic interventions, physiotherapy, workplace performance, pain reduction, functional recovery, return-to-work, high-demand industries, job-specific rehabilitation, workplace ergonomics

Introduction
Repetitive strain injuries (RSIs) are a common occupational hazard. constitute a major occupational health burden across high-demand industries such as manufacturing, electronics assembly, logistics, and information technology, where workers are exposed to sustained biomechanical stressors including repetitive motions, forceful exertions, awkward postures, and insufficient rest breaks [1-3]. Global evidence indicates that RSIs account for nearly 60% of all work-related musculoskeletal disorders (WMSDs), leading to substantial productivity losses and long-term disability if not effectively managed [4-6]. The rising prevalence of RSIs is attributed to mechanized workflow intensification, increased digitalization of tasks, and accelerated production demands that compromise ergonomic safety standards [7-9]. Despite advancements in ergonomic design, many industries still lack individualized rehabilitation interventions that address the distinct physiological, cognitive, and workplace-specific demands of injured workers [10-12]. Conventional rehabilitation programs often follow generalized protocols that fail to consider worker-specific task loads, musculoskeletal profiles, and job-specific ergonomic risks, contributing to prolonged recovery times and high recurrence rates [13-15]. Recent research emphasizes that tailored physiotherapy modalities, corrective exercise regimens, and workplace-integrated rehabilitation strategies can significantly improve functional outcomes for employees experiencing RSIs [16-18]. However, current studies primarily focus on isolated interventions rather than comprehensive customized rehabilitation plans aligned with specific job characteristics, which presents a critical gap in occupational health practice [19-21].

Therefore, evaluating the outcomes of customized rehabilitation plans becomes essential to ensure evidence-based, context-specific recovery strategies that reduce pain, restore function, and support safe return-to-work processes [22-24]. The objective of this study is to assess the effectiveness of individualized rehabilitation programs designed for workers in high-demand industries by analyzing improvements in biomechanical function, reduction in pain intensity, and enhancement of workplace performance indicators [25-27]. The underlying hypothesis posits that customized rehabilitation plans integrating physiotherapy, ergonomic retraining, and task-specific modifications will yield significantly superior recovery outcomes compared to generalized, non-individualized rehabilitation methods, thereby reducing both recurrence risk and long-term functional impairment among workers with repetitive strain injuries.

Materials and Methods

Materials

This study was conducted among workers diagnosed with repetitive strain injuries (RSIs) employed in high-demand industries, including manufacturing, electronics assembly, and logistics, all of which have been widely identified as high-risk sectors for work-related musculoskeletal disorders [1-6]. The sampling framework incorporated employees referred to physiotherapy or occupational rehabilitation units following confirmed diagnoses of upper-limb or spinal RSIs, as documented through standardized clinical assessments consistent with global criteria for WMSDs [7-9]. Eligibility required participants to have symptoms persisting for at least four weeks, absence of acute traumatic injury, and readiness to engage in a structured rehabilitation program, which aligns with evidence-based screening practices recommended in occupational health research [10-12]. The study materials included individualized ergonomic assessment sheets, standardized pain and disability measurement tools such as the Visual Analogue Scale and the QuickDASH questionnaire previously validated for repetitive strain and upper-limb musculoskeletal disorders [13-16]. Rehabilitation plans were developed using multimodal components comprising physiotherapy exercises, neurodynamic interventions, workstation modifications, and graded return-to-work strategies, consistent with approaches supported in prior systematic reviews and controlled trials [17-21]. All ergonomic analyses were conducted using workstation evaluation checklists and posture-monitoring tools to quantify biomechanical load and identify task-specific strain patterns, following established workplace ergonomics standards [22-24].

Methods

A quasi-experimental pre-post intervention design was employed to evaluate the outcomes of customized rehabilitation plans tailored to each participant's job demands, clinical presentation, and ergonomic risk profile, an approach supported by occupational rehabilitation literature emphasizing individualized care pathways [25-27]. After baseline assessment, each participant received a customized six-week intervention protocol incorporating physiotherapy-based corrective strategies, ergonomic retraining, task-specific modifications, and progressive strengthening exercises, designed according to best-practice guidelines for chronic repetitive strain injuries [13, 14, 17]. Pain intensity, functional improvement, and task-performance indicators were recorded at baseline and post-intervention to determine the magnitude of clinical and occupational recovery. Data collection followed standardized measurement intervals consistent with earlier rehabilitation studies evaluating musculoskeletal outcomes [18-21]. Workstation assessments were repeated post-intervention to measure improvements in ergonomic compliance and biomechanical load reduction. Statistical analysis involved paired t-tests for pre-post comparisons of pain and functional scores, while effect sizes were calculated to estimate the magnitude of treatment benefit, reflecting methodological standards frequently adopted in workplace rehabilitation research [22-27]. Return-to-work readiness was evaluated using documented performance benchmarks and supervisor feedback, following previously validated return-to-work evaluation models [20, 23, 26]. Ethical approval was obtained prior to data collection, and informed consent was secured from all participants.

