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RAILWAY WORK ORGANIZATION AND THE OCCUPATIONAL HEALTH OF TRAIN DRIVERS: REFLECTIONS ON PHYSICAL ACTIVITY, SEDENTARY BEHAVIOR, AND QUALITY OF LIFE

ORGANIZAÇÃO DO TRABALHO FERROVIÁRIO E SAÚDE OCUPACIONAL DOS MAQUINISTAS: REFLEXÕES SOBRE A ATIVIDADE FÍSICA, O COMPORTAMENTO SEDENTÁRIO E A QUALIDADE DE VIDA

ORGANIZACIÓN DEL TRABAJO FERROVIARIO Y SALUD OCUPACIONAL DE LOS MAQUINISTAS: REFLEXIONES SOBRE LA ACTIVIDAD FÍSICA, EL COMPORTAMIENTO SEDENTARIO Y LA CALIDAD DE VIDA

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ABSTRACT

Railway work organization, characterized by long working hours, shift work, high cognitive demands, and prolonged sitting, may adversely affect the occupational health and quality of life of train drivers. This theoretical-reflective essay aimed to critically examine the influence of railway work organization on physical activity (PA), sedentary behavior (SB), occupational health, and quality of life among train drivers, contributing to a broader understanding of the contemporary challenges associated with health promotion in this occupational group. The reflections were based on a critical appraisal of the national and international scientific literature, as well as relevant technical documents related to occupational health, rail transport, ergonomics, chronobiology, PA, and SB. The literature indicates that long working hours, shift work, and circadian misalignment are associated with fatigue, sleep disturbances, occupational stress, increased SB, and reduced of PA level, with potential implications for cardiometabolic, musculoskeletal, and mental health. It is concluded that promoting the health of train drivers requires integrated strategies that combine improvements in work organization, fatigue management, reductions in SB, promotion of PA, and the development of research specifically addressing the needs of this occupational group.

Keywords: Occupational health; Railway locomotive drivers; Physical activity; Sedentary behavior; Quality of life; Shift work.

RESUMO

A organização do trabalho ferroviário, caracterizada por jornadas prolongadas, trabalho em turnos, elevadas demandas cognitivas e permanência prolongada na posição sentada, pode afetar negativamente a saúde ocupacional e a qualidade de vida dos maquinistas ferroviários. Este ensaio teórico-reflexivo teve como objetivo refletir criticamente sobre a influência da organização do trabalho ferroviário na atividade física (AF), no comportamento sedentário (CS), na saúde ocupacional e na qualidade de vida dos maquinistas ferroviários, buscando contribuir para uma compreensão mais ampla dos desafios contemporâneos para a promoção da saúde nesse grupo ocupacional. A reflexão fundamentou-se na análise crítica da literatura científica nacional e internacional e de documentos técnicos relacionados à saúde ocupacional, ao transporte ferroviário, à ergonomia, à cronobiologia, à AF e ao CS. A literatura analisada indica que as jornadas prolongadas, o trabalho em turnos e o desalinhamento circadiano estão associados à fadiga, às alterações do sono, ao estresse ocupacional, ao aumento do comportamento sedentário e à redução dos níveis de atividade física, com potenciais repercussões para a saúde cardiometabólica, musculoesquelética e mental. Conclui-se que a promoção da saúde dos maquinistas ferroviários requer estratégias integradas que articulem mudanças na organização do trabalho, gestão da fadiga, redução do comportamento sedentário, promoção da atividade física e o desenvolvimento de pesquisas direcionadas às especificidades dessa categoria profissional.

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Palavras-chave: Saúde ocupacional; Maquinistas ferroviários; Atividade física; Comportamento sedentário; Qualidade de vida; Trabalho em turnos.

