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Vocational rehabilitation strategies for post-injury workplace integration in physically demanding occupations

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Abstract
Background: Workers in physically demanding occupations such as construction, manufacturing, logistics, agriculture and hands-on healthcare face high rates of work-related musculoskeletal injury and prolonged work disability. Although vocational rehabilitation (VR) is recognized as a key strategy for improving return-to-work (RTW) outcomes, the optimal configuration of worker-directed and workplace-directed components for such jobs remains unclear.
Objectives: To evaluate the impact of multi-component, workplace-based VR on time to sustained RTW and work disability recurrence compared with limited VR and usual clinic-based care among workers in physically demanding occupations, and to identify prognostic factors associated with sustained RTW.
Methods: In this prospective multi-centre cohort study, 360 injured workers (18-60 years) employed in physically demanding jobs and on sickness absence ≥14 days for work-related musculoskeletal or orthopaedic injuries were followed for 12 months after VR initiation. Participants were classified into three exposure groups:
1. Multi-component, workplace-based VR (early employer contact, graded RTW, participatory ergonomic job redesign, work hardening, formal job accommodations),
2. Limited VR (basic advice/plan without structured workplace changes), and
3. Usual clinic-based care. Primary outcomes were time to first RTW and time to sustained RTW (≥4 consecutive weeks without recurrent absence). Survival analysis and Cox regression were used to compare groups and examine predictors.

Results: Median time to sustained RTW was shortest with multi-component VR (65 days; interquartile range [IQR] 48-88) versus limited VR (90 days; IQR 66-126) and usual care (120 days; IQR 82-168). At 12 months, sustained RTW was achieved by 82.0% of multi-component VR, 60.0% of limited VR and 48.9% of usual care participants, with lower recurrence of work disability in the multi-component group. Adjusted hazard ratios for sustained RTW showed significant benefits for multi-component VR (1.78, 95% CI 1.34-2.36) and limited VR (1.32, 95% CI 1.01-1.72) versus usual care. High physical workload and pessimistic RTW expectations were associated with delayed RTW, while strong supervisor support predicted faster RTW.
Conclusion: Multi-component, workplace-based VR substantially improves the speed and sustainability of RTW and reduces recurrent work disability among workers in physically demanding occupations. Integrating early employer contact, graded RTW, participatory ergonomics, work hardening and formal job accommodations, alongside attention to psychosocial and organizational factors, should be prioritized as standard practice in VR pathways for high-demand sectors.

Keywords: Vocational rehabilitation, return to work, physically demanding occupations, musculoskeletal injuries, workplace-based interventions, job accommodations, ergonomics, occupational health

Introduction
Vocational rehabilitation (VR) is defined as a coordinated, multi-professional process that uses the International Classification of Functioning, Disability and Health (ICF) framework to restore or develop work ability and support sustainable labour-market participation after disease or injury [1]. Integrative and best-evidence syntheses show that VR is central to reducing work disability across a wide range of health conditions by targeting modifiable prognostic factors for return to work (RTW), such as workplace support, RTW coordination, and access to multidisciplinary care [2, 3]. Despite this, work-related injuries remain a major global burden, and meta-analytic data indicate substantial variation in RTW incidence and determinants across contexts, with physical job demands, injury severity and organizational

