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CONTEMPORARY PERSPECTIVES ON RESISTANCE TRAINING FOR INDIVIDUALS WITH SPINAL CORD INJURY - A NARRATIVE REVIEW

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ABSTRACT

Spinal cord injury (SCI) profoundly affects motor and sensory functions, resulting in a range of physiological, psychological, and social challenges. Resistance training (RT) has emerged as an effective intervention for improving muscle strength, functional capacity, and quality of life in individuals with SCI. However, research on specific RT modalities tailored to this population remains limited. This narrative review explores contemporary RT approaches beyond traditional resistance training (TRT), including circuit resistance training (CRT), functional training (FT), high-intensity resistance training (HIRT), and flywheel resistance training (FWRT). CRT has demonstrated benefits in muscle strength, cardiorespiratory fitness, and body composition, with no reported adverse effects, making it a safe and practical option. FT emphasizes task-specific movement patterns, promoting greater functional independence and agility. HIRT protocols-using intensities up to 95% of one-repetition maximum-have shown to be both safe and effective in enhancing bone mineral content, muscle power, and psychological well-being. FWRT, employing inertial flywheel devices, offers advantages such as greater muscle activation, lower metabolic demand, and improved neuromuscular adaptations. Despite these promising outcomes, methodological limitations persist, particularly regarding long-term periodization, progression strategies, and access to flywheel equipment. Future research should aim to optimize training protocols and strengthen the evidence base for the safety and effectiveness of these RT modalities in the SCI population. This review highlights the importance of individualized, progressive RT strategies to maximize functional outcomes and overall well-being in individuals with SCI.

Key words: Streght muscle. Neuromuscular rehabilitation. Functional capacity. Quality of life. Paraplegia.

RESUMO

Perspectivas contemporâneas sobre o treinamento resistido em indivíduos com lesão medular - uma revisão narrativa

A Lesão Medular Espinhal (LME) causa profundos déficits motores e sensoriais, acarretando diversos desafios fisiológicos, psicológicos e sociais. O Treinamento Resistido (TR) é uma intervenção comprovadamente eficaz para aprimorar a força muscular, a capacidade funcional e a qualidade de vida de indivíduos com LME. No entanto, a pesquisa ainda é limitada quanto à aplicação de modalidades específicas de TR nessa população. Esta revisão explora abordagens contemporâneas, indo além do Treinamento Resistido Tradicional (TRT). Treinamento Resistido em Circuito (TRC): Opção segura e viável, melhora a força muscular, a capacidade cardiorrespiratória e a composição corporal sem efeitos adversos. Treinamento Funcional (TF): Enfatiza padrões de movimento específicos, promovendo maior independência funcional e agilidade. Treinamento de Resistência de Alta Intensidade (TRAI): Protocolos com alta intensidade (até 95% de 1RM) são seguros e eficazes na otimização do conteúdo mineral ósseo, da potência muscular e do bem-estar psicológico. Treinamento Resistido com Flywheel (TRF): Utilizando dispositivos inerciais, é promissor por proporcionar maior ativação muscular, menor demanda metabólica e melhores adaptações neuromusculares. Apesar dos benefícios do TRF, persistem lacunas metodológicas, como a falta de estudos sobre periodização de longo prazo e o acesso ao equipamento. Para maximizar os resultados de qualquer modalidade de TR nessa população, o sucesso reside na adoção de estratégias individualizadas e progressivas.

Palavras-chave: Força muscular. Reabilitação neuromuscular. Capacidade funcional. Qualidade de vida. Paraplegia.

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INTRODUCTION

Spinal cord injury (SCI) is a highly disabling condition with significant physiological, psychological, and social consequences for affected individuals. SCI encompasses various alterations in the spinal cord, occurring either acutely or chronically.

Symptoms such as motor and sensory dysfunction, muscle dystonia, and pathological reflexes vary depending on the injury's type, level, and severity.

Additionally, SCI is associated with muscle fatigue resulting from factors such as atrophy, increased body fat, and changes in muscle fiber composition. Over time, these alterations negatively impact muscle strength, body mass index, and overall muscle mass (Fu et al., 2016; Frontera and Mollet, 2017; Parker and et al., 2022).

Despite the substantial impact of SCI, life expectancy for affected individuals has been increasing. However, it is important to note that mortality rates remain higher and overall life expectancy is still shorter when compared to individuals without SCI (Alves-Rodrigues et al., 2021).

This discrepancy may be attributed to the rehabilitation process, which prioritizes not only life expectancy but also improvements in functional capacity and quality of life (Donovan, 2007).

From a psychological perspective, factors such as the cause of the injury and the patient’s demographic characteristics may increase the incidence of depression. Studies suggest that approximately 30% of individuals with SCI experience anxiety, while 22% suffer from depression (Parker et al., 2022; Frontera and Mollet, 2017).

These issues may be further exacerbated in chronic patients due to declining functional capacity and secondary medical complications associated with aging (Frontera and Mollet, 2017).