RESUMEN:

La organización del trabajo ferroviario, caracterizada por jornadas laborales prolongadas, trabajo por turnos, elevadas demandas cognitivas y permanencia prolongada en posición sentada, puede afectar negativamente la salud ocupacional y la calidad de vida de los maquinistas ferroviarios. Este ensayo teórico-reflexivo tuvo como objetivo reflexionar críticamente sobre la influencia de la organización del trabajo ferroviario en la actividad física (AF), el comportamiento sedentario (CS), la salud ocupacional y la calidad de vida de los maquinistas ferroviarios, con el propósito de contribuir a una comprensión más amplia de los desafíos contemporáneos para la promoción de la salud en este grupo ocupacional. La reflexión se fundamentó en el análisis crítico de la literatura científica nacional e internacional y de documentos técnicos relacionados con la salud ocupacional, el transporte ferroviario, la ergonomía, la cronobiología, la AF y el CS. La literatura analizada indica que las jornadas laborales prolongadas, el trabajo por turnos y la desalineación circadiana se asocian con fatiga, alteraciones del sueño, estrés ocupacional, aumento del CS y reducción de los niveles de AF, con posibles repercusiones sobre la salud cardiometabólica, musculoesquelética y mental. Se concluye que la promoción de la salud de los maquinistas ferroviarios requiere estrategias integradas que articulen mejoras en la organización del trabajo, la gestión de la fatiga, la reducción del CS, la promoción de la AF y el desarrollo de investigaciones dirigidas específicamente a las necesidades de esta categoría profesional.

Palabras clave: Salud ocupacional; Conductores ferroviarios; Actividad física; Comportamiento sedentario; Calidad de vida; Trabajo por turnos.

INTRODUCTION

In this context, railway transport plays a strategic role in economic development and logistics, particularly in long-distance freight transportation, owing to its high energy efficiency, lower greenhouse gas emissions, and greater environmental sustainability compared with other modes of transport (IEA, 2019). The high demands inherent to railway operations make train drivers a particularly vulnerable occupational group to the effects of working conditions and work organization on their health (Yu et al., 2024), This underscores the need for critical

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reflections grounded in scientific evidence to advance the understanding of the complex relationships among work organization, occupational health, and workers' quality of life (World Health Organization, 2022; Yu et al., 2024). The working conditions of these professionals are typically characterized by long working hours, shift work, and simultaneous exposure to adverse physical and psychosocial factors, including vibration, noise, heat, sleep deprivation, and occupational stress (Pega et al., 2021). Scientific evidence has shown that exposure to long working hours is an important risk factor for ischemic heart disease and stroke (Rugulies, 2024).

Among railway locomotive drivers, shift work represents one of the major occupational health challenges because it promotes circadian misalignment, impairs sleep quality, and increases the risk of metabolic disorders and cardiovascular disease (Boivin, Boudreau, & Kosmadopoulos, 2022). Beyond its physiological effects, these alterations may reduce engagement in physical activity, increase fatigue, and negatively affect workers' overall health and well-being (Fitton et al., 2025).

In the railway sector, shift work is common and typically involves rotating work schedules, including day, evening, and night shifts (Tàpia-Caballero et al., 2022). This work organization model promotes circadian misalignment and the progressive accumulation of fatigue, particularly when shift rotations occur over short intervals and provide insufficient time for physiological recovery (Cho et al., 2026).

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Consequently, a bidirectional relationship emerges in which shift work may reduce physical activity (PA) levels, whereas sedentary behavior (SB) tends to exacerbate the adverse effects of work organization (Monnaatsie et al., 2021), particularly those related to metabolic health, sleep, and overall well-being. Among railway locomotive drivers, these effects may be intensified by long working hours, prolonged sitting, and limited time available for recovery and regular physical activity. In this context, promoting active lifestyles and reducing sedentary behavior represent important strategies for occupational health promotion, as workplace interventions have been shown to reduce fatigue, improve functional capacity, and enhance workers' well-being (Gomes et al., 2025).

