LUCAS BARBOSA ALMADA

EFFECTS OF DETRAINING ON HEALTH INDICATORS IN PEOPLE WITH SPINAL CORD INJURY

Thesis submitted to the Federal University of Viçosa as part of the requirements of the Graduate Program in Physical Education for the attainment of the degree of Magister Scientiae.

Advisor: Osvaldo Costa Moreira
Co-Advisor: Cláudia Eliza Patrocínio de Oliveira

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Lucas Barbosa Almada
Autor

Documento assinado digitalmente
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Osvaldo Costa Moreira
Orientador

Dedico este trabalho em primeiro lugar aos meus avós, ***Breno de Souza Almada*** *e* ***Reini Barbosa Almada*** *e aos meus pais,* ***Betânia Barbosa Almada*** *e* ***Camilo Lelis de Almeida****. Sem vocês essas realizações não seriam possíveis.*

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“Knowledge is power.”
Francis Bacon

RESUMO

ALMADA, Lucas Barbosa, M.Sc., Universidade Federal de Viçosa, janeiro de 2024. **Efeitos do destreinamento nos indicadores de saúde de em pessoas com lesão medular espinhal.** Orientador: Osvaldo Costa Moreira. Co-orientadora: Cláudia Eliza Patrocínio de Oliveira.

A lesão medular espinhal (LME) é uma condição debilitante que causa prejuízos motores, fisiológicos e sensoriais, podendo levar à incapacidade permanente, aumento da morbidade e mortalidade, impactando, em última análise, a qualidade de vida (QV) do indivíduo. O exercício físico surge como uma alternativa eficaz para mitigar essas consequências e manter a autonomia e QV para essa população. O destreinamento (DT), definido como a perda parcial ou total das adaptações induzidas pelo treinamento físico em resposta à sua interrupção completa ou estímulo insuficiente, representa uma preocupação significativa. Esta Dissertação foca no impacto do DT nos indicadores de saúde em indivíduos com LME. Foram realizados dois estudos, uma revisão sistemática e um estudo observacional, visando (1) verificar o estado da arte a respeito do DT em indivíduos com LME; e (2) elucidar os efeitos a longo prazo do DT na força muscular (FM), capacidade funcional (CF), saúde mental (SM) e composição corporal (CC). O primeiro estudo é uma revisão sistemática seguindo as diretrizes do Preferred Reporting Items for Systematic Review and Meta-Analyses (PRISMA). A investigação utilizou bases de dados como PubMed, Web of Science, Embase, SPORTDiscus e Cochrane, empregando palavras-chave em inglês pertinentes relacionadas a "Detraining" e "Spinal Cord Injury" juntamente com seus respectivos sinônimos. Devido à escassez de pesquisas nesta área, nenhum período de tempo foi estabelecido para a elegibilidade dos estudos. A busca, conduzida em novembro de 2023, identificou inicialmente 42 estudos, que foram reduzidos para 15 após a remoção de duplicatas. Após a análise de título, mais dois estudos foram descartados. Dos 13 resumos examinados, sete foram excluídos, restando um total de seis para análise aprofundada. As características únicas destes estudos impediram a execução de uma meta-análise. Como resultados, o DT parece impactar na saúde reduzindo a área da seção tranversa do músculo, o consumo máximo de oxigênio (VO2pico), alterando CC e perfil metabólico. No capítulo II, o objetivo do estudo observacional foi avaliar o impacto do DT durante a pandemia em cinco indivíduos com LME torácica. Avaliações de FM, CF, CC e SM foram realizadas utilizando técnicas como avaliações de força, varreduras DEXA e pesquisas de saúde mental focadas em ansiedade e depressão. Após um período de 33 meses de DT, foram observadas diminuições notáveis na agilidade funcional e MS, acompanhadas de um agravamento dos sintomas de ansiedade e depressão. Variações foram vistas na massa corporal total e na massa de gordura entre os participantes. Os resultados sobre a massa corporal magra também mostraram diversidade, com um sujeito experimentando declínio considerável. O DT levou a mudanças significativas em CC quando o treinamento foi realizado por músculos inativos, caracterizado por um aumento na gordura corporal e uma diminuição na massa muscular, particularmente após cessar o treinamento relacionado à testosterona. Essa cessação dos regimes de exercício também impactou notavelmente os perfis metabólicos, causando alterações nos níveis de glicose, perfis lipídicos e sensibilidade à insulina. Além disso, foram observadas alterações em fatores hemodinâmicos, como pressão arterial e frequência cardíaca, aumentando o risco de problemas cardiovasculares. Uma redução no VO2pico também foi evidente após o período de DT, indicando declínio cardiorrespiratório. Concomitantemente, o período de DT durante a pandemia resultou em uma deterioração dos estados físico e mental em indivíduos com LME, sublinhando a necessidade de exercício regular para este grupo. Isso destaca a importância de avaliações personalizadas para entender completamente os efeitos do DT, enfatizando a necessidade crítica de treinamento físico contínuo para mitigar resultados adversos à saúde.

Palavras-chave: Lesão Medular Espinhal. Destreino. Saúde.

ABSTRACT

ALMADA, Lucas Barbosa, M.Sc., Federal University of Viçosa, january of 2024. **Effects of detraining on health indicators in people with spinal cord injury.** Advisor: Osvaldo Costa Moreira. Co-Advisor: Cláudia Eliza Patrocínio de Oliveira.

Spinal cord injury (SCI) is a debilitating condition that causes motor, physiological, and sensory impairments, potentially leading to permanent disability, increased morbidity, and mortality, ultimately impacting an individual's quality of life (QoL). Physical exercise emerges as an effective alternative to mitigate these consequences and uphold the autonomy and QoL for this population. Detraining (DT), defined as the partial or total loss of adaptations induced by physical training in response to its complete interruption or insufficient stimulus, represents a significant concern. This thesis focuses on the impact of DT on health indicators in individuals with SCI. Two studies were conducted, a systematic review and an observational study, aimed at (1) verifying the state of the art regarding DT in individuals with SCI; and (2) To elucidate the long-term effects of DT on muscle strength (MS), functional capacity (FC), mental health (MH), and body composition (BC). The first study is a systematic review following the Preferred Reporting Items for Systematic Review and Meta-Analyses (PRISMA) guidelines. The investigation utilized databases such as PubMed, Web of Science, Embase, SPORTDiscus, and Cochrane, employing pertinent English keywords related to "Detraining" and "Spinal Cord Injury" along with their respective synonyms. Owing to the scarcity of research in this area, no timeframe was established for the eligibility of studies. The search, conducted in November 2023, initially identified 42 studies, which was narrowed down to 15 after removing duplicates. Post-title analysis, two more studies were discarded. Of the 13 abstracts scrutinized, seven were further excluded, leaving a total of six for in-depth analysis. The unique characteristics of these studies precluded the execution of a meta-analysis. As results DT seems to impact on health reducing cross-sectional muscle area, maximum oxygen uptake (VO2peak), altering BC and metabolic profile. In chapter II, the aim of the observational study was to assess the impact of DT during the pandemic on five individuals with thoracic SCI. Evaluations of MS, FC, BC, and MH were conducted using techniques such as strength assessments, DEXA scans and mental health surveys focusing on anxiety and depression. After a 33-month period of DT, notable decreases in functional agility and MS were observed, accompanied by an aggravation of anxiety and depression symptoms. Variations were seen in the total body mass and fat mass across participants. The outcomes regarding lean body mass also showed diversity, with one subject experiencing considerable decline. DT led to significant changes in BC when training was realized by inactive muscles, characterized by an increase in body fat and a decrease in muscle mass, particularly after ceasing testosterone-related training. This cessation of exercise regimens also notably impacted metabolic profiles, causing alterations in glucose levels, lipid profiles, and insulin sensitivity. Additionally, changes in hemodynamic factors, such as blood pressure and heart rate, were observed, increasing the risk of cardiovascular issues. A reduction in VO2peak was also evident following the DT period, indicating cardiorespiratory decline. Concurrently, the DT period during the pandemic resulted in a deterioration of both physical and mental states in individuals with SCI, underscoring the necessity of regular exercise for this group. This highlights the importance of personalized evaluations to fully understand the effects of DT, emphasizing the critical need for sustained physical training to mitigate adverse health outcomes.