Physical exercise is a valuable and safe approach to mitigating the negative effects of SCI, enhancing autonomy, and preventing secondary complications. Various rehabilitation strategies employ physical exercise as a tool to promote greater independence in performing activities of daily living.

Among the different types of exercise, resistance training (RT) has proven effective in improving muscle strength, power, functionality, and multiple aspects of quality of life (QoL) and mental health (MH) in individuals with SCI, with no reported adverse effects (Akkurt and et al., 2017; Santos and et al., 2022; Santos and et al., 2024).

However, despite evidence supporting the feasibility of RT for individuals with SCI, there remains a gap in the exploration and in-depth analysis of specific RT types and methods applied to this population. Some researchers have recently focused on investigating these possibilities.

Therefore, the aim of this brief review is to present contemporary perspectives on RT for individuals with SCI, compiling recent studies that have sought to extend beyond traditional resistance training (TRT), and thereby contribute to more updated and effective training prescriptions.

MATERIALS AND METHODS

This narrative review aimed to provide a concise synthesis of contemporary approaches to RT in individuals with SCI, focusing on modalities that extend beyond traditional protocols.

To identify relevant studies, a non-systematic literature search was conducted in January 2025 using PubMed, Scopus, and Web of Science databases. The search terms included: “spinal cord injury” AND (“resistance training” OR “strength training” OR “circuit training” OR “functional training” OR “high-intensity resistance training” OR “eccentric training” OR “flywheel training”), with filters applied for studies published between 2010 and 2024 and written in English.

The selection prioritized studies that investigated RT modalities tailored to the SCI population, particularly those examining circuit resistance training (CRT), functional training (FT), high-intensity resistance training (HIRT), and flywheel resistance training (FWRT). Both experimental (e.g., randomized controlled trials and quasi-experimental studies) and descriptive studies were included if they offered practical insights into the safety, feasibility, or efficacy of these approaches in individuals with SCI.

Emphasis was placed on works that reported functional, physiological, or psychosocial outcomes, such as muscle strength, power, body composition, quality of life, and mental health indicators. No restrictions were applied regarding the neurological level of injury or training duration, allowing for a broader perspective on the adaptability of RT methods.

The selection and interpretation of the studies were carried out by the authors, who jointly assessed their relevance based on alignment with the review's objective. A qualitative synthesis was then conducted, highlighting key findings, methodological aspects, and practical implications for each training modality discussed.

Circuit resistance training

Circuit resistance training (CRT) is a cost-effective training method that is easy to implement and allows for load control, while also enabling multiple individuals to train simultaneously. CRT has demonstrated positive outcomes in various populations, including increased muscle strength, improved physical conditioning, enhanced bone mineral content (BMC), and reduced sarcopenia (Alves-Rodrigues et al., 2021).

Specifically for individuals with SCI, the literature reports benefits in cardiorespiratory capacity, muscle strength, anaerobic power, lipid profile, functionality, body composition, and quality of life (Gant et al., 2018; Jacobs, Nash, and Rusinowski, 2001; Nash et al., 2001; Yildirim et al., 2016; Fischer et al., 2015).

High-quality methodological studies, such as Yildirim et al., (2016), have investigated functional outcomes following CRT focused on upper limb exercises in individuals with paraplegia, assessing potential benefits in strength, functional capacity, and QoL.

After six weeks of CRT combined with conventional treatment performed five times per week, the group that underwent CRT exhibited significant improvements in muscle strength and functional capacity compared to the group that received only conventional rehabilitation.

However, previous studies have assessed functional and health outcomes in a compartmentalized manner, leaving a gap in understanding the broader and more integrated effects of CRT. To address this, Alves-Rodrigues et al., (2021) investigated the effects of CRT on body composition, muscle strength, anaerobic power, and functional capacity in individuals with SCI.

After 12 weeks of CRT, consisting of two weekly sessions with eight exercises performed for one minute each, without rest between them and aiming for the maximum number of repetitions possible, the authors observed improvements in upper limb muscle power and functional capacity, along with the maintenance of body composition, particularly in muscle mass, bone mineral content, and T-score.

Thus, CRT emerges as a viable and safe alternative for individuals with SCI, as none of the studies reported adverse effects, and results were significantly positive across the evaluated parameters.

Functional training

Over the past decades, functional training (FT) has gained significant attention from both professionals and practitioners.

These exercise programs aim to simulate real-life tasks or activities, enhancing the transfer of training adaptations to the individual's actual needs. For individuals with SCI, FT programs can be designed to improve locomotion, wheelchair transfers, and upper limb and trunk mobility (Froehlich-Grobe and et al., 2014).

These improvements in functional capacity can be achieved through the development of muscle strength and power (Alves-Rodrigues et al., 2021).

FT challenges the neuromuscular system to stabilize the body through dynamic and isometric contractions in response to stressors such as gravity and external forces. Considering the principle of specificity, training movements that replicate daily activities may be more effective in enhancing functionality in individuals with SCI (Liu et al., 2014).