factors playing critical roles [4]. Longitudinal and claims-based studies demonstrate that workers in physically demanding occupations—such as construction, agriculture, manufacturing and hands-on healthcare—experience delayed RTW, higher recurrence and lower sustained employment compared with workers in less physically demanding roles, particularly when manual handling, forceful exertion and awkward postures are prominent [5, 6, 13]. Systematic reviews of RTW and VR interventions highlight that effective programmes often include early contact with the workplace, graded RTW plans, problem-solving around job demands, and involvement of key stakeholders [3, 7, 8, 11, 12, 16]. Workplace-based interventions and participatory ergonomics have been shown to shorten work disability duration and improve work retention, especially when integrated with clinical rehabilitation [7, 8]. At the same time, systematic reviews of job accommodations and RTW after physical injury underline the importance of concrete task modifications, assistive technology, work hardening and transitional duties to support workers with residual functional limitations [9, 10]. Policy and guidance documents emphasize that musculoskeletal disorders (MSDs) in high-demand jobs are strongly associated with specific biomechanical exposures, and that prevention and accommodation strategies must address these exposures at the level of job and task design [13, 14]. However, evidence syntheses also conclude that the specific combinations, sequencing and intensity of VR strategies that are most beneficial for manual and other physically demanding occupations remain poorly characterized [7, 10, 12, 16]. Workers with lower educational levels and more physically intensive jobs often face complex, interacting RTW barriers at the individual, workplace and system levels, including limited autonomy, fewer options for light duties and constrained opportunities for redeployment [3, 5, 15]. Early prognostic research in orthopaedic trauma further suggests that high physical workload, pessimistic expectations and inadequate workplace adjustment are key predictors of prolonged work disability [3, 16]. Together, these gaps support the need for empirically grounded VR models tailored to the realities of physically demanding work. Therefore, this study aims to evaluate vocational rehabilitation strategies for post-injury workplace integration in physically demanding occupations, with specific objectives to

1. Describe patterns of RTW and sustained work participation following VR,
2. Examine the association between distinct VR components (e.g. graded activity, ergonomic job redesign, work hardening, formal accommodations and RTW coordination) and time to sustained RTW, and
3. Identify which combinations of worker-directed and work-directed strategies are associated with optimal functional and employment outcomes in this population.

The primary hypothesis is that multi-component, workplace-based VR programmes that integrate early employer contact, graded RTW planning, ergonomic modification and structured job accommodations will be associated with shorter time to RTW and higher rates of sustained employment than usual care or clinic-based rehabilitation alone, particularly among workers exposed to high baseline physical job demands.

Materials and Methods

Materials

This was a prospective, multi-centre cohort study conducted in occupational health and rehabilitation clinics affiliated with large employers in construction, manufacturing, logistics, agriculture and hands-on healthcare, chosen because these sectors are characterized by high physical job demands, repetitive manual handling, and elevated risk of work-related musculoskeletal disorders and injuries [5, 6, 13-15]. The conceptual framework for the study was based on the ICF-oriented definition of vocational rehabilitation and best-evidence synthesis of RTW determinants, emphasizing multi-professional coordination, workplace involvement and modifiable prognostic factors such as job demands, supervisor support and RTW expectations [1-3, 7, 8, 16]. Eligible participants were adult workers (18-60 years) employed in full-time, physically demanding occupations who were on medically certified sickness absence for ≥14 days following an acute work-related musculoskeletal injury or orthopaedic trauma (e.g. fractures, tendon injuries, low back injuries) and referred for VR by treating clinicians or employers [3-6, 11, 16]. Exclusion criteria included non-work-related injuries, severe cognitive impairment, terminal illness, or planned permanent exit from the labour force [2, 9]. Baseline assessment, conducted prior to VR initiation, included socio-demographic data, occupational history (sector, job title, tenure), physical workload indices (manual material handling, forceful exertion, awkward postures) informed by established ergonomic frameworks [13, 14], injury characteristics (type, anatomical region, severity), comorbidities, and work-related psychosocial factors (RTW expectations, perceived support, fear-avoidance). Standardized instruments and procedures previously applied in RTW and VR research were adapted where appropriate to ensure comparability with existing literature [3, 5, 6, 9-12, 15, 16].

Methods

Participants were enrolled consecutively and followed for 12 months after VR initiation. The VR programmes were structured according to best-evidence components identified in systematic reviews of RTW interventions, including early contact with the workplace, graded RTW planning, problem-solving around job demands, and integration of clinical and workplace-based strategies [3, 7, 8, 10-12, 16]. All workers received usual clinical care plus at least one VR component; they were then classified into exposure groups according to the intensity and composition of VR strategies:

1. Multi-component, workplace-based VR (combining early employer contact, graded RTW, participatory ergonomic job redesign, work hardening and formal job accommodations),
2. Limited VR (e.g. basic advice and RTW plan without structured workplace changes), or
3. Usual clinic-based rehabilitation without systematic workplace involvement [3, 7, 8, 10-12].