Although the literature has advanced in understanding the effects of work organization on workers' health, studies that critically integrate the relationships among working conditions, physical activity, sedentary behavior, and quality of life in the specific context of railway locomotive drivers remain scarce (Schulte et al., 2022). In light of this gap, the present essay aims to critically reflect on the influence of railway work organization on physical activity, sedentary behavior, occupational health, and quality of life among railway locomotive drivers, thereby contributing to a broader understanding of the contemporary challenges for health promotion in this occupational group.

MATERIALS AND MEHODS

This manuscript is a theoretical-reflective scientific essay developed through a critical and interpretative analysis of the scientific literature on the occupational

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health of railway locomotive drivers. A theoretical essay is a form of scientific production aimed at developing reflections based on the integration of knowledge and theoretical perspectives, thereby fostering a critical understanding of complex phenomena without intending to provide an exhaustive review of the literature (Meneghetti, 2011).

The reflection was guided by the following research question: How do the available scientific evidence contribute to understanding the relationships among physical activity, sedentary behavior, work organization, and the occupational health of railway locomotive drivers, and what are the implications for health promotion in this population?

To address this question, relevant national and international scientific literature and technical documents were examined, covering topics related to occupational health, railway work organization, physical activity, sedentary behavior, ergonomics, chronobiology, and the quality of life of railway workers. The references were selected intentionally based on their conceptual relevance, recency, and their ability to support the proposed reflection.

The essay was developed through critical reading, interpretative analysis, and the integration of the available evidence, with the aim of identifying relationships, convergences, tensions, and knowledge gaps that could contribute to a broader understanding of the phenomenon under investigation. Based on this reflective process, the manuscript was organized into three thematic sections: (i) railway work organization as a determinant of the occupational health of railway locomotive drivers; (ii) physical activity and sedentary behavior: challenges and

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opportunities for promoting the health of railway locomotive drivers; and (iii) from scientific evidence to practice: perspectives for health promotion in the railway workplace.

REFLECTIONS ON RAILWAY WORK ORGANIZATION AND THE OCCUPATIONAL HEALTH OF TRAIN DRIVERS

Railway Work Organization as a Determinant of the Occupational Health of Train Drivers

Rail transport plays a strategic role in the economic and logistical development of many countries. In Brazil, in addition to its historical importance, it is an essential component of the transportation of agricultural, mineral, and industrial commodities, contributing to economic competitiveness and territorial integration (Yu et al., 2024). However, behind the operational efficiency of the railway system lies a complex work organization that shapes the daily activities of railway locomotive drivers and directly affects their occupational health, well-being, and quality of life.

In recent decades, the Brazilian railway sector has undergone significant transformations driven by the concession of railway services to the private sector, infrastructure modernization, expansion of the railway network, and the progressive adoption of technologies aimed at improving operational efficiency and logistical competitiveness (Brazil, 2024; ANTT, 2023).

Although these changes have enhanced the competitiveness of rail transport, they have also reshaped work organization, modifying the physical, cognitive, and organizational demands placed on railway train drivers.

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In this context, railway train drivers occupy a central role in railway operations. They are responsible for the safe operation of locomotives, the continuous monitoring of operational conditions, and decision-making in situations requiring high levels of attention, precision, and safety (Naweed, 2013). Performing these duties requires sustained attention, continuous monitoring of the operational environment, constant information processing, the ability to anticipate potential hazards, and rapid decision-making in response to critical situations, all of which impose a substantial cognitive workload and considerable responsibility for railway safety (Naweed, 2013; Hassanzadeh-Rangi et al., 2023). These characteristics extend railway work beyond its purely technical dimension, establishing it as an occupation characterized by substantial psychophysiological demands.

From this perspective, it is insufficient to understand occupational health solely as the absence of disease or work-related injuries. Contemporary railway work organization encompasses factors such as long working hours, irregular work schedules, shift work, and prolonged periods of sitting (Chappel et al., 2025), creating a set of working conditions that promote fatigue accumulation, circadian misalignment, sleep disturbances, increased occupational stress, and reduced functional capacity (Kecklund & Axelsson, 2016; Chappel et al., 2025). Consequently, the occupational health of railway locomotive drivers should be understood from a holistic perspective that takes into account the interplay among biological, organizational, environmental, and psychosocial factors.

