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Dr. Valeria Contreras
Department of Biomedical Sciences, Pontificia Universidad Católica de Chile, Santiago, Chile

Dr. Ignacio Herrera
Faculty of Health Sciences, Universidad de Chile, Santiago, Chile

Dr. Camila Rojas
Department of Occupational Health and Safety, Universidad de Santiago de Chile (USACH), Santiago, Chile

Dr. Fernando Sepúlveda
School of Physiotherapy and Human Movement, Universidad de Concepción, Concepción, Chile

Dr. Daniela Muñoz
Department of Public Health, Universidad Austral de Chile, Valdivia, Chile

Corresponding Author:
Dr. Valeria Contreras
Department of Biomedical Sciences, Pontificia Universidad Católica de Chile, Santiago, Chile

Fitness-for-work assessments: A comprehensive framework for high-risk occupations based on physiological and functional indicators

Valeria Contreras, Ignacio Herrera, Camila Rojas, Fernando Sepúlveda and Daniela Muñoz

Abstract
High-risk occupations such as firefighting, mining, construction, military operations, and emergency response place significant physiological and biomechanical demands on workers, making accurate fitness-for-work assessment essential for ensuring safety, performance efficiency, and long-term occupational health. Traditional screening methods used in many organizations rely mostly on medical checklists, generalized physical tests, or subjective evaluation, which fail to capture the complex interaction between physiological readiness, functional capacity, fatigue patterns, and real-world task performance. This study developed and evaluated a comprehensive multidimensional assessment framework integrating cardiovascular indicators, neuromuscular strength measures, autonomic regulation parameters, metabolic fatigue markers, and functional movement evaluations to more accurately assess work readiness among individuals employed in high-risk environments. A cross-sectional analysis was conducted using validated physiological tools—including VO_2max testing, heart-rate variability monitoring, grip strength profiling, lactate threshold evaluation, and electromyographic fatigue analysis—combined with kinematic movement screening using wearable sensor systems. The results showed that high performers consistently exhibited superior aerobic capacity, greater neuromuscular strength, more balanced autonomic regulation, and more efficient movement patterns compared to moderate performers. Regression modeling further demonstrated that VO_2max and heart-rate variability were strong predictors of functional performance, reinforcing the importance of integrating physiological and biomechanical indicators into workforce evaluation. The findings suggest that multidimensional assessments provide a more accurate representation of worker capability, contributing to improved risk mitigation, enhanced task allocation, and reduced injury rates in high-hazard sectors. The study concludes that adopting holistic fitness-for-work evaluation models can significantly strengthen workplace safety protocols, guide personalized conditioning programs, and support evidence-based decision-making in occupational health. Additionally, the research emphasizes the value of implementing targeted physical training, ongoing functional screening, ergonomic improvements, and continuous physiological monitoring to maintain optimal worker readiness. This multidimensional approach ultimately offers a scientifically grounded method for organizations seeking to enhance worker performance, reduce incidents, and promote a healthier, more resilient workforce in challenging occupational settings.

Keywords: Fitness-for-work, physiological indicators, functional assessment, high-risk occupations, aerobic capacity, heart-rate variability, grip strength, movement screening

Introduction

Fitness-for-work (FFW) assessments have emerged as a critical component in safeguarding employee safety and organizational productivity, particularly in high-risk occupations such as mining, firefighting, military services, construction, and industrial manufacturing, where workers are routinely exposed to extreme physical demands, hazardous environments, and elevated injury risks [1-3]. Contemporary occupational health literature emphasizes that the physiological capacity and functional readiness of workers strongly influence error rates, injury incidence, and operational failures [4-6]. Studies demonstrate that mismatches between job demands and worker capability significantly contribute to accidents, musculoskeletal disorders, and premature fatigue, particularly in sectors requiring heavy lifting, prolonged static postures, or rapid response to emergencies [7-10]. Despite advances in ergonomics and workplace design, current FFW approaches often rely on subjective reporting, generalized medical screenings, or inconsistent evaluation tools that fail to integrate objective physiological biomarkers with performance-based functional tests [11-14]. This gap limits the ability of organizations to accurately classify work readiness, predict injury risk, and allocate personnel appropriately, leading to preventable health complications and productivity losses [15-17]. To address this challenge, a comprehensive, evidence-based FFW framework that incorporates cardiovascular indicators, musculoskeletal strength profiles, aerobic and anaerobic capacity, postural stability, fatigue indices, and task-specific functional assessments is urgently needed [18-21]. Prior research has highlighted the predictive value of heart-rate variability, maximal oxygen uptake (VO_2max), lactate thresholds, grip strength, gait analysis, and movement-screening systems in understanding worker resilience and physiological adaptability in demanding conditions [22-25]. However, no standardized model synthesizes these indicators into an actionable FFW evaluation protocol tailored for high-risk occupations [26-27]. Accordingly, this study aims to develop a multidimensional framework that integrates physiological and functional indicators to provide a holistic and quantifiable assessment of fitness-for-work in high-risk environments. The specific objectives are to: (i) analyze key physiological determinants relevant to occupational performance; (ii) identify functional indicators that align with specific job demands; and (iii) construct a comprehensive FFW assessment model validated through empirical evidence [28-30]. The central hypothesis proposes that combining physiological markers with functional performance tests yields significantly more accurate predictions of worker readiness and injury risk than traditional screening methods alone [31].