Keywords: Spinal Cord Injury. Detraining. Health.

LIST OF FIGURES

LIST OF TABLES

LIST OF ABREVIATIONS AND ACRONYMS

1RM – 1 Repetition Maximum

ASIA – American Spinal Cord Injury Association

BAI – Beck Anxiety Inventory

BC – Body Composition

BDI – Beck Depression Inventory

BFR – Blood Flow Restriction

BMC – Bone Mineral Content

BMD – Bone Mineral Density

BP – Blood Pressure

CEAP – Certificate of Ethical Appreciation Presentation

CEFESLE – Computerized Functional Electrical Stimulation Leg Ergometry

CK – Creatine Kinase

COVID-19 – *Coronavírus Disease*

CRP – C-Reactive Protein

CS – Clinical Significance

CSA – Cross-sectional Muscle Area

DT – Detraining

ES – Effect Size

ET-1 – Endothelin 1

ET-2 – Endothelin 2

FES – Functional Electrical Stimulation

FM – Fat Mass

HbA1c – Glycated Hemoglobin

HDL-C – High-density Lipoprotein Cholesterol

HOMA-IR – HOMA index of insulin resistance

HR – Heart Rate

Hz – Hertz

ICF – Informed Consent Form

IL-6 – Interleukin 6

IL-13 – Interleukin 13

JT – Jacobson and Truax

k – Cohen’s Kappa coefficient

Kg – Kilogram

LDL-C – Low-density Lipoprotein Cholesterol

LM – Lean Mass

MDD – Minimal Detectable Difference

MS – Muscle Strength

MT – Muscle Thickness

MVIC – Maximum Voluntary Isometric Contraction

NC – No Reliable Chance

NES – Neuromuscular Electrical Stimulation

NRI – Non-Randomized Interventions

p – *p*-Value

p. – Page

PRISMA – Transparent Reporting of Systematic Reviews and Meta-Analyses

RCI – Reliability of Change Index

RCT – Randomized Controlled Trials

ROB2 – Risk of Bias Tool

ROBINS-I – Risk of Bias In Non-Randomized Studies of Intervention

SCI – Spinal Cord Injury

SD – Standard Deviation

SEM – Standard Error of Measurement

SPE – Subjective Perception of Effort

QoL – Quality of Life

TNF-α – Tumor Necrosis Factor Alpha

TT – Testosterone replacement Therapy

Vo2peak – Maximum Oxygen Consumption

vs. – *versus*

LIST OF SYMBOLS

> Greater than

< Less than

+ Plus

± Standard deviation

% Percentage or relative value

= Equal

↓ Decrease

↑ Increase

SUMMARY

GENERAL INTRODUCTION

Spinal Cord Injury (SCI) is a debilitating condition resulting in motor, physiological, sensory, and cognitive impairments, potentially leading to permanent disability, increased morbidity, and mortality, and negatively impacting an individual's quality of life (QoL) (Li *et al.*, 2022; SANTOS *et al.*, 2022; AKKURT *et al.*, 2017; LI *et al.*, 2020).

Individuals with SCI experience significant limitations in performing daily life activities and social participation, resulting in a reduced QoL (MICKENS *et al.*, 2022). Maintaining physical fitness and functional capacity is essential to minimize the deleterious effects of SCI on health and QoL (SANTOS *et al.*, 2022; ALVES *et al.*, 2021). In this context, detraining (DT), defined as the reduction or cessation of physical training, may pose a threat to the health status and QoL of individuals (MAZINI FILHO *et al.*, 2022).

The chronic effects of SCI have long been focused on sensorimotor deficits, neuropathic pain, bladder/bowel dysfunction, loss of sexual function, and emotional distress (LI *et al.*, 2020).

Furthermore, it is known that the reduction of physical activity in individuals with SCI can lead to adverse physiological and metabolic alterations, including increased adiposity, decreased muscle and bone mass, as well as changes in the metabolic and cardiovascular profile, such as elevated blood pressure and fasting blood sugar. These physiological and metabolic changes can lead to chronic complications and increase the risk of cardiovascular diseases (MCMILLAN *et al.*, 2021; VAN DER SCHEER *et al.*, 2021).

Therefore, understanding the effects of DT on individuals with SCI, focusing on strength and body composition (BC) variables, is important. These variables are essential for the health and functionality of these individuals, and understanding how DT affects them may lead to more effective interventions to prevent complications and improve the QoL of people with SCI.

OBJECTIVE

General objective

The aim of this research was to analyze the effects of DT on health indicators in individuals with SCI.

Specific objectives

A. To survey the state of the art regarding DT in individuals with SCI.

B. To verify the long-term effects of DT on muscle strength, functional capacity, mental health, and BC of individuals with SCI.

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CHAPTER I

IMPACT OF DETRAINING ON THE HEALTH OF INDIVIDUALS WITH SPINAL CORD INJURY: A SYSTEMATIC REVIEW

INTRODUCTION

Spinal cord injury (SCI) is a debilitating condition that causes motor, physiological, and sensory impairments, potentially leading to permanent disability, increased morbidity, and mortality, ultimately impacting an individual's quality of life (QoL). Physical exercise emerges as an effective alternative to mitigate these consequences and uphold the autonomy and QoL for this population. Detraining (DT), defined as the partial or total loss of adaptations induced by physical training in response to its complete interruption or insufficient stimulus, represents a significant concern.

EVIDENCE ACQUISITION

The objective of this systematic review was to conduct a comprehensive literature review regarding the current state of knowledge on the potential impacts of DT on the health of individuals with SCI. The search was conducted on PubMed, Web of Science, Embase, SPORTDiscus, and Cochrane databases using relevant English terms (("Detraining") AND ("Spinal Cord Injury")) and their synonyms. Due to the limited number of studies addressing this topic, no specific time frame was set for study eligibility.