Paradoxically, while technological advances have enhanced the safety and efficiency of railway operations, they have also increased the complexity of railway

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train drivers' work. Process automation does not necessarily reduce job demands; on the contrary, it may increase cognitive demands, the need for continuous monitoring, and the level of responsibility assigned to railway locomotive drivers, who remain essential for supervision and decision-making to ensure operational safety (Kusumastuti et al., 2025). This scenario underscores that technological innovations are reshaping the nature of work and call for new approaches to understanding occupational risks and developing effective prevention strategies.

In addition, the risks associated with railway operations are multifactorial in nature: to exposure to noise, vibration, and prolonged static postures, railway train drivers face high psychosocial demands, substantial mental workload, responsibility for the safety of passengers and freight, and, in many cases, prolonged periods of working in relative isolation throughout the workday (Naweed, 2013; Hassanzadeh-Rangi et al., 2023). The interplay among these physical, ergonomic, organizational, and psychosocial factors demonstrates that the occupational health of railway locomotive drivers cannot be addressed solely through accident prevention but requires an integrated approach that recognizes work as a fundamental determinant of health and quality of life.

From this perspective, interventions focused exclusively on reducing occupational risks are insufficient (Jin et al., 2025). Health promotion in the railway sector requires coordinated strategies encompassing work schedule organization, mental health protection, ergonomic improvements, the development of healthy work environments, and the promotion of physically active lifestyles (Xu, Yin, & Gong, 2023). Accordingly, work organization should no longer be viewed solely as

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Pages: 1-25

an operational component but rather as a strategic element for fostering healthier, more sustainable work environments that support workers' health and well-being.

PA & SB: Challenges and Opportunities for Promoting Health Among Railway Train Drivers

The characteristics inherent to railway locomotive drivers' work promote the adoption of a predominantly sedentary occupational lifestyle. Long working hours, shift work, high cognitive demands, prolonged sitting, and limited opportunities for movement during the workday are intrinsic features of contemporary railway work organization that may contribute to reduced levels of physical activity (PA), increased sedentary behavior (SB), and the progressive deterioration of occupational health (Chappel et al., 2025). From this perspective, PA should not be understood solely as participation in structured exercise or sports during leisure time. Rather, it is a biological, social, and cultural phenomenon that encompasses bodily movement across multiple domains of daily life and is shaped by individual, environmental, occupational, and social factors (Salvo et al., 2026). Consequently, the ability to adopt an active lifestyle depends not only on individual choices but also on the objective conditions imposed by work organization.

Complementarily, SB encompasses all waking activities performed while sitting, reclining, or lying down that involve an energy expenditure of ≤1.5 metabolic equivalents (METs), regardless of an individual's level of PA (Tremblay et al., 2017). In recent years, SB has come to be recognized not merely as the absence of physical activity but as a distinct health behavior with independent effects on health

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Pages: 1-25

outcomes. A growing body of evidence indicates that prolonged exposure to sedentary behavior is associated with an increased risk of cardiovascular disease, type 2 diabetes mellitus, obesity, musculoskeletal disorders, and adverse mental health outcomes, even among individuals who meet current physical activity recommendations (Ramírez Varela et al., 2026).

Within the field of occupational health, the interaction between high levels of sedentary behavior and low levels of physical activity is of particular concern. Although PA is widely recognized as one of the most effective strategies for preventing noncommunicable diseases (Jin et al., 2025), its benefits extend well beyond clinical outcomes and directly influence the workplace. Physically active workers tend to experience lower levels of occupational stress, fatigue, anxiety, and depressive symptoms, together with better sleep quality, greater functional capacity, and a more favorable perception of quality of life. These benefits are consistently documented in scientific literature and supported by international physical activity guidelines (World Health Organization, 2020; Warburton & Bredin, 2017). Furthermore, structured workplace exercise programs have been associated with reductions in sedentary behavior, prevention of musculoskeletal disorders, improved productivity, and enhanced workplace well-being (Santos et al., 2024).