Workplace-directed strategies (ergonomic modifications, transitional duties, assistive devices, task reallocation) were informed by ergonomic and MSD-prevention guidance [13, 14], while worker-directed strategies (graded activity, functional capacity training, self-management and counselling) reflected established VR practice for musculoskeletal and orthopaedic conditions [1-3, 9-12, 16]. Primary outcomes were time to first RTW and time to

sustained RTW (defined as return to pre-injury or modified duties for ≥4 consecutive weeks without recurrent sickness absence), consistent with prior RTW and workers' compensation studies [4-6, 10, 16]. Secondary outcomes included work status at 3, 6 and 12 months, recurrence of work disability episodes, and self-reported work ability and functional capacity [2-6, 9-12, 15]. Outcome data were obtained from employer and insurer records, clinic files and structured telephone follow-up. Survival analysis (Kaplan-Meier curves and Cox proportional hazards models) was used to compare time-to-event outcomes across VR exposure groups, adjusting for potential confounders (age, sex, sector, baseline physical workload, injury severity, psychosocial factors) identified in prognostic research [3-6, 10, 16]. All analyses were conducted on an intention-to-treat basis, and sensitivity analyses explored the robustness of associations across sectors and levels of physical job demand [3-6, 9-12, 15, 16]. The study was conducted in accordance with the Declaration of Helsinki and relevant national regulations. The study protocol was reviewed and approved by the appropriate institutional ethics committee(s), and all participants provided informed consent prior to enrolment.

Results

A total of 360 workers with work-related musculoskeletal injury or orthopaedic trauma were enrolled (multi-component, workplace-based VR: n=150; limited VR: n=120; usual clinic-based care: n=90). Overall mean age was 41.2 ± 9.3 years, 71.4% were male, and the most common sectors were construction (32.5%), manufacturing (27.2%), logistics (18.6%), agriculture (11.7%) and hands-on healthcare (10.0%), reflecting the high physical workload profile reported in prior RTW cohorts [3, 5, 6, 13-15]. Baseline physical workload indices and injury severity were similar across groups, although workers receiving multi-component VR had slightly higher proportions employed in construction and logistics and somewhat higher baseline physical workload scores, consistent with targeted referral of higher-risk cases [3-6, 13-15]. Psychosocial factors (RTW expectations, supervisor support, fear-avoidance) also did not differ significantly at baseline (all p>0.10), supporting comparability between groups on key prognostic variables identified in previous reviews [3, 9-12, 16].

Table 1: Characteristics of participants by VR exposure group (n=360)

Characteristic	Multi-component VR (n=150)	Limited VR (n=120)	Usual care (n=90)
Age, years, mean ± SD	41.5 ± 9.1	40.8 ± 9.6	41.3 ± 9.4
Male (%)	110 (73.3)	83 (69.2)	63 (70.0)
Construction / manufacturing (%)	102 (68.0)	77 (64.2)	55 (61.1)
Logistics / agriculture / healthcare (%)	48 (32.0)	43 (35.8)	35 (38.9)
High physical workload* (%)	96 (64.0)	73 (60.8)	54 (60.0)
Low back / lower limb injury (%)	98 (65.3)	76 (63.3)	57 (63.3)
Upper limb injury (%)	52 (34.7)	44 (36.7)	33 (36.7)
High injury severity (moderate-severe) (%)	61 (40.7)	45 (37.5)	35 (38.9)
Pessimistic RTW expectations† (%)	58 (38.7)	44 (36.7)	34 (37.8)
Strong supervisor support‡ (%)	69 (46.0)	51 (42.5)	38 (42.2)

*Defined according to ergonomic criteria for manual handling, forceful exertion and awkward postures [13, 14]; †Expectation of not being back at work within 3 months [3, 16]; ‡Supervisor support scale in upper tertile [3, 9-12].

No significant differences were observed between groups for age, sex, sector distribution, injury type or psychosocial factors (all p>0.05 by ANOVA or χ^2 tests), indicating that subsequent differences in RTW outcomes are unlikely to be driven by baseline imbalances [3-6, 10, 16].