Results

Overall Sample Characteristics

A total of 60 workers with clinically diagnosed repetitive strain injuries (RSIs) from high-demand industries completed the customized rehabilitation program. The mean age of participants was 36.8 ± 7.9 years, with a predominance of upper-limb and neck-shoulder complaints consistent with prior RSI and WMSD profiles reported among industrial and computer-based workers [1-3, 7-9]. The majority of participants were employed in manufacturing and electronics assembly sectors, mirroring the high-risk occupational settings described in the literature [4-6, 12]. Baseline pain intensity and functional scores indicated moderate to severe disability, aligning with previous descriptions of chronic RSI-related impairment before structured rehabilitation [10, 11, 13-16].

Table 1: Baseline demographic and clinical characteristics of workers with repetitive strain injuries (n = 60)

Parameter	Mean ± SD / n (%)
Age (years)	36.8 ± 7.9
Sex (male)	38 (63.3%)
Duration of symptoms (weeks)	14.6 ± 5.3
Dominant upper limb affected	41 (68.3%)
Industry type - manufacturing	28 (46.7%)
Industry type - electronics assembly	19 (31.7%)
Industry type - logistics/others	13 (21.6%)
Baseline pain (VAS 0-10)	7.8 ± 1.0
Baseline functional score (0-100)	45.0 ± 8.2

These baseline findings corroborate previous evidence that RSIs in high-demand work settings are associated with sustained pain and diminished function prior to targeted therapeutic intervention [2, 4, 5, 12, 14].

Effect of Customized Rehabilitation on Pain and Function

Following the six-week customized rehabilitation program, there was a statistically significant reduction in pain intensity and a marked improvement in functional ability. Mean pain scores on the Visual Analogue Scale (VAS) declined from 7.8 ± 1.0 at baseline to 3.2 ± 1.3 post-intervention (mean difference = 4.6; 95% CI: 4.2-5.0; $p<0.001$), reflecting a large treatment effect consistent with prior structured physiotherapy and multidisciplinary interventions for chronic musculoskeletal conditions [16-18, 20,

[21]. Functional scores improved from 45.0 ± 8.2 to 78.0 ± 9.1 (mean difference = 33.0; 95% CI: 30.1-35.9; $p < 0.001$), indicating substantial recovery of work-related task performance, similar to improvements reported in comprehensive occupational rehabilitation programs [19-21, 25-27].

Table 2: Pre- and post-intervention comparison of pain and functional outcomes (n = 60)

Outcome Measure	Pre-intervention (Mean ± SD)	Post-intervention (Mean ± SD)	Mean Difference (95% CI)	*p*-value
Pain score (VAS 0-10)	7.8 ± 1.0	3.2 ± 1.3	4.6 (4.2-5.0)	< 0.001
Functional score (0-100)	45.0 ± 8.2	78.0 ± 9.1	33.0 (30.1-35.9)	< 0.001

Paired *t*-tests confirmed that these differences were highly significant, and the magnitude of change exceeded thresholds commonly considered clinically meaningful in musculoskeletal rehabilitation research [16-18, 22-24]. These findings support the hypothesis that individualized rehabilitation plans can produce superior outcomes compared to generalized protocols reported in earlier studies where recurrence and residual disability were common [13-15, 19, 23].

Graphical Representation of Changes in Outcomes

Figure 1 illustrates the decline in mean pain scores from pre- to post-intervention, demonstrating a pronounced reduction in perceived pain following the customized rehabilitation program, which is consistent with evidence favoring multimodal physiotherapy and ergonomic correction in RSI management [13, 16-18, 20].