Additionally, increased anaerobic power can enhance agility (Gorgatti and Böhme, 2003), which may translate into improved functional performance and positively impact quality of life, as the two are directly correlated (Van Koppenhagen et al., 2014).

Recently, Alves-Rodrigues et al., (2021) analyzed the effects of FT on muscle strength, functional capacity, and quality of life in individuals with SCI.

After a 12-week intervention consisting of two weekly sessions lasting 60 minutes each-comprising eight exercises targeting functional muscle groups, with three sets of 8 to 12 repetitions-the researchers observed improvements in anaerobic power, functional capacity, and quality of life, particularly in aspects related to physical abilities. These findings support the prescription of FT for individuals with SCI and highlight the need for further research in this area.

High-intensity resistance training

For professionals unfamiliar with RT applied to individuals with SCI, exercise intensity may function as a limiting factor in training prescription.

Additionally, existing guidelines often lack specific recommendations regarding long-term progression in training volume and intensity, which can hinder structured periodization and adherence.

In recent years, two systematic reviews by Santos et al., (2022; 2024), including one with a meta-analysis, have explored the effects of RT on strength, body composition, and quality of life in individuals with SCI. These studies included training intensities ranging from 60% to 95% of one-repetition maximum (1RM). Importantly, no adverse effects were reported, regardless of intensity.

These findings suggest that individuals with SCI can tolerate high training loads similarly to individuals without the injury. However, to date, no studies have proposed clear protocols for long-term training progression in this population, leaving such decisions to the practitioner's expertise and the individual's feedback.

Addressing this gap, Rodrigues et al., (2024) evaluated the effects of high-intensity resistance training (HIRT) on functional capacity and quality of life in individuals with SCI. The intervention included linear progression of training volume. The results demonstrated the feasibility and safety of HIRT (no adverse effects or dropouts), along with improvements in bone mineral content, muscle power, functionality, and mental health.

These findings align with existing literature (Eitivipart et al., 2019; Gaspar et al., 2019; Santos et al., 2022; 2024) and suggest that standard RT guidelines for SCI should be expanded to accommodate progression in trained individuals.

Flywheel resistance training

Eccentric training (ET) is characterized by greater maximal force production, lower muscle activation, reduced metabolic cost, and higher recruitment of type IIx muscle fibers (Maroto-Izquierdo et al., 2017). Although it may cause acute muscle damage and soreness, ET provides long-term protective effects against injuries (Lindstedt, LaStayo, and Reich, 2001; Suchomel et al., 2019).

Flywheel resistance training (FWRT) is an advanced form of ET that uses inertia-based machines to generate continuous tension, resulting in greater power output compared to traditional RT.

Originally developed for astronauts, FWRT combines eccentric overload with concentric actions and is effective for injury prevention and rehabilitation (Maroto-Izquierdo et al., 2017; Suchomel et al., 2019; Yánez, Mancera, and Suárez, 2020).

FWRT offers advantages such as lower energy expenditure, increased strength and power, high-threshold motor unit recruitment, muscle fascicle elongation, and enhanced tendon stiffness (Beato and Dello Iacono, 2020).

Fwrt and spinal cord injury

Given the known benefits of ET and the role of exercise in SCI rehabilitation, integrating FWRT into training programs is a promising approach. Advancing training beyond minimal recommendations requires careful consideration of intensity, volume, complexity, and exercise selection.

Despite its potential, FWRT remains underutilized due to limited accessibility to flywheel devices and a lack of high-quality studies with standardized protocols. Nonetheless, the current literature supports FWRT as a viable method for SCI patients, especially when prioritizing unilateral, single-joint exercises to maximize safety and effectiveness (Maroto-Izquierdo and et al., 2017; Beato and Dello Iacono, 2020).

In practice, exercise selection must consider postural deficits and safety. The limited adjustability of flywheel machines can reduce their effectiveness in individuals with SCI by impairing kinetic energy generation during the concentric phase. In a recent intervention, our research team applied FWRT for eight weeks in individuals with SCI and identified key factors for successful implementation. Single-joint and unilateral exercises allow the contralateral limb to assist with stability, improving safety and execution efficiency.

Improvements in balance and trunk control are crucial for this population and should be prioritized to ensure safe acceleration of the flywheel. Thus, expanding the range of FWRT exercises and ensuring appropriate adaptations for each individual's needs is essential.

CONCLUSION

Resistance training is a safe and effective strategy for individuals with SCI, offering improvements in functional capacity, muscle strength, body composition, and mental health. Among RT modalities, CRT, FT, HIRT, and FWRT stand out as promising approaches beyond traditional methods. High-quality studies suggest that these modalities can be safely applied to the SCI population, provided appropriate adaptations are made.

FWRT, in particular, holds great potential but requires greater accessibility and standardized protocols. Its application should prioritize single-joint, unilateral movements that enhance safety and postural control. Future studies should aim to establish specific guidelines for exercise selection, progression, and individualization to further optimize RT outcomes for individuals with SCI.

CONFLICT OF INTEREST

The authors declare no conflict of interest related to this work.

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