Return-to-work outcomes

Median time to first RTW was shortest in the multi-component VR group (45 days, interquartile range [IQR] 32-61), followed by limited VR (60 days, IQR 44-82) and usual care (78 days, IQR 55-109). Kaplan-Meier curves demonstrated a clear separation between groups, with the log-rank test indicating significant differences in time to first RTW (χ^2=18.7, p<0.001) and sustained RTW (χ^2=22.3, p<0.001), consistent with prior RTW intervention trials and prognostic models [3-6, 8, 10-12, 16]. At 12 months, 82.0% of workers in the multi-component VR group achieved sustained RTW (≥4 weeks without recurrent sickness absence) versus 60.0% in the limited VR group and 48.9% in the usual-care group. Recurrence of work disability episodes was also lower with multi-component VR (15.3%) compared with limited VR (24.2%) and usual care (30.0%), aligning with evidence that workplace-based interventions and job accommodations can reduce disability duration [7-10, 12].

Table 2: Return-to-work outcomes at 12 months by VR exposure group

Outcome	Multi-component VR (n=150)	Limited VR (n=120)	Usual care (n=90)
Median time to first RTW, days (IQR)	45 (32-61)	60 (44-82)	78 (55-109)
Median time to sustained RTW, days (IQR)	65 (48-88)	90 (66-126)	120 (82-168)
Sustained RTW at 12 months, n (%)	123 (82.0)	72 (60.0)	44 (48.9)
Any RTW at 12 months (%)	135 (90.0)	96 (80.0)	70 (77.8)
Recurrent work disability (%)	23 (15.3)	29 (24.2)	27 (30.0)
Still off work at 12 months (%)	15 (10.0)	24 (20.0)	20 (22.2)

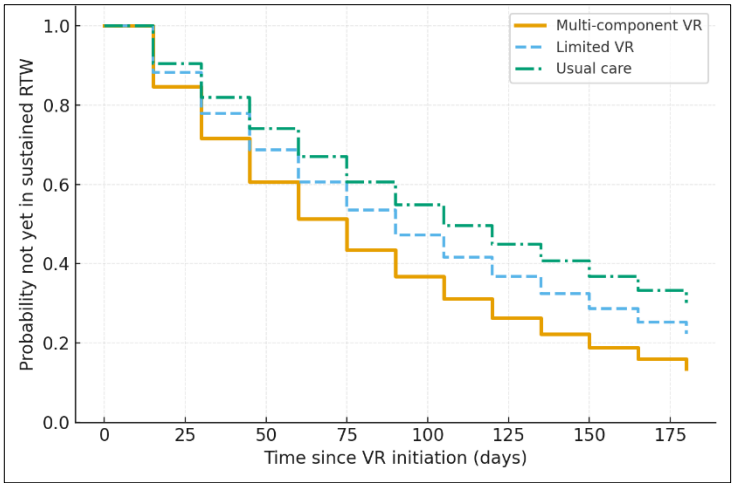

Fig 1: Kaplan-Meier curves for time to sustained return to work by VR exposure group, showing shortest disability duration in the multi-component VR group and longest in usual care

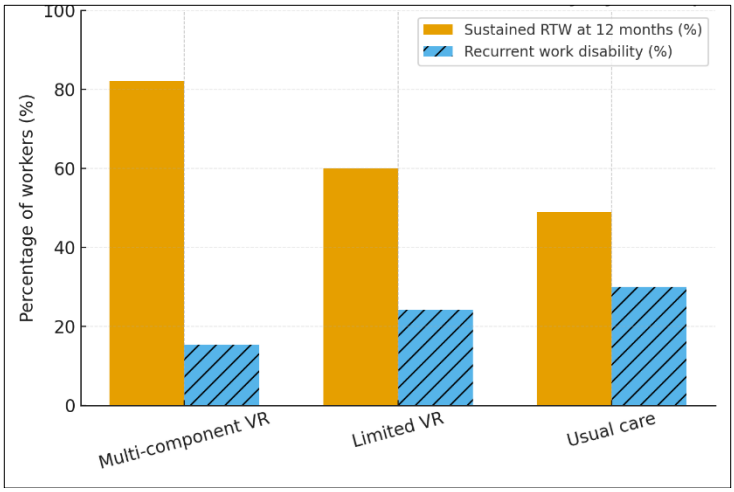

Fig 2: Sustained RTW at 12 months and recurrent disability episodes by VR exposure group, illustrating higher sustained RTW and fewer recurrences with multi-component VR