These findings are particularly relevant for railway locomotive drivers. The combination of prolonged sitting, continuous exposure to vibration, shift work, and high cognitive demands promotes fatigue accumulation, reduced physical fitness, and progressive deterioration of cardiometabolic and musculoskeletal health (Ramírez Varela et al., 2026; Salvo et al., 2026). In this context, regular physical

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activity represents a promising strategy for improving cardiorespiratory fitness, reducing work-related fatigue, enhancing sleep quality, preventing musculoskeletal disorders, and preserving functional capacity. Although evidence specifically involving railway locomotive drivers remains limited, studies conducted among other occupational groups exposed to shift work and high job demands have reported consistent benefits across these outcomes (Fox et al., 2026). Nevertheless, placing sole responsibility on individuals for adopting healthy lifestyles reflects an overly narrow perspective. For railway train drivers, opportunities to maintain adequate PA level are strongly shaped by work organization, long working hours, shift scheduling, opportunities for recovery, and access to workplace health promotion programs. From this perspective, promoting physical activity should be viewed not merely as a behavioral change strategy but also as an integral component of occupational health policies and work organization.

Despite the well-established benefits of physical activity for workers' health, studies specifically examining PA levels, SB, and the effects of exercise interventions among railway train drivers remain scarce. This knowledge gap limits our understanding of the specific needs of this occupational group and underscores the need for further research to build the evidence base required to inform health promotion interventions and occupational health policies tailored to the unique characteristics of railway work.

From Knowledge to Practice: Perspectives for Health Promotion in Railway Work

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Pages: 1-25

Over the past decades, workplace health promotion programs have emerged as effective strategies for reducing work-related risk factors, improving functional capacity, and enhancing workers' quality of life (Proper & van Oostrom, 2019; World Health Organization, 2022). Among the interventions most frequently associated with positive occupational health outcomes are workplace exercise programs, active breaks, supervised exercise programs, health education initiatives, ergonomic interventions, and multicomponent strategies designed to promote healthier behaviors (Tarro et al., 2020).

Structured programs based on walking, aerobic exercise, and resistance training have been associated with improvements in cardiorespiratory fitness, blood pressure control, body composition, and functional capacity. These interventions have also been shown to promote adherence to regular PA while enhancing workers' productivity and quality of life (Andersen, 2024; van der Put et al., 2023). However, translating these findings into the railway setting requires careful consideration, as the organizational characteristics of railway train driver differ substantially from those of other occupational environments (Moroni et al., 2023).

For railway train drivers, long working hours, prolonged sitting, high cognitive demands, shift work, and limited autonomy to interrupt work tasks present additional challenges to the implementation of conventional workplace health promotion programs (Schulte et al., 2022). Recent studies have reported prolonged sedentary time and limited movement variability throughout the workday, reinforcing the need for interventions tailored to the operational characteristics of the railway sector (Soares et al., 2023).

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Furthermore, the high mental workload and occupational fatigue experienced by railway operators indicate that programs focused exclusively on physical exercise are unlikely to adequately address the complexity of the challenges associated with this profession (Yiu et al., 2024). Promoting the health of railway train drivers requires integrated strategies that combine organizational, ergonomic, psychosocial, and behavioral approaches, incorporating initiatives related to PA, fatigue management, sleep health, work schedule organization, and physiological recovery (Hassanzadeh et al., 2023).

This perspective is consistent with contemporary health promotion frameworks, which recognize that health-related behaviors are shaped not only by individual choices but also by the social and organizational conditions in which people live and work. Accordingly, work organization should be viewed as an active component of health promotion strategies rather than merely the setting in which they are implemented.