EVIDENCE SYNTHESIS

The literature search was performed in November 2023, yielding 42 results, from which 15 remained after removing duplicates. Two articles were excluded following title analysis. Thirteen abstracts were reviewed, and 7 were excluded, leaving 6 articles for full analysis. Due to the nature of the studies, a meta-analysis was not conducted.

CONCLUSION

DT resulted in alterations in body composition (BC), including increased body fat and reduced muscle mass, especially following the interruption of testosterone-associated training. Additionally, the cessation of training impacted the metabolic profile, leading to changes in glucose, lipids, and insulin sensitivity. Furthermore, hemodynamic variables, such as blood pressure (BP) and heart rate (HR), underwent changes, elevating the risk

of cardiovascular complications. Regarding cardiorespiratory components, there was a decline in peak oxygen consumption ($VO2_{peak}$) following the DT period. Halting exercise can lead to detrimental health consequences, underscoring the imperative of maintaining consistent physical training for these individuals.

Keywords: Spinal Cord Injury. Detraining. Health.

1 INTRODUCTION

SCI is a debilitating condition that causes motor, physiological, and sensory impairments, which can result in permanent disability, increased morbidity, and mortality, impacting the QoL of the individual (LI *et al*., 2022; SANTOS *et al*., 2022; AKKURT *et al*., 2017;). It is caused by any trauma that damages the structures of the spinal canal, interrupting the axons of the nerves that traverse the spinal cord, leading to total or partial loss of sensory and motor functions below the level of injury (LI *et al*., 2022). Although trauma is the most common cause, other etiologies include autoimmune, infectious, neoplastic, vascular, and hereditary-degenerative myelopathies (ZIU; MESFIN, 2022).

Individuals who suffer from neurological traumas, such as SCI, undergo significant changes in BC, such as increased fat mass (FM), decreased lean mass (LM), and reduced bone mineral density (BMD), ultimately increasing the risk of secondary health conditions (MCMILLAN *et al*., 2021; VAN DER SCHEER *et al*., 2021). These effects may vary depending on the level of the injury, where individuals with cervical injuries show higher rates of FM and visceral fat (RAGUINDIN *et al*., 2021).

In this context, physical exercise proves to be an effective tool as an alternative to reduce such consequences and maintain the autonomy and QoL of this population (ALVES *et al*., 2021; SANTOS *et al*., 2022). It promotes improvements in physical conditioning, such as increased muscle strength (MS), cardiorespiratory capacity, improved BC, among other health factors in individuals with SCI, contributing to the prevention of secondary complications (SANTOS *et al*., 2022; LIU; WANG; NIEBAUER, 2021; AKKURT *et al*., 2017;).

When compared to their sedentary peers, physically active individuals with SCI have greater overall life satisfaction, for example, regarding their earnings and work capacity; they have better interpersonal relationships; better physical and emotional health; and are more self-determined, among other factors indicating a better QoL (FILIPCIC *et al*., 2021). However, to achieve these benefits, a minimum amount of exercise is recommended (HOEVENAARS *et al*., 2022).

According to the Evidence-Based Physical Activity Guidelines for Individuals with Spinal Cord Injury (MARTIN GINIS *et al*., 2018), individuals with SCI should engage in at least 20 minutes of moderate to vigorous aerobic exercise, twice a week, and 3 sets of strength exercises, of moderate to vigorous intensity, twice a week, to achieve cardiorespiratory and MS benefits.

These recommendations differ from those for individuals without disabilities, in which the World Health Organization (BULL et al., 2020) advises that an individual should accumulate at least 150 minutes of aerobic activities per week and engage in strength training two or more times per week to benefit from physical activity. This difference in recommendations suggests that people with SCI can derive fitness and health benefits from levels of physical activity below 150 minutes per week (VAN DER SCHEER *et al*., 2017). Tends to raise questions about DT.

DT is the partial or total loss of adaptations induced by physical training in response to a complete interruption or insufficient stimulus (MAZINI FILHO *et al*., 2022). The reduction in physical activity and/or exercise quantity has negative effects on health and sports performance in the short and long term, such as reduced strength, power and muscle size, cardiorespiratory capacity, functional capacity, and alteration of BC in different populations (CHEN *et al*., 2022; CHULVI-MEDRANO; THOMAS; PADUA, 2022; GRGIC, 2022; MUJIKA; PADILLA, 2000). The decrease in physical fitness due to DT can vary depending on the variable investigated, the population, and primarily the duration of the training interruption (MAZINI FILHO *et al*., 2022).

Although the effects of DT in healthy individuals are well defined in the literature, the same cannot be said for individuals with SCI. Thus, it is necessary to develop studies that seek to fill this gap in an applicable manner, since people with SCI often find it impossible to exercise in traditional spaces such as gyms, training centers, among others, due to lack of accessibility or variations in their overall clinical condition. As a result, they end up discontinuing training programs.

Therefore, the aim of this study was to conduct a systematic literature review on the potential impacts of DT on the health of individuals with SCI.

2. METHODS

2.1 Protocol and registration

This study was conducted in accordance with the Transparent Reporting of Systematic Reviews and Meta-Analyses (PRISMA) guidelines (PAGE *et al.*, 2021), and its protocol is accessible on the International Prospective Register of Systematic Reviews (PROSPERO) (link: https://www.crd.york.ac.uk/PROSPERO/) under the registration number CRD42023393209.

2.2 Search strategy

The databases used in this study were MEDLINE (accessed through PubMed), Web of Science, Embase, SPORTDiscus, and Cochrane. The last search update was conducted in November 2023. The search phrase was constructed using descriptors retrieved from the Virtual Health Library and their synonyms from the Medical Subject Headings (MeSH), using logical operators AND between the descriptors and OR between the synonyms. The electronic search strategies for all databases are provided in the supplementary material (S1).

Supplementary Material (S1): Search Strategy.

("exercise cessation"[Title/Abstract] OR "training cessation"[Title/Abstract] OR "detraining"[Title/Abstract] OR "exercise detraining"[Title/Abstract]) AND ("spinal cord injury"[Title/Abstract] OR "spinal cord injuries"[Title/Abstract] OR "spinal cord"[Title/Abstract])

2.3 Eligibility criteria

The following eligibility criteria for the study were adopted, as defined by the PICOS strategy: Population (P): humans with Spinal Cord Injury; Intervention (I): DT, a period of total or partial interruption of an exercise program; Comparison (C): not observed; Outcome (O): health-related variables; Study Design (S): Randomized Controlled Trials (RCTs) and non-randomized interventions (NRI). No restrictions were made on the publication year and languages to ensure a comprehensive survey.