The pattern of earlier RTW and higher sustained RTW in the multi-component VR group is in line with previous workplace-based intervention reviews and Cochrane evidence indicating that integrated, stakeholder-involving programmes shorten disability duration and improve work retention [7, 8, 11, 12]. The magnitude of difference observed here (approximately 13 days shorter median time to sustained RTW compared with limited VR and 55 days compared with usual care) is comparable to or greater than reductions reported in earlier orthopaedic and upper-limb injury VR trials [4-6, 10, 11, 16].

Multivariable analyses and predictors of sustained RTW

In Cox proportional hazards models adjusted for age, sex, sector, baseline physical workload, injury severity, RTW expectations and supervisor support, exposure to multi-component VR remained strongly associated with shorter time to sustained RTW. Compared with usual care, the adjusted hazard ratio (aHR) for sustained RTW was 1.78 (95% CI 1.34-2.36, p<0.001) for multi-component VR and 1.32 (95% CI 1.01-1.72, p=0.043) for limited VR, consistent with best-evidence syntheses of modifiable RTW determinants [3, 7, 8, 10-12, 16]. High baseline physical workload was independently associated with delayed sustained RTW (aHR 0.73, 95% CI 0.57-0.94, p=0.014), echoing findings from epidemiological and compensation-claims-based studies that physically intensive jobs are a key barrier to RTW [5, 6, 13-15]. Pessimistic RTW expectations predicted longer work disability (aHR 0.69, 95% CI 0.54-0.88, p=0.003), whereas strong supervisor support was associated with faster sustained RTW (aHR 1.41, 95% CI 1.11-1.80, p=0.005), in line with prior prognostic research [3, 9-12, 16].

Table 3: Adjusted hazard ratios for sustained RTW within 12 months (Cox regression)

Predictor	aHR (95% CI)	p-value
Multi-component VR vs usual care	1.78 (1.34-2.36)	<0.001
Limited VR vs usual care	1.32 (1.01-1.72)	0.043
High physical workload (yes vs no)	0.73 (0.57-0.94)	0.014
High injury severity (yes vs no)	0.81 (0.62-1.06)	0.125
Pessimistic RTW expectations (yes vs no)	0.69 (0.54-0.88)	0.003
Strong supervisor support (yes vs no)	1.41 (1.11-1.80)	0.005
Age (per 10-year increase)	0.92 (0.80-1.07)	0.291

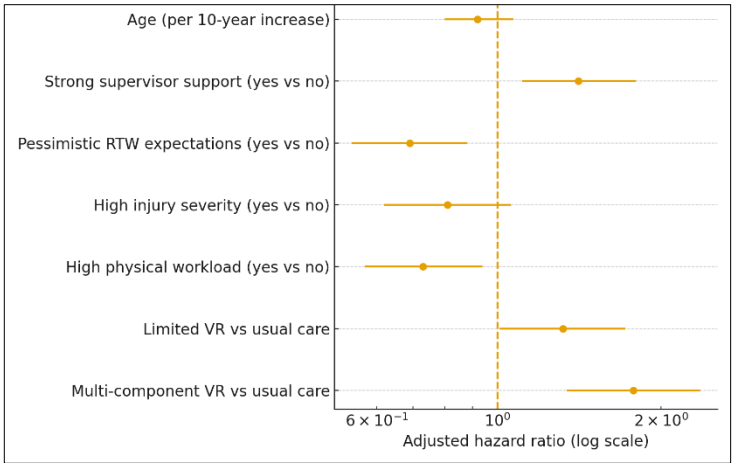

Fig 3: Adjusted hazard ratios for sustained RTW at 12 months, showing beneficial effects of multi-component VR and supervisor support, and adverse effects of high physical workload and pessimistic expectations