Although studies specifically involving railway train drivers remain limited, research conducted among other occupational groups exposed to prolonged sitting and irregular working hours, such as professional drivers, suggests that multicomponent interventions combining physical exercise, health education, ergonomic modifications, and behavior change strategies can reduce musculoskeletal pain, improve physical fitness, enhance sleep quality, and lower cardiometabolic risk factors (Zeb et al., 2025). These findings suggest that integrated approaches may also represent a promising strategy for the railway

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sector, provided they are appropriately adapted to the specific demands of this occupation.

Nevertheless, implementing PA programs in isolation is unlikely to produce sustainable improvements in the health of railway train drivers. The success of these interventions depends on their integration into the occupational health policies of railway companies, including improvements in work organization, incentives to promote PA both during and outside working hours, strategies to reduce SB, fatigue monitoring systems, and initiatives aimed at fostering healthy work environments (Nyberg et al., 2025).

This essay has the inherent limitations of a theoretical-reflective study. As it is neither an empirical investigation nor a systematic review, the reflections presented are based on a purposive selection and critical appraisal of the scientific literature and relevant technical documents. Furthermore, the limited availability of studies specifically involving railway train drivers required the discussion to draw on research involving other occupational groups with similar working conditions. Future observational and intervention studies specifically targeting this population are warranted to expand the current knowledge base.

From this perspective, the primary contribution of research extends beyond demonstrating the benefits of physical activity. It lies in informing health promotion models that integrate the individual, organizational, and environmental determinants shaping railway work (WHO, 2010). Expanding research through intervention studies specifically targeting railway locomotive drivers is an essential step toward informing more effective public policies and corporate health promotion programs,

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Pages: 1-25

ultimately contributing to improved occupational health, workers' quality of life, and the safety of railway operations.

Taken together, the literature reviewed indicates that railway work organization is a key determinant of the occupational health of railway locomotive drivers, influencing physical activity, sedentary behavior, sleep, fatigue, and occupational stress, with important implications for physical health, mental health, and quality of life. To synthesize these interrelationships and facilitate their understanding, Figure 1 presents a conceptual model integrating the main mechanisms discussed in this essay, together with potential health promotion strategies aimed at mitigating the adverse effects of work organization and fostering healthier work environments.