2.4 Study selection

Potential studies were selected for inclusion using three methods: (1) title only; (2) title and abstract; and (3) full-text review. Two investigators independently searched and selected the articles. Disagreements were resolved by consensus. Agreement between investigators regarding the inclusion/exclusion of potential studies was ratified using the Cohen's Kappa coefficient ($k=0.7273$, $p< 0.05$).

2.5 Data collection

The following data were systematically extracted into a Microsoft Excel (2019) spreadsheet: (1) Study participant characteristics (clinical profile, total sample number, sex, age); (2) type and period of pre-DT, physical exercise performed; and (3) main outcomes related to health indicators.

2.6 Risk of bias

The risk of bias was independently assessed by two evaluators using two instruments: the latest version of the Cochrane Collaboration Risk-of-Bias tool (RoB2, Mar 2019) for randomized trials and the Risk of Bias In Non-randomized Studies – of Intervention (ROBINS-I, Aug 2016).

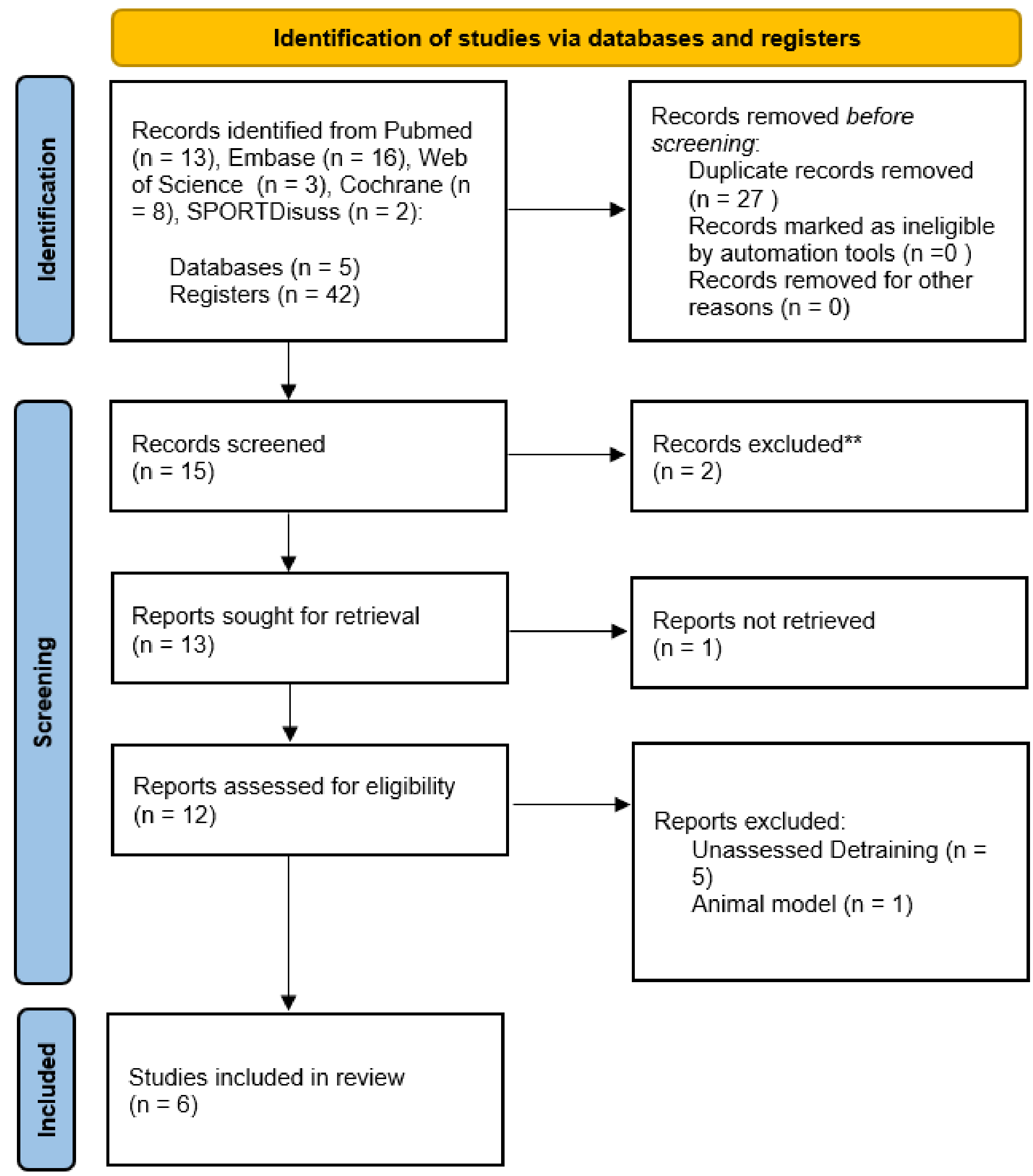
The RoB2 tool assesses bias risk through five domains: Bias in the randomization process; bias due to deviations from intended interventions; bias due to missing outcome data; bias in outcome measurement; bias in outcome reporting. The tool includes an algorithm that maps responses to signaling questions into a proposed risk of bias judgment for each domain at three levels: low risk of bias, some concerns, and high risk of bias (STERNE *et al.*, 2019).

On the other hand, ROBINS-I aims to assess bias risk in Non-Randomized Intervention Studies (NRI). It evaluates seven domains: Bias due to confounding; bias in participant selection; bias in intervention classification; bias due to deviations from intended interventions; bias due to missing data; bias in outcome measurement; bias in selection of the reported results. The tool also includes a signaling questions mapping algorithm guiding the judgment for each domain into three levels similar to RoB2 (STERNE *et al.*, 2016).

3 RESULTS

Figure 1 displays the flow diagram of the screening and selection process. The search identified a total of 42 studies, which initially underwent the selection phase. 27 duplicates were excluded, leaving 15 studies for initial screening. After title and abstract reading, two studies were excluded, leaving 13 for full-text reading. Seven studies were excluded for not meeting the inclusion criteria. Finally, six studies were included in the systematic review, involving 61 participants. Among these, two were RCTs (SKIBA; ANDRADE; RODACKI, 2022; GORGEY *et al*., 2021), and four were NRIs (FROTZLER *et al*., 2009; THIJSSEN *et al*., 2006; GURNEY *et al*., 1998; ROBERGS *et al*., 1993).

Figure 1 - PRISMA flow diagram



Source: Author

3.1 Overall results

Table 1 presents the following information from the studies included in this review: Sample size, age, gender, injury classification, injury level, clinical profile, type of intervention, intervention duration, weekly frequency, volume, intensity, DT duration, and primary outcomes. The sample sizes ranged from 4 to 27 (10.16 ± 8.42) participants, and the ages ranged from 17 to 52 years. The duration of physical exercise interventions varied from 6 weeks to 12 months, and the weekly frequency ranged from 2 to 5 times. The observed DT period varied from 3 weeks to 12 months, with weekly exercise sessions ranging from 1 to none (SKIBA; ANDRADE; RODACKI, 2022; GORGEY *et al*., 2021; FROTZLER *et al*., 2009; THIJSSEN *et al*., 2006; GURNEY *et al*., 1998; ROBERGS *et al*., 1993;)

Table 1 - Characteristics of studies examining the effects of detraining on health variables in individuals with spinal cord injury.