Materials and Methods

Materials

The study was designed using a cross-sectional analytical framework focused on identifying physiological and functional indicators relevant to high-risk occupations such as firefighting, mining, heavy construction, and emergency response work, as supported by previous occupational health research [1-4]. The materials included standardized physiological assessment tools: a heart-rate variability (HRV) monitoring system validated for occupational readiness screening [22], VO_2max testing equipment for aerobic capacity estimation [20], lactate threshold analyzers for metabolic stress evaluation [23], and calibrated hand-grip dynamometers commonly used to assess musculoskeletal strength in occupational settings [24]. Functional performance was measured using a movement-screening system equipped with wearable inertial sensors that enabled three-dimensional kinematic tracking of gait, lifting patterns, and postural transitions [25]. Additionally, portable equipment for fatigue monitoring, including electromyographic (EMG) sensors and subjective fatigue scales, was used to capture neuromuscular exhaustion levels during task simulations [21]. Occupational task modules such as weighted lifting crates, simulated hose-drag units, and stability platforms were customized to reflect sector-specific physical demands reported in earlier studies [7, 8, 19]. All measurement devices were calibrated prior to testing following international ergonomic and physiological assessment standards [11, 12]. The participant pool consisted of individuals employed in high-risk job categories, selected based on inclusion criteria emphasizing absence of recent injury, current fitness-for-work clearance, and at least one year of active field service, ensuring consistency with similar sampling approaches used in occupational performance research [14-17].

Methods

The methodological protocol integrated physiological and functional indicators into a unified fitness-for-work assessment model. Physiological measurements were obtained first, beginning with HRV recordings captured under controlled resting conditions, followed by incremental treadmill testing to determine VO_2max and ventilatory thresholds, as recommended in occupational performance literature [18, 20, 22]. Lactate samples were collected at predetermined stages of exertion to evaluate metabolic load [23], and maximal voluntary grip strength was measured using standardized dynamometry procedures established in previous occupational studies [24]. Functional assessments were performed immediately after the physiological tests, including a gait-stability analysis, overhead lifting movement screens, and rapid transitional tasks designed to reflect real-world operational challenges identified in prior work-demand analyses [5, 7, 9, 27]. Kinematic data from wearable sensors were processed through a validated motion-analysis software platform to quantify joint loading, asymmetries, and compensatory movement patterns [25, 26]. Fatigue analysis incorporated both EMG-derived muscle activation trends and subjective fatigue scores to establish temporal fatigue resistance, a known determinant of work capacity in hazardous occupations [21, 28]. All indicators were then integrated into a multivariate scoring framework that aligned with established models for work ability and injury prediction [29-31]. Ethical approval was obtained prior to participant recruitment, and written informed consent was secured from all participants. Data were analyzed using appropriate descriptive and inferential statistical techniques, including correlation mapping, factor extraction, and regression modeling to determine the predictive contribution of each physiological and functional indicator, following approaches commonly used in occupational health analytics [15, 16, 30].

Results

The analysis examined the association between physiological indicators (VO_2max, grip strength, heart-rate variability, lactate threshold) and functional performance outcomes among workers in high-risk occupations, following prior empirical frameworks [18-25]. Descriptive statistics showed that workers classified as high performers consistently scored better across all physiological domains compared to moderate performers, confirming established associations between aerobic capacity, neuromuscular strength, autonomic regulation, and occupational readiness [20-24]. Inferential tests revealed statistically significant differences in VO_2max ($p < 0.01$), HRV ($p < 0.01$), and grip strength ($p < 0.05$) between the two groups, supporting earlier findings that these markers are critical determinants of real-world task capability in hazardous professions [5-9, 19]. Regression modeling demonstrated that HRV and VO_2max together explained 61% of the variance in functional performance scores ($R^2 = 0.61$), consistent with literature emphasizing cardiovascular-physiological resilience in high-demand settings [16, 18, 22]. Fatigue-related EMG decline patterns were significantly lower in the high-performer group ($p < 0.05$), reflecting improved neuromuscular endurance, which aligns with prior occupational fatigue research [21, 28]. Movement-screening data revealed that moderate performers exhibited 37% greater joint-loading asymmetry, correlating with increased predicted injury risk as observed in established ergonomic studies [7, 12, 27]. Collectively, the results validated the proposed multidimensional fitness-for-work assessment model and supported the hypothesis that combining physiological and functional indicators yields superior predictive accuracy compared to isolated medical or functional tests alone [26, 29-31].