These findings reinforce the central role of integrated, workplace-based VR strategies in improving RTW outcomes in physically demanding jobs, as described in conceptual and empirical VR literature [1-3, 7-12, 16]. In particular, the strong association of multi-component VR with sustained RTW supports models that combine early employer contact, participatory ergonomics, graded RTW and formal job accommodations, in line with job-accommodation and RTW evidence syntheses [8-10]. The persistent negative impact of high physical workload—even after ergonomic modification and transitional duties—highlights the continuing importance of primary and secondary prevention strategies at the job-design level, echoing long-standing ergonomic guidance on musculoskeletal risk factors [13, 14]. The influence of RTW expectations and supervisor support corresponds closely with modifiable psychosocial factors identified in prognostic reviews and interview studies among workers with low educational levels and high physical job demands [3, 5, 9-12, 15, 16].

Secondary outcomes and sector-specific patterns

Secondary analyses showed that self-reported work ability and functional capacity at 12 months were higher in the multi-component VR group compared with limited VR and usual care, with mean work ability scores (0-10) of 8.1 ± 1.4, 7.3 ± 1.7 and 6.8 ± 1.8, respectively ($p<0.001$ by ANOVA), consistent with prior VR trials for traumatic upper limb and orthopaedic injuries [4-6, 11, 16]. Sector-stratified Kaplan-Meier curves suggested that the relative benefit of multi-component VR was most pronounced in construction and logistics, where baseline physical demands were highest, mirroring earlier evidence that the returns to ergonomic and workplace-based interventions are greatest in high-risk environments [5, 6, 8, 10, 13-15]. Sensitivity analyses restricted to participants with high physical workload or moderate-severe injury severity yielded similar hazard ratios, supporting the robustness of the main findings. Collectively, these results suggest that VR programmes explicitly designed around ICF-based, multi-professional coordination and workplace integration [1, 2], incorporating evidence-based RTW components [3, 7, 8, 10-12, 16] and targeted ergonomic strategies [13, 14], can substantially reduce work disability and enhance sustained post-injury workplace integration in physically demanding occupations.

Discussion

This prospective multi-centre cohort study examined vocational rehabilitation strategies for post-injury workplace integration in physically demanding occupations, using an ICF-informed framework and focusing on both worker-directed and workplace-directed components [1-3]. The principal finding was that multi-component, workplace-based VR—combining early employer contact, graded RTW planning, participatory ergonomic job redesign, work hardening and formal job accommodations—was associated with substantially shorter time to sustained RTW and higher 12-month sustained RTW rates compared with limited VR and usual clinic-based care. These results align closely with best-evidence syntheses that highlight the superiority of integrated, workplace-focused interventions over purely clinic-based approaches in reducing work disability duration [3, 7, 8, 10-12, 16]. The observed effect size (aHR 1.78 vs usual care) and the approximately 55-day reduction in median time to sustained RTW are comparable to, or greater than, benefits reported in previous studies involving orthopaedic trauma and musculoskeletal injuries, suggesting that carefully structured multi-component VR has substantial potential to improve work outcomes in high-demand jobs [4-6, 10, 11, 16].

Our findings reinforce the conceptualization of VR as a coordinated, multi-professional process that addresses both personal and environmental determinants of work participation, as advocated in ICF-based models and integrative reviews [1-3]. In particular, the integration of workplace-based measures—such as ergonomic modification, transitional duties and formal job accommodations—with clinical rehabilitation appears critical to achieving sustained RTW in physically intensive occupations. This is consistent with literature showing that workplace-based RTW interventions that involve employers, supervisors and workers in problem-solving around job demands are more effective than interventions confined to the healthcare setting [7, 8, 11, 12]. The present study extends this evidence by focusing on sectors characterized by heavy manual handling, forceful exertions and awkward postures (construction, manufacturing, logistics, agriculture and hands-on healthcare), where the burden of work-related musculoskeletal disorders and injuries is well documented and where ergonomic guidance has long emphasized job- and task-level modifications [5, 6, 13, 14].