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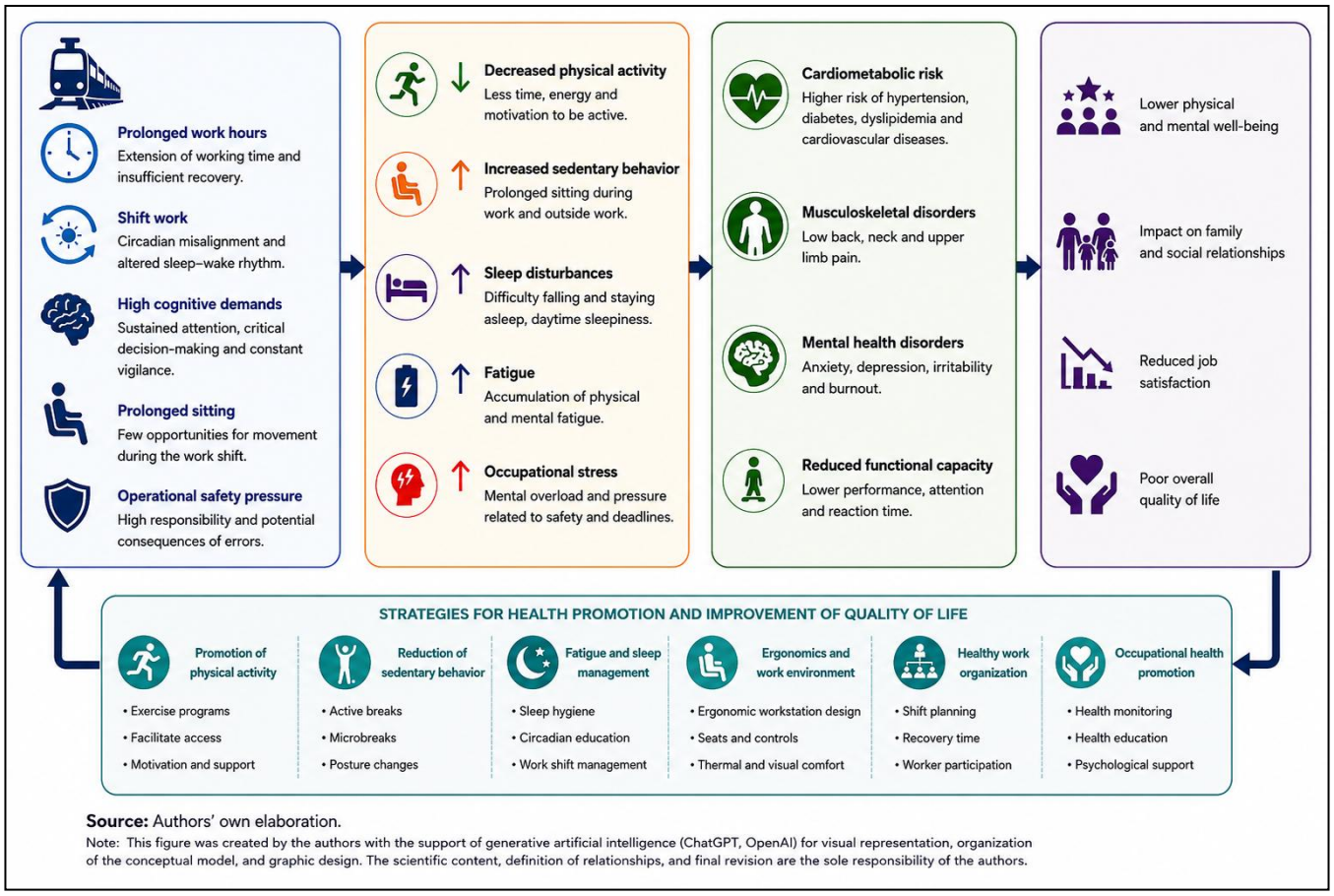


Figure 1. Conceptual model of the influence of railway work organization on physical activity, sedentary behavior, occupational health, and quality of life among train drivers.

CONCLUSIONS

The reflections presented in this essay indicate that the occupational health of railway train drivers is strongly shaped by the contemporary organization of railway work, characterized by long working hours, shift work, high cognitive demands, prolonged sitting, and simultaneous exposure to physical, ergonomic, and psychosocial factors. The interaction among these elements contributes to sleep disturbances, occupational fatigue, increased sedentary behavior, reduced physical

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activity, and diminished quality of life, with potential consequences for both workers' health and the safety and efficiency of railway operations.

Although regular PA and workplace health promotion programs have been consistently associated with improvements in functional capacity, reductions in cardiometabolic risk factors, prevention of musculoskeletal disorders, and enhanced physical and mental well-being, research specifically involving railway train drivers remains limited. This lack of occupation-specific knowledge constrains the development of recommendations tailored to the organizational and operational characteristics of this professional group.

From this perspective, promoting the health of railway train drivers requires moving beyond approaches that focus exclusively on individual lifestyle changes. Instead, it calls for comprehensive strategies that address work schedule organization, fatigue management, ergonomic improvements, mental health promotion, reductions in sedentary behavior, and the creation of meaningful opportunities for regular physical activity. Such an approach recognizes that health-related behaviors arise from the interaction of individual, organizational, and social factors, and that work organization is a fundamental determinant of occupational health.

Finally, this essay highlights the need for further observational and intervention studies specifically involving railway train drivers, integrating assessments of physical activity, sedentary behavior, sleep, fatigue, mental health, quality of life, and work ability. Expanding knowledge in this field will help inform

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more effective public policies, institutional programs, and management strategies, ultimately contributing not only to improved worker health and well-being but also to safer, more sustainable, and more efficient railway operations.

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