Author	Study design	Sample size	Age (years)	Sex	SCI classification	Injury level	Intervention type	Intervention duration	Weekly frequency	Volume	Intensity	Detraining duration	Primary outcomes
SKIBA; ANDRADE; RODACKI (2022)	RCT	27	17-40	M	A	T4-12	FES & FES+BFR	8 weeks	2 times	3x4min	Light	3 weeks	↓ MT
GORGEY *et al.* (2021)	RCT	7	37±11	M	A/B	C5-T11	TT+TR	16 weeks	2 times	3x10RM	High	16 weeks	%FM =FM (kg) ↓LM (kg) =BMD (kg) ↓FFM (kg) ↓MT (cm)
FROTZLER *et al.* (2009)	NRI	4	38.6±8,1	M/F	A	T4-7	FES Cyclic	12 months	5 times	60min	High	52 weeks	↓BMD ↓BMC ↓MT

THIJSSEN et al. (2006)	NRI	9	39±3	M/F	A/C	C5-7 e T4-11	FES Cyclic	6 weeks	2 times	25min	Not specified	6 weeks	↓Blood flow ↓Flow-mediated dilation ↓Femoral artery diameter
GURNEY et al. (1998)	NRI	6	23-41	M	-	C4-7 e T4-10	CFES LE	12 weeks	3 times	30min	Light	8 weeks	↑CK HR Ve ↓Vo2peak
ROBERGS et al. (1993)	NRI	8	32±2	M/F	A	C7 e T4-L1	CFES LE	12 weeks	3	30min	Light	8 weeks	↑CK ↑Endothelin ↑SBP ↑DBP

Legend: ↑ increase, ↓ decrease, = unaltered, **RCT**: Randomized Controlled Trial; **NRI**: Non-Randomized Interventions; **M**: Male; **F**: Female; **M/F**: Male and Female; **FES**: Functional Electrical Stimulation; **BFR**: Blood Flow Restriction; **TT**: Testosterone Therapy; **RT**: Resistance Training; **CFES LE**: Computerized Functional Electrical Stimulation Cycling; **Min**: Minutes; **RM**: Repetitions Maximum; **MT**: Muscle Thickness; **FM**: Fat Mass; **LM**: Lean Mass; **BMD**: Bone Mineral Density; **FFM**: Fat-Free Mass; **BMC**: Bone Mineral Content; **CK**: Creatine Kinase; **HR**: Heart Rate; **Ve**: Ventilation; **Vo2peak**: Peak Oxygen Consumption; **SBP**: Systolic Blood Pressure; **DBP**: Diastolic Blood Pressure.

Source: Author

3.2 Intervention protocols

The training protocols applied before DT were as follows: Computerized functional electrical stimulation leg ergometry (CFESLE) (66.68%); functional electrical stimulation with blood flow restriction (FES+BFR) (16.67%); and surface neuromuscular electrical stimulation associated with testosterone replacement therapy (NES+TT) (16.67%). The intervention duration ranged from 6 weeks to 12 months, and the DT period ranged from 3 weeks to 12 months. In one study, both intervention and DT lasted 6 weeks (16.67%); in another, the intervention lasted 8 weeks and DT 3 weeks (16.67%); two studies had 12 weeks of intervention followed by 8 weeks of DT (33.33%); another one lasted 16 weeks for both phases (16.67%); and finally, one study had a duration of 12 months for both phases (16.67%).

Regarding exercise intensity, three studies indicated low intensity (50%), another two indicated moderate to high intensity (33.33%), and only one did not specify the exercise intensity (16.67%). As for volume, it varied in terms of exercise duration for leg ergometry and blood flow restriction exercises (83.35%) and in the number of sets and repetitions (16.67%) for strength exercises.

The training sessions with ergometer varied between 25 and 60 minutes. Specifically, one study had sessions lasting 25 minutes (16.67%), another had sessions lasting 60 minutes (16.67%), and two studies featured sessions lasting 30 minutes (33.33%). The study that utilized FES+BFR had sessions consisting of 3 sets of 4 minutes (16.67%). The studies that involved strength training (16.67%) had sessions comprising 3 sets of 10 repetition maximum (RM).

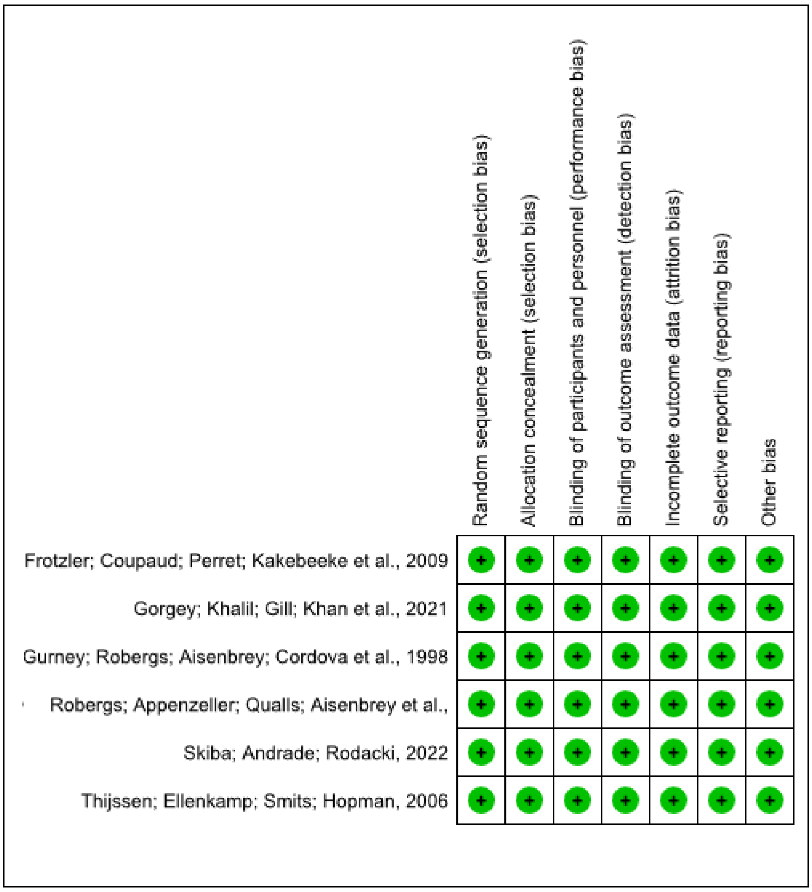
The health variables considered were systolic and diastolic blood pressure, creatine kinase (CK), endothelin (ROBERGS *et al*., 1993), heart rate (HR), maximum oxygen consumption (VO_2peak), ventilation (VE) (GURNEY *et al*., 1998), blood flow, flow-mediated dilation, arterial diameter (THIJSSEN *et al*., 2006), BMD, bone mineral content (BMC), cross-sectional muscle area (CSA) (FROTZLER *et al*., 2009), BC, and metabolic profile (SKIBA; ANDRADE; RODACKI, 2022; GORGEY *et al*., 2021).