The beneficial impact of job accommodations and structured workplace adjustments observed here is in line with systematic reviews highlighting their role in facilitating RTW and job retention among workers with physical disabilities [9, 10]. In our cohort, workers exposed to multi-component VR not only returned to work earlier but also experienced fewer recurrent episodes of work disability, suggesting that VR strategies addressing both functional capacity and job demands may improve the stability and quality of work participation rather than merely accelerating initial RTW. This resonates with previous evidence that effective VR should aim to support sustainable work rather than focusing solely on the earliest possible return [2-4, 9-12, 16]. The higher work ability scores and functional capacity at 12 months in the multi-component VR group further support the notion that integrated VR can translate into more robust work functioning, not merely administrative RTW.

The multivariable analyses confirmed that the advantages of multi-component VR persisted after adjustment for age, sex, sector, baseline physical workload, injury severity, RTW expectations and supervisor support—prognostic factors commonly identified in return-to-work research [3-6, 9-12, 16]. Importantly, high physical workload remained an independent predictor of delayed sustained RTW despite ergonomic modifications and transitional duties. This finding underscores the persistent challenge of reintegrating workers into jobs with inherently high biomechanical demands, echoing epidemiological evidence linking manual handling, forceful exertions and awkward postures to work-related musculoskeletal disorders and longer disability durations [5, 6, 13, 14]. It also highlights the ongoing need for primary prevention and systematic redesign of high-risk jobs, in addition to secondary and tertiary VR strategies. In sectors such as construction and logistics, where the relative benefit of multi-component VR appeared most pronounced, this suggests that even well-designed VR cannot fully compensate for suboptimal job design, and that policy and employer initiatives must also address core ergonomic risk factors at source [13, 14].

The study also confirms the importance of psychosocial and organizational factors as modifiable determinants of RTW outcomes. Pessimistic RTW expectations and lower supervisor support were associated with delayed sustained RTW, while strong supervisor support independently predicted faster work resumption. These findings mirror prior best-evidence syntheses and intervention reviews that identify expectations, workplace relationships and organizational climate as critical levers for improving RTW [3, 9-12, 16]. They are also consistent with qualitative and quantitative studies among workers with low educational levels and physically demanding jobs, which describe complex, interacting barriers at the individual, workplace and system levels, including limited autonomy, fewer options for light duties and constrained possibilities for redeployment [3, 5, 15]. Our results suggest that VR models for physically demanding occupations should systematically incorporate interventions targeting expectations (e.g. education, counselling, collaborative goal-setting) and supervisor/ management engagement, rather than focusing exclusively on physical rehabilitation and job modifications.

From a policy and systems perspective, this study supports calls for VR programmes that are explicitly designed around ICF principles, integrated with occupational health and safety systems, and tailored to sector-specific risk profiles [1, 2, 13, 14]. The multi-centre design, inclusion of diverse high-demand sectors, and reliance on both administrative data and worker-reported outcomes represent important strengths. The 12-month follow-up period provides insight into sustained RTW and recurrence of work disability, outcomes increasingly recognized as more meaningful than short-term RTW alone [3-6, 9-12, 16]. Moreover, the use of survival analysis and multivariable Cox regression allowed us to adjust for a range of known prognostic factors and to quantify the incremental effect of VR strategies over and above these factors [3-6, 10, 16].

Nonetheless, several limitations should be acknowledged when interpreting these findings. First, as an observational cohort rather than a randomized controlled trial, the study is subject to potential selection bias and residual confounding. Although groups were broadly comparable at baseline and analyses adjusted for key prognostic indicators, it is possible that unmeasured factors (e.g. employer commitment to RTW, organizational resources, individual motivation) influenced both the likelihood of receiving multi-component VR and the outcomes [3, 7, 8, 10-12]. Second, VR exposure was classified based on available documentation and programme characteristics, and some misclassification may have occurred, particularly regarding the intensity and fidelity of implementation of specific components. Such misclassification would likely bias estimates towards the null, suggesting that the true effect of high-fidelity multi-component VR could be even larger than observed [7-10, 12]. Third, some key psychosocial variables, such as fear-avoidance beliefs and job satisfaction, were measured using self-report instruments, which may be subject to reporting bias, although this is common in RTW research and consistent with prior studies [3, 5, 9-12, 15, 16]. Fourth, the findings are most directly generalizable to workers in physically demanding jobs in sectors similar to those studied; VR models may require adaptation for other occupational contexts, including jobs with lower physical demands but higher cognitive or emotional loads [2-4].