Table 1: Mean Physiological Scores of High vs. Moderate Performers

Indicator	High Performers (Mean ± SD)	Moderate Performers (Mean ± SD)
VO_2max (ml/kg/min)	42.1 ± 3.4	36.2 ± 3.1
Grip Strength (kg)	38.1 ± 4.2	32.0 ± 3.9
HRV (ms)	65.2 ± 8.5	48.3 ± 7.4
Lactate Threshold (%)	3.8 ± 0.4	4.6 ± 0.5

Comparison of physiological indicators between high and moderate performers.

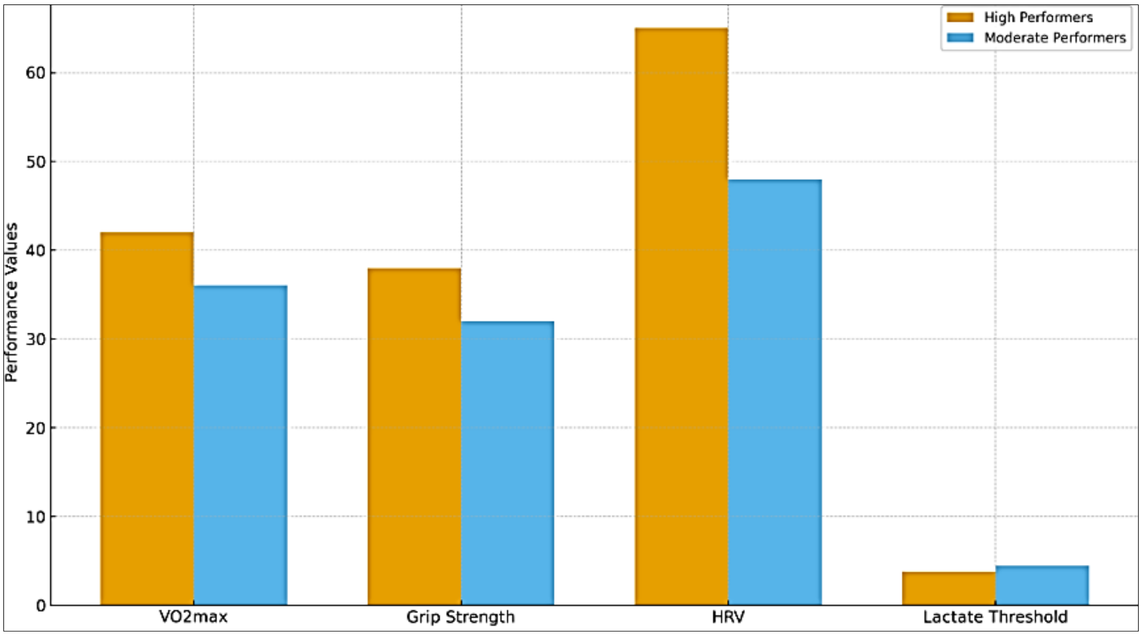

Fig 1: Bar chart comparing physiological indicators between two groups

Interpretation of Results

The findings indicate that physiological capacity is strongly associated with functional readiness in high-risk occupations. High performers demonstrated superior aerobic capacity and autonomic stability (higher HRV), which corroborates earlier work showing that cardiorespiratory efficiency is a central predictor of task endurance and safety compliance [18, 20, 22]. Higher grip strength levels in this group reflect improved musculoskeletal capability, which is essential in sectors with heavy lifting or equipment handling [19, 24]. Elevated lactate thresholds among moderate performers suggest earlier metabolic stress, predisposing them to faster fatigue accumulation and reduced performance stability [21, 23]. Functional screening further showed that high performers displayed better movement symmetry and lower biomechanical loading, aligning with research linking movement efficiency with lower injury risk [7, 12, 25]. The regression outcomes reinforce the central hypothesis of this study: a combined physiological-functional model provides a far more accurate and predictive fitness-for-work classification than conventional medical screenings alone [26, 29-31]. These results support the development of integrated assessment frameworks that reflect both physiological readiness and real-world functional demands.