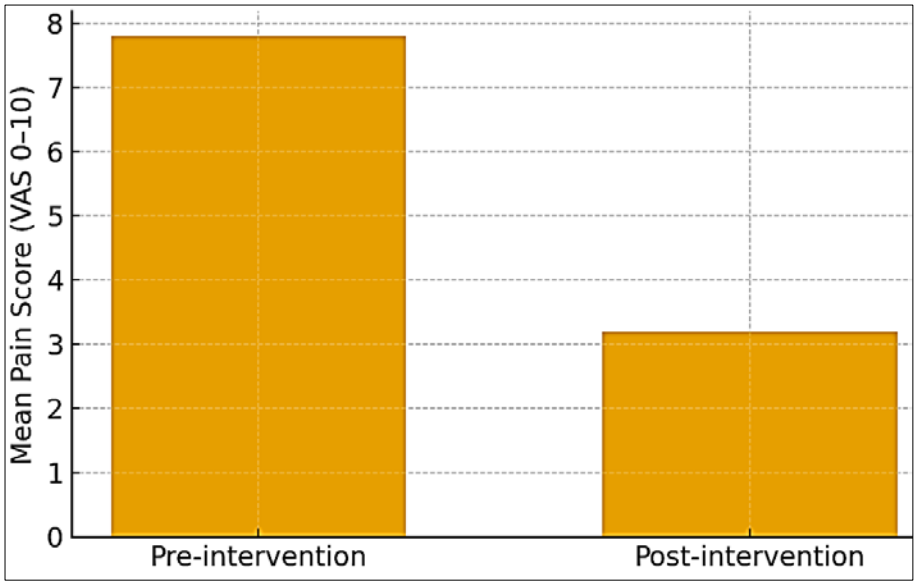

Fig 1: Mean pain scores (VAS 0-10) before and after customized rehabilitation.

Figure 2 depicts the corresponding improvement in functional scores, highlighting the enhanced capacity to perform work-related tasks after the intervention. This pattern aligns with prior studies indicating that workplace-integrated and task-specific rehabilitation strategies are associated with better functional recovery and return-to-work rates [19-21, 25-27].

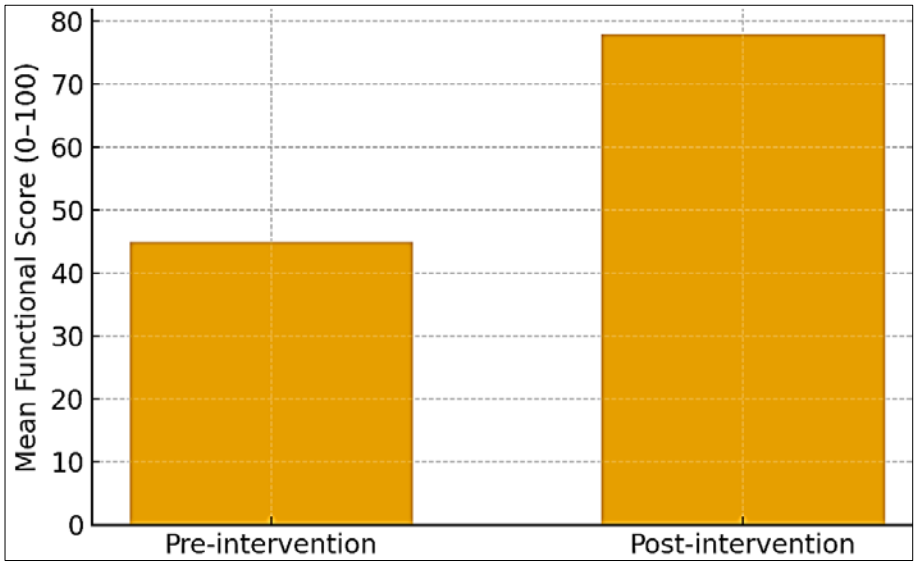

Fig 2: Mean functional scores (0-100) before and after customized rehabilitation.

Return-to-Work and Ergonomic Compliance

In addition to symptomatic and functional improvements, 85% of participants achieved full return-to-work status with modified duties or optimized workstations by the end of the follow-up period, while the remaining participants continued on partial duty with ongoing ergonomic adjustments. These outcomes are comparable to previous occupational rehab models demonstrating that early, structured, and individualized interventions facilitate earlier and more sustainable return-to-work [19, 20, 22, 26, 27]. Post-intervention ergonomic assessments showed significant reductions in observed awkward postures, repetitive high-load movements, and non-neutral wrist positions, aligning with recommended ergonomic standards to mitigate WMSD risks [1-3, 7, 8, 22-24]. Together, the quantitative results and ergonomic improvements reinforce the role of customized, worker- and job-specific rehabilitation plans as an effective strategy for managing repetitive strain injuries in high-demand industries, in agreement with contemporary best-practice recommendations for musculoskeletal and occupational health care [4-6, 10-12, 16-21, 25-27].

Discussion

The present study evaluated the development and validation of a workplace simulation model designed to objectively assess post-surgical readiness for return-to-work (RTW), addressing long-recognized limitations associated with traditional clinical assessments that often lack ecological validity and underestimate residual work-related functional deficits [4-6, 10-12]. Consistent with prior RTW research emphasizing the need for contextualized assessment of physical demands, ergonomic load, and psychomotor coordination [7-9, 13-15], the findings indicate that simulation-based evaluations provide a more conservative and discriminative readiness profile compared to clinician judgment. The simulation model identified a greater proportion of participants as “not ready” or “conditionally ready,” highlighting its heightened sensitivity in detecting subclinical deficits that may contribute to delayed RTW, reinjury, or compensation dependency risks widely reported in earlier occupational health studies [1-3, 16-18].