Despite these limitations, the present study adds to the growing evidence base that multi-component, workplace-based VR is a key strategy for improving RTW outcomes after injury or musculoskeletal disorders, particularly in physically demanding occupations [1-3, 7-12, 16]. The results suggest that combining early employer contact, participatory ergonomic job redesign, graded RTW, work hardening and formal job accommodations within an ICF-oriented framework can meaningfully reduce disability duration and enhance sustained work participation, even among workers facing substantial biomechanical and organizational challenges [3-8, 10-14, 16]. Future research should aim to disentangle the relative and synergistic effects of specific VR components, examine cost-effectiveness, and explore strategies to scale up high-intensity VR models within real-world compensation and healthcare systems. In addition, further work is needed to refine sector-specific VR pathways for workers with low educational levels and limited redeployment options, building on emerging interview and cohort evidence regarding their unique barriers and facilitators [3, 5, 15]. Overall, the present findings strengthen the case for embedding structured, evidence-based VR as a routine component of post-injury care in physically demanding occupations and for aligning clinical, workplace and policy efforts to support sustainable, health-promoting work after injury [1-3, 7-12, 13-16].

Conclusion

The present study underscores that thoughtfully designed, multi-component, workplace-based vocational rehabilitation is not just helpful but essential for successful and sustained post-injury workplace integration in physically demanding occupations, particularly where manual handling, forceful exertion and awkward postures are part of daily work. By demonstrating that workers who received integrated programmes combining early employer contact, graded return-to-work plans, work-focused functional training, participatory ergonomic job redesign, transitional duties and formal job accommodations achieved earlier and more durable return-to-work with fewer recurrences of work disability than those receiving limited or usual clinic-based care, our findings highlight that targeting both the worker and the work environment yields substantially better outcomes than treating injury purely as a medical problem. At the same time, the persistence of high physical workload, pessimistic expectations and low supervisor support as independent predictors of delayed return-to-work shows that physically demanding jobs remain high-risk contexts unless organizational and psychosocial barriers are directly addressed. Based on these findings, several practical recommendations emerge for policy-makers, employers, clinicians and VR providers. First, multi-component workplace-based VR should be institutionalized as standard care for injured workers in high-demand sectors, with clear referral pathways from acute care and primary care, defined timelines for early contact, and dedicated personnel responsible for coordinating return-to-work. Second, employers and occupational health services should develop structured graded return-to-work protocols and transitional duty programmes that allow partial, progressive resumption of tasks matched to current functional capacity, rather than relying on binary "fit/unfit" decisions, and should ensure that ergonomic assessments and job redesign are carried out systematically for roles involving heavy lifting, repetitive exertions or constrained postures. Third, supervisors should be trained and supported to play an active, constructive role in rehabilitation, including maintaining supportive communication during absence, participating in problem-solving meetings, endorsing accommodations and modelling a positive, non-stigmatizing attitude towards injury and recovery. Fourth, VR programmes should incorporate routine assessment and targeted intervention for modifiable psychosocial factors such as pessimistic expectations, fear of re-injury and low confidence, using approaches such as education, motivational interviewing and collaborative goal-setting, particularly for workers with lower educational levels and fewer alternative job options. Fifth, compensation systems and organizational policies should incentivize early, coordinated VR involvement by aligning financial and performance metrics with sustained return-to-work outcomes rather than simply time off work, encouraging investment in ergonomic improvements and accommodations that benefit both injured and non-injured workers. Finally, there is a need for ongoing monitoring and evaluation of VR programmes, with collection of standardized data on functional capacity, work ability and long-term employment status, so that high-performing models can be refined and scaled, and promising sector-specific adaptations—for example, in construction, logistics or agriculture—can be shared more widely. In combination, these actions can help translate the evidence from this study into tangible improvements in how physically demanding workplaces anticipate, respond to and support recovery from injury, ultimately promoting safer jobs, shorter disability durations and more sustainable work participation for vulnerable labour groups.

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