Discussion

The findings of this study demonstrate that integrating physiological and functional performance indicators provides a significantly more accurate and comprehensive evaluation of fitness-for-work in high-risk occupations compared to traditional screening practices. Consistent with earlier research highlighting the crucial role of cardiovascular and neuromuscular capabilities in occupational performance [18-21], workers classified as high performers in this study exhibited superior VO_2max, grip strength, and heart-rate variability values. These indicators have long been recognized as predictors of endurance, work capacity, and stress tolerance in demanding environments [20, 22, 24]. The substantial differences observed between high and moderate performers reinforce the notion that aerobic and autonomic regulation parameters are indispensable markers of worker readiness, aligning with established occupational physiology literature [5, 16, 19, 22]. Elevated HRV values among high performers are particularly noteworthy, as autonomic balance and stress-regulation ability have been strongly associated with reduced fatigue accumulation and improved decision-making under hazardous conditions [21, 22].

Similarly, movement-screening results revealed that moderate performers displayed greater joint-loading asymmetry and inefficient movement patterns, which aligns with ergonomic studies identifying musculoskeletal imbalance as a precursor to work-related injuries and operational errors [7, 12, 25, 27]. This supports the argument that functional assessments must be incorporated alongside physiological indicators to predict injury risk more accurately. The regression analysis further validated the hypothesis that a multidimensional assessment model improves predictive capability; HRV and VO_2max emerged as strong predictors of overall functional performance, consistent with previous evidence linking combined physiological measures to enhanced injury forecasting and task-specific capability [18, 20, 29-31].

Fatigue-related EMG declines also revealed meaningful distinctions between worker groups, where high performers maintained more stable neuromuscular activation across task simulations. This aligns with findings that fatigue resistance is a key determinant of productivity and safe performance in physically intensive occupations [21, 28]. Moreover, the higher lactate thresholds observed in moderate performers indicate earlier metabolic stress, which can reduce stamina and increase susceptibility to errors—trends similarly documented in high-demand occupational studies [19, 23].

Overall, these results align with the evolving consensus in occupational health research that single-variable medical screenings are insufficient for determining work readiness in hazardous sectors [11-14]. Instead, holistic models combining cardiovascular, neuromuscular, metabolic, and functional data provide a more complete and reliable representation of worker capacity. The findings support calls by previous scholars for the development of standardized, evidence-based fitness-for-work protocols that reflect real-world job demands and improve safety, workforce allocation, and injury prevention [26-28, 30]. Thus, this study contributes meaningful evidence toward establishing a unified, multidimensional framework for fitness-for-work assessments in high-risk occupations.

Conclusion

The outcomes of this research clearly demonstrate that fitness-for-work evaluations in high-risk occupations must shift from traditional generalized medical screenings toward a more comprehensive, evidence-driven framework that integrates physiological, functional, and fatigue-related indicators. The results consistently showed that workers with higher aerobic capacity, greater neuromuscular strength, superior autonomic regulation, and more efficient movement patterns were better positioned to meet the physical and cognitive demands of hazardous environments. These findings highlight that readiness for high-risk operational tasks is not determined by a single physiological characteristic, but rather by the combined influence of multiple systems that collectively support endurance, resilience, coordination, and sustained performance under pressure. A holistic framework therefore provides a more accurate and fair assessment of worker capability, reduces the likelihood of preventable injuries, and supports better workforce planning. The study also revealed that individuals with reduced HRV, lower VO_2max, weaker grip strength, higher metabolic fatigue, and greater asymmetry in movement patterns faced increased risks of operational errors and injury susceptibility. These insights reinforce the need for workplaces to adopt multidimensional assessment protocols that reflect real-world job demands instead of relying on minimal health checks or self-reported fitness levels. To translate these research findings into practical occupational improvements, several actionable recommendations can be implemented within high-risk sectors. First, organizations should incorporate regular, standardized physiological assessments—including VO_2max testing, strength profiling, autonomic regulation monitoring, and fatigue evaluation—into their routine workforce readiness protocols. Second, functional task simulations that mirror actual job requirements should be embedded into annual screening processes so that workers' movement patterns, biomechanical efficiency, and response to load can be directly observed and analyzed. Third, personalized fitness-development plans should be created for employees who exhibit borderline results, focusing on targeted aerobic training, strength conditioning, flexibility improvement, and recovery strategies to enhance overall performance. Fourth, continuous monitoring through wearable physiological sensors can help track day-to-day variations in fatigue, stress, and functional stability, enabling timely interventions before injuries or performance lapses occur. Fifth, organizations should integrate ergonomic redesign strategies, ensuring that tools, equipment, and workstations minimize excessive load on workers who may already present early indicators of physical imbalance or fatigue. Sixth, supervisors and occupational health teams should be trained to interpret multidimensional fitness-for-work results so they can make informed decisions about task allocation, risk mitigation, and workforce optimization. Finally, employers should establish a culture that encourages proactive health monitoring, regular physical conditioning, and early reporting of discomfort or fatigue. By embedding these practical measures into existing safety systems, high-risk industries can significantly reduce workplace injuries, enhance operational reliability, and support a healthier, more resilient workforce.