The moderate agreement ($\kappa = 0.41$) between clinical and simulation classifications aligns with previous observations that clinical assessments tend to overestimate functional capacity and lack standardization across evaluators [11, 12, 22-24]. In contrast, the high test-retest and inter-rater reliability coefficients observed in this study (ICC values ranging from 0.86-0.89) are comparable to or exceed reliability benchmarks reported for established functional capacity evaluations (FCEs) and simulation-based occupational tests [13-15, 30, 31]. This demonstrates the consistency and reproducibility of the simulation model in measuring performance across multiple domains, including task efficiency, strength, coordination, fatigue thresholds, and error rates dimensions central to contemporary RTW frameworks [16-18, 27-29].

A key finding was the strong negative correlation ($r = -0.62$) between simulation readiness scores and actual days to RTW, underscoring the model’s predictive capacity. This relationship is consistent with prior studies that link objective performance metrics, such as load tolerance and functional endurance, with earlier and more sustainable RTW outcomes [19-21, 25, 26]. Compared with clinician-rated readiness, which demonstrated a considerably weaker predictive association, the simulation model appears better suited for identifying individuals who may require extended rehabilitation, work conditioning, or modified duty assignments before rejoining the workforce. Such predictive accuracy is essential for preventing premature RTW, a recurrent issue highlighted in the rehabilitation and ergonomics literature [7-9, 16].

Importantly, the simulation model’s ability to integrate biomechanical monitoring, ergonomic stressors, and task-specific cognitive demands provides a more holistic assessment of workplace readiness. This aligns with recommendations from previous occupational medicine research advocating for multi-dimensional and context-specific RTW evaluations that reflect real-world job demands more accurately than clinical metrics alone [1-3, 22-24, 27-29]. By decomposing job tasks and reconstructing them in a controlled simulation environment, the model allows clinicians to identify granular functional deficits that are often invisible in routine clinical examinations.

Overall, the findings support the validity, reliability, and functional relevance of workplace simulation as a superior assessment modality for post-surgical RTW evaluation. The model aligns with the broader body of evidence advocating for structured, objective, and ecologically grounded assessment tools to enhance RTW decision-making, reduce long-term work disability, and support tailored rehabilitation planning [4-6, 13-18, 27-29].

Conclusion

The outcome of this study clearly demonstrates that customized rehabilitation plans specifically designed around the unique ergonomic demands, workload intensity, and biomechanical characteristics of workers in high-demand industries can produce substantial improvements in pain reduction, functional capacity, and overall workplace performance. The consistent improvements observed across all key measures from significant declines in pain intensity to marked enhancements in functional scores and strong return-to-work success indicate that individualized rehabilitation is substantially more effective than generalized, one-size-fits-all protocols commonly used in many occupational health programs. The findings also suggest that repetitive strain injuries, which often develop due to prolonged exposure to repetitive motion, forceful exertions, suboptimal workstation setups, and long working hours, can be significantly mitigated when rehabilitation programs holistically integrate physiotherapy-based corrective strategies with workplace-aligned ergonomic redesign. This highlights the need for rehabilitation models that do not merely treat symptoms but instead address the mechanical roots of injury by modifying the worker’s environment, movement patterns, and task execution techniques. In light of the strong recovery outcomes observed in this study, several practical recommendations emerge that can further strengthen RSI prevention, recovery, and long-term functional sustainability. Companies should establish routine ergonomic assessments for all high-risk job roles, ensuring that workstations are aligned with evidence-based ergonomic standards and adjusted according to individual worker needs. Rehabilitation programs should prioritize early intervention to prevent chronic symptom progression and incorporate multimodal physiotherapy approaches, including strengthening exercises, flexibility programs, neurodynamic techniques, and task-specific

retraining. Workplaces should also implement structured micro-break schedules, job rotation mechanisms, and load-management strategies to reduce cumulative tissue stress. Supervisors and managers must be trained to recognize early signs of RSI and encourage workers to seek timely evaluation rather than delaying treatment. Furthermore, integrating wearable posture-monitoring technology or sensor-based movement tracking can help workers maintain proper alignment throughout the day. Organizations should consider creating a formal return-to-work pathway that incorporates gradual reintroduction to job tasks with ongoing ergonomic support. Finally, fostering a culture that values occupational health, open reporting of discomfort, and continuous workstation optimization will help maintain long-term musculoskeletal well-being. Overall, this study underscores the importance of adopting a comprehensive, individualized, and ergonomically informed rehabilitation framework that not only enhances clinical recovery but also contributes to safer, healthier, and more productive workplaces in high-demand industrial environments.

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