In FROTZLER *et al*. (2009), 73% (SD 13.4) of distal BMD and 63.8% (SD 8.0) of total femoral BMD, along with 59.4% (SD 3.9) of BMC, were maintained after 12 months of DT. In the femoral diaphysis, both BMC and cortical BMD decreased by 1.8% (SD 0.8) and 3.6% (SD 2.8), respectively. Regarding the thigh CSA, 22.1% (SD 21.0) was maintained after DT. Conversely, the cross-sectional area of fat increased by 7.6% when the individual ceased training.

3.3 Risk of bias

The risk of bias is summarized in Figure 2, where the classification of risk for each domain of the respective tool can be observed. The overall classification of the included studies was low risk of bias for both RoB2 and ROBINS-I.

Figure 2 – Risk of bias in included studies.



Source: Author.

4. DISCUSSION

The present study investigated the impacts of DT on the health of individuals with SCI. The findings indicated that various variables (BC, metabolic profile, blood flow, arterial and muscular thickness, blood pressure, heart rate, maximum oxygen consumption, ventilation, creatine kinase, and endothelin) affect the studied population. They suggest that DT (mean 16.33, SD ± 16.31) can lead to a partial or total loss of the benefits provided by physical training if it is interrupted.

4.1 Body composition

BC refers to the different components of the human body, such as muscle mass, FM, bone mass, water, and minerals (GOLDSMITH *et al*., 2022). It is a significant determinant of cardiometabolic health, including cardiovascular diseases, metabolic syndrome, and type 2 diabetes. Increased body fat, particularly central adiposity, is associated with multiple metabolic abnormalities, such as impaired glucose metabolism and dyslipidemia (RAGUINDIN *et al*., 2021).

Several variables can influence an individual's BC, including age, sex, level of physical activity, and diet (STAŚKIEWICZ *et al*., 2023). In the case of individuals with SCI, other variables may play a crucial role, such as the level of injury, degree of muscle atrophy, and the presence of spasticity (RAGUINDIN *et al*., 2021). Changes in BC can lead to alterations in metabolism, cardiovascular function, and MS, affecting the QoL and functional capacity of these individuals (SANTOS *et al*., 2022; HOLM *et al*., 2019;).

Individuals with neurological injuries like SCI experience significant changes in BC, increasing the risk of secondary health conditions, including increased FM, decreased LM, and reduced BMD (ALAZZAM *et al*., 2023; MCMILLAN *et al*., 2021). These changes occur rapidly after the injury, including skeletal muscle atrophy and intramuscular fat accumulation below the level of injury (RAGUINDIN *et al*., 2021).

The review conducted shows that the application of FES+BFR in individuals with SCI for a period of 8 weeks resulted in an increase in muscle thickness (MT), which was lost after 3 weeks of DT. It was observed that the loss in MT returned to initial values at an average rate of 0.5% per day (SKIBA; ANDRADE; RODACKI, 2022). This rate is higher than previous findings in healthy individuals and may be attributed to the absence of muscle activity in individuals with SCI (TEIXEIRA *et al*., 2021; BRANDNER *et al*., 2019; NATSUME *et al*., 2015; YASUDA *et al*., 2005).

SKIBA; ANDRADE; and RODACKI (2022) also suggest that a negative regulator of protein synthesis, myostatin, and a positive regulator, mammalian target of rapamycin (mTOR) protein, may play a role in muscle mass during DT. Furthermore, SCI decreases the expression of myogenin, an important factor for the positive regulation of protein synthesis (TRENDELENBURG *et al*., 2009; DRUMMOND *et al*., 2008). In support of this suggestion, GAVANDA *et al*. (2020) observed in young athletes that after 12 weeks of resistance training followed by 3 weeks of DT, there was no reduction in gains in body mass and MT from exercise. However, an increase in FM and a decrease in LM were observed.

Among the findings of this review, FROTZLER *et al*. (2009) also investigated changes in MT, muscle density, and CSA, after 12 months of training and a similar period of DT. They found that 73% (SD 13.4) of distal muscle density and 63.8% (SD 8.0) of total femoral muscle density, and 59.4% (SD 3.9) of CSA were maintained after such a period. In the femoral diaphysis, muscle density and cortical muscle density decreased by 1.8% (SD 0.8) and 3.6% (SD 2.8), respectively. Regarding the CSA of the thigh, 22.1% (SD 21.0) was maintained after DT. The cross-sectional area of fat increased by 7.6%.

Even though to a lesser effect, among the results found, mild losses were observed in the CSA in a study conducted by GORGEY *et al*. (2021). Additionally, it was found that after a reduction in training dosage for 16 weeks combined with low testosterone dose, individuals with SCI exhibited a significant decrease in arm LM and total body LM.

The loss of metabolically active skeletal muscle results in a decrease in basal metabolic rate and resting energy expenditure, while fat accumulation leads to impaired glucose metabolism and dyslipidemia. Moreover, individuals with chronic injuries often have sedentary lifestyles and low adherence to dietary recommendations, creating a positive energy balance that contributes to fat accumulation and obesity in chronic SCI (VAN DER SCHEER *et al*., 2021). Due to the loss of bone properties, individuals with SCI are at higher risk of fractures from mild trauma, and these fractures occur mainly in the distal femur and proximal and distal tibia. This can lead to comorbidity and reduced QoL (DHARNIPRAGADA *et al*., 2023; FROTZLER *et al*., 2009).

4.2 Metabolic profile

The assessment of the metabolic profile involves a set of variables that measure the body's ability to metabolize nutrients and store energy (LEHTOVIRTA *et al*., 2023). In individuals with SCI, the metabolic profile is crucial because metabolic alterations can lead to complications such as diabetes mellitus, dyslipidemia, and obesity, contributing to an increased cardiovascular risk through changes in blood flow and endothelial function (LIU; WANG; NIEBAUER, 2021; O'BRIEN *et al*., 2018).

According to the results found in this review, individuals with SCI who underwent strength training with electrical stimulation and testosterone treatment for 16 weeks, followed by an equal DT period, did not experience significant changes in their basal metabolic rate, carbohydrates, lipids, and inflammatory markers, fasting insulin and glucose, insulin sensitivity, glucose effectiveness, HbA1c (%), lipid panel, CRP, TNF-α, IL-6, or free fatty acids, heart rate, and resting blood pressure (GORGEY *et al.*, 2021). These findings are consistent with ROSSI *et al.* (2017), where no metabolic profile alterations were observed after 6 months of training and DT in postmenopausal women.