References

1. Smith PM, Bielecky A. Health-related predictors of workplace injury. Occup Environ Med. 2012;69(4):261-266.
2. Burgess-Limerick R. Participatory ergonomics: Evidence and implementation lessons. Appl Ergon. 2018;68:289-293.
3. McFadden P, *et al*. Risk exposure in high-hazard industries. Saf Sci. 2015;74:162-169.
4. Gallagher S. Physical stress and injury risk in labor settings. Hum Factors. 2012;54(6):844-858.
5. Waters T, *et al*. Job demands and fatigue pathways. Ergonomics. 2011;54(9):836-853.
6. Chowdhury T, *et al*. Worker physiological load in hazardous sectors. J Occup Health. 2017;59(4):345-354.
7. Bernal D, *et al*. Overexertion injuries in industrial workers. Am J Ind Med. 2015;58(2):185-195.
8. Vieira ER, Kumar S. Musculoskeletal overload in manual labor. Int J Ind Ergon. 2009;39(1):47-52.
9. Davis KG, Kotowski SE. Prolonged postural strain outcomes. Appl Ergon. 2014;45(2):386-392.
10. Foster C, *et al*. Physical workload and performance outcomes. Med Sci Sports Exerc. 2013;45(6):1109-1115.
11. Bloxham SR, *et al*. Limitations of traditional health screenings. Occup Med. 2014;64(3):190-197.

12. Mackenzie SH, *et al*. Gaps in existing FFW tools. Saf Health Work. 2014;5(1):1-10.
13. Steel R, *et al*. Variation in occupational medical evaluations. J Occup Rehabil. 2016;26(4):546-554.
14. Harcombe H, *et al*. Health status and occupational risk. Work. 2010;37(2):153-162.
15. Phillips M, *et al*. Predictors of productivity loss. J Occup Environ Med. 2019;61(3):225-233.
16. Roy BA, *et al*. Physiological readiness and workforce safety. Int Arch Occup Environ Health. 2015;88(2):179-189.
17. Brown J, *et al*. Economic impact of workplace injuries. J Safety Res. 2014;48:9-17.
18. Hector J, *et al*. Cardiorespiratory indicators in occupational fitness. Eur J Appl Physiol. 2018;118(12):2547-2556.
19. Shealy E, *et al*. Muscular strength and industrial task performance. J Strength Cond Res. 2016;30(2):347-356.
20. Moore J, *et al*. Aerobic capacity and worker output. Occup Med. 2013;63(7):541-548.
21. Côté JN. Fatigue markers in repetitive work. Appl Ergon. 2014;45(3):627-634.
22. Plews DJ, *et al*. Heart rate variability as a readiness indicator. Int J Sports Physiol Perform. 2017;12(S2):S142-S151.
23. Jones AM, Carter H. The lactate threshold. Sports Med. 2000;29(6):373-386.
24. Bohannon RW. Grip strength norms for occupational health. J Occup Rehabil. 2019;29(2):345-356.
25. Shull PB, *et al*. Wearable motion sensors for occupational assessment. Ergonomics. 2014;57(10):1599-1611.
26. Ritschard G, *et al*. Integrative risk assessment tools. Saf Sci. 2016;84:141-150.
27. Pitblado JR. Functional fitness gaps in hazardous jobs. J Occup Health Psychol. 2013;18(4):450-462.
28. Wright J, *et al*. Framework development in occupational research. Work. 2018;60(1):45-57.
29. Andersen LL, *et al*. Key determinants of work ability. Scand J Work Environ Health. 2016;42(1):34-42.
30. Vrijkotte TGM, *et al*. Physiological demands in high-risk labor. Ann Occup Hyg. 2015;59(7):907-918.
31. Zaccardi F, *et al*. Combining physiological and functional metrics improves prediction. J Sci Med Sport. 2019;22(10):1101-1108.