Considering the detrimental effects generated by SCI, it can be compared to an accelerated aging model (O'BRIEN *et al.*, 2017). In line with previous findings, in a study involving elderly women, CELESTRIN *et al.* (2020) found that a 4-week DT period led to a decrease in insulin sensitivity and cholesterol metabolism, as indicated by increased HOMA-IR and low-density lipoprotein cholesterol (LDL-C) levels, along with a decrease in circulating IL-13 levels. Corroborating these results, AMARANTE DO NASCIMENTO *et al.* (2022) observed that elderly women, after training for 12 weeks and DT for an equal period, experienced increases in fasting glucose (~8%), LDL-C (~21%), and triglycerides (~24%).

Despite the findings, individuals with SCI tend to undergo alterations in the metabolic profile, including elevated fasting blood glucose, insulin levels, and triglycerides, along with a reduction in high-density lipoprotein cholesterol (HDL-C), which may be related to immobility, reduced physical activity, autonomic dysfunction, and factors resulting from SCI (CIRNIGLIARO *et al.*, 2021; O'BRIEN *et al.*, 2018; RANKIN *et al.*, 2017). Studies show that the cessation of physical training, in different populations, can lead to an increase in fasting blood glucose, insulin levels, and triglyceride levels, as well as a decrease in HDL-C (AMARANTE DO NASCIMENTO *et al.*, 2022; LEITÃO *et al.*, 2019). These changes may be related to reduced insulin sensitivity, decreased glucose uptake, and reduced lipoprotein lipase activity (DIMENNA; ARAD, 2021). Therefore, it is important for individuals with SCI to maintain regular physical exercise to preserve a healthy metabolic profile.

4.3 Hemodynamic variables and inflammatory markers

Blood pressure (BP) and heart rate (HR) are important indicators of cardiovascular health. The regulation of BP after SCI is often compromised due to impaired vascular sympathetic control, leading to a greater dependence on baroreflex sensitivity to maintain pressure (SOLINSKY *et al.*, 2021). It is common for individuals with SCI to have a higher risk of cardiovascular complications, including high BP and cardiac arrhythmias. Moreover, changes in BP and HR can affect the functional capacity and QoL of these individuals (SINGH; MITRA, 2022; TSOU *et al.*, 2022).

One of the potential regulators of BP in the body is endothelin, a peptide produced in endothelial tissue, which has two main isoforms, ET-1 and ET-2. The first of these is considered a vasoconstrictor capable of increasing blood pressure, while the second has a lesser effect and it is suggested that its main function lies in the regulation of blood flow and vessel growth (DHAUN; WEBB, 2019).

Among the findings of this review, ROBERGS *et al*. (1993) conducted a 12-week training protocol followed by 8 weeks of DT in individuals with SCI. The study evaluated the behavior of resting BP, resting HR, peak HR, and inflammatory markers creatine kinase (CK) and endothelin (ET). They observed that despite a significant increase in ET after one training session following the DT, there were no significant differences in BP and HR.

Other data found in this review show that one week of DT was enough to return vascular parameters (peak leg blood flow, diameter, and flow-mediated dilation of the femoral artery) to pre-training baseline values (THIJSSEN *et al*., 2006). This contrasts with studies that observed the loss of training effects between 4 to 12 weeks, where these variables returned to pre-training levels in healthy individuals (STEBBINGS *et al*., 2013), those with recent myocardial infarction (VONA *et al*., 2009), and those with chronic diseases (WILLIAMS *et al*., 2020).

4.4 Cardiorespiratory components

Determining VO_2peak is important for assessing aerobic fitness and functional capacity in individuals with SCI. This indicator is particularly relevant because it is associated with cardiovascular risk, the ability to perform daily activities, and the QoL of these individuals (GERVASI *et al*., 2022). The results of this study show that individuals with SCI trained for 12 weeks on a cycle ergometer, who experienced an 8-week DT period, had a significant decrease in VO2peak by 23%. However, there were no significant differences for peak HR and ventilation, although these variables worsened (GURNEY *et al*., 1998). In line with these findings, a systematic review by ZHENG *et al*. (2022) shows that athletes' VO2peak decreased on average by 9.43% after training interruptions lasting more than 30 days.

In healthy individuals, these variables tend to show a similar pattern, indicating that cardiovascular endurance is partially maintained (WILLIAMS *et al*., 2020; LEITÃO *et al*., 2019). However, the greater loss in individuals with SCI may be attributed to the lower amount of physical activity performed in daily life (PETERS *et al*., 2021).

One of the main limitations of the present study is the difficulty in identifying studies that have incorporated control groups in their research. Additionally, some studies did not provide detailed American Spinal Injury Association (ASIA) classifications of the participants and did not offer information about the specific classification of the type of SCI. These aspects are crucial to ensure the quality of evidence on the subject, allowing for more solid conclusions regarding the topic. Furthermore, it's important to note that the lack of monitoring of dietary habits and medication control in the included studies represents an additional limitation, as these factors can significantly influence the outcomes and interpretation of the results.

The results presented highlight the need for further research to understand how DT affects individuals with SCI. Future studies investigating the effects of DT on various health variables in individuals with SCI should incorporate control groups, enabling more accurate comparisons and less conjectural conclusions.

5 CONCLUSION

Based on the results presented in this systematic review, it can be concluded that DT in individuals with SCI can lead to a partial or total loss of the benefits gained from regular physical exercise. The period of interruption in physical training can result in changes in BC, metabolic profile, and cardiorespiratory variables, potentially leading to an increase in body fat, decrease in muscle mass, metabolic impairment, reduction in VO2peak, glucose changes, and dyslipidemia. Furthermore, alterations in BP and HR may occur, increasing the risk of cardiovascular complications.

In summary, the cessation of physical exercise in individuals with SCI can have various negative health consequences, underscoring the importance of consistent engagement in regular physical activity as a fundamental strategy for maintaining health and QoL in this population.

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CHAPTER II

EFFECT OF DETRAINING ON MUSCLE STRENGTH, FUNCTIONAL CAPACITY, MENTAL HEALTH, AND BODY COMPOSITION IN INDIVIDUALS WITH SPINAL CORD INJURY.

Spinal Cord Injury (SCI) is a serious condition that significantly affects the quality of life (QoL) of individuals, causing motor, physiological, social, and psychological impairments. Physical exercise plays a crucial role in maintaining the health and functional capacity of these individuals, helping to minimize the negative impacts of SCI. The aim of the current study was to evaluate the effect of detraining (DT) (reduction or cessation of physical exercise) during the pandemic on five individuals with thoracic SCI. Muscle strength (MS), functional capacity, mental health, and body composition (BC) were assessed using methods including DEXA, strength tests, and anxiety and depression inventories. The results after 33 months of DT showed significant losses in functional agility and MS, as well as a worsening in symptoms of anxiety and depression. It was observed that total body mass and fat mass (FM) exhibited varied behaviors among the individuals. Similarly, the results for lean body mass were heterogeneous, with one participant showing significant deterioration. It is concluded that DT caused by the pandemic worsened the physical and mental condition of individuals with SCI, highlighting the importance of continuous exercise for this population, and underscoring the need for individual assessments to fully understand the impacts of DT.

Keywords: Spinal Cord Injury, Muscle Strength, Functional Capacity, Mental Health, Body Composition.

1 INTRODUCTION

Spinal Cord Injury (SCI) is a debilitating condition characterized by the disruption of neural pathways within the spinal cord, leading to partial or permanent impairment of motor, sensory, and autonomic functions (AKKURT et al., 2017; LI et al., 2022). The level and extent of impairment depend on the severity and location of the injury within the spinal cord (RAGUINDIN et al., 2021). This injury can negatively impact an individual's health and quality of life (QoL), affecting their ability to perform daily activities and fully participate in society (FILIPCIC et al., 2021).

Among the alterations caused by SCI, those impacting health-related variables such as muscle strength (MS), functional capacity (FC), mental health (MH), and body composition (BC) are particularly noteworthy, especially for individuals with SCI (ALVES et al., 2021; SANTOS et al., 2022).

BC and MS are essential indicators of health, as their controlled levels and parameters provide metabolic balance and maintain physical mobility, thereby reducing the risk of chronic non-communicable diseases (STAŚKIEWICZ et al., 2023; SANTOS et al., 2022; HOLMES; RACETTE, 2021).

FC is an indicator of an individual's autonomy in performing different daily life activities, ranging from simple to complex, and encompasses physical capacities such as cardiorespiratory fitness, MS, flexibility, among others, directly influencing an individual's independence and participation in society (ARAGÃO-SANTOS et al., 2023). Meanwhile, MH is considered the capacity to connect, function, cope with challenges, and thrive, ranging from optimal well-being to states of intense emotional distress (WHO, 2022). It influences the individual's perception of their abilities, coping mechanisms, and overall life satisfaction (BJERREGAARD et al., 2023; SINGH; MITRA, 2022). In the context of SCI, the development and maintenance of these variables are important as they are intrinsically linked to the individual's rehabilitation and long-term adaptation to the challenges posed by the injury. Therefore, regular physical exercise emerges as an important tool in the development of the aforementioned variables (AKKURT et al., 2017). The human body undergoes acute and chronic physiological adaptations in response to regular physical exercise, enhancing physical and mental health, as well as overall well-being (MAHINDRU; PATIL; AGRAWAL, 2023). However, when physical exercise is interrupted or reduced, these adaptations diminish over time, increasing the risk of developing health problems, and loss of autonomy and mobility (LEITÃO et al., 2022; MAZINI FILHO et al., 2022).

The cessation or reduction of regular physical exercise, known as detraining (DT), negatively impacts the health and physical conditioning of individuals (MAZINI FILHO et al., 2022; ZHENG et al., 2022). The unique physiological and functional characteristics of individuals with SCI have the potential to amplify the effects of DT, leading to quicker and more pronounced declines in their physical conditioning variables, adversely affecting their health (SKIBA; ANDRADE; RODACKI, 2022).

DT in individuals with SCI can lead to changes in BC, metabolic profile, and variables related to the cardiorespiratory system (FROTZLER et al., 2009; GURNEY et al., 1998). The interruption of physical exercise impacts the increase in adipose tissue, decrease in muscle mass, alteration in metabolism, reduction in maximal oxygen consumption, glucose, and lipid imbalance (GORGEY et al., 2021). Additionally, alterations in blood pressure and heart rate may manifest, raising the possibility of cardiovascular complications (ROBERGS et al., 1993).

Although the phenomenon of DT has been studied in the general population, emphasizing the importance of regular physical exercise for health maintenance (ARAGÃO-SANTOS et al., 2023; CHULVI-MEDRANO; THOMAS; PADUA, 2022; ZHENG et al., 2022) in individuals with SCI, the literature is limited to observing the behavior of DT experienced by the injured limbs in exercise programs aimed at managing their condition (SKIBA; ANDRADE; RODACKI, 2022; GORGEY et al., 2021).

In this context, the present study distinguishes itself as it investigates the impact of DT in relation to exercises targeting the active musculature, not affected by the injury, in individuals with SCI. This contrasts with the predominant approach, seeking to understand how long-term DT behaves in measures of physical performance, MH, and body parameters in this population.

This study emerges as a significant contribution to the scientific literature and for professionals who work directly with the training of individuals with SCI. By investigating the consequences of DT, this work seeks to fill a gap by addressing the long-term effects on the active musculature, which is often marginalized in conventional research of this population. DT has been studied in a broader spectrum of the population without disabilities, primarily in athletes and the elderly population (ARAGÃO-SANTOS et al., 2023; CÓRDOVA-MARTÍNEZ et al., 2022; MAZINI FILHO et al., 2022; ZHENG et al., 2022). However, by focusing on individuals with SCI, this study recognizes and highlights the unique needs and responses of this population.

In this sense, the present study becomes relevant as the knowledge generated by it can assist health professionals in prescribing training for individuals with SCI. Additionally, in-depth knowledge of how DT affects physical performance variables, MH, and BC indicators in individuals with SCI could support more effective and personalized training programs, rehabilitation strategies, and health maintenance for this population.

Given the above, the aim of this study was to evaluate the effect of DT on physical and MH indicators in individuals with SCI, with a particular focus on MS, functional agility, MH, and BC.

2 METHODS

This research is characterized as an observational study, due to its intention to identify and record changes in health indicators after a period of DT, without intervening in or modifying the training regimen of the participants (COUTINHO; CUNHA, 2005).

The sample for the study was a convenience sample and consisted of five individuals with SCI with previous experience of one year in strength training, thoracic level injury, and of both sexes. The inclusion criteria were A) having SCI at the thoracic level; B) being physically fit to participate in physical tests, as determined by a medical examination; C) possessing independence in performing Activities of Daily Living; D) not having musculoskeletal or cardiometabolic problems that limited or contraindicated the practice of planned physical exercise; G) not participating in other regular physical exercise programs.

All evaluated individuals participated voluntarily, signed an Informed Consent Form (ICF), and received information about the study, as determined in Resolution 466/2012 of the National Health Council.

The study was approved by the Research Ethics Committee involving human beings of the Federal University of Viçosa, Minas Gerais, Brazil, and was conducted under license number CEAP: 51624715.2.0000.5153.

All study procedures were developed in the Strength Laboratory of the Department of Physical Education at the Federal University of Viçosa.

2.1 Detraining protocol

The sample of the present study was part of a training program (Projeto Fortalecer) that was interrupted in December 2019. However, with the COVID-19 pandemic that affected Brazil and the world in 2020 and 2021, this interruption continued until September 2022. Thus, the study evaluated the effect of 33 months of DT on the investigated variables.

Prior to the DT period, the volunteers of this research participated in a 12-week resistance training program, in which interventions occurred twice a week, each session lasting approximately 60 minutes. The volunteers performed 8 exercises targeting functional muscle groups, performing 3 to 4 sets of 8 to 12 repetitions for each exercise, with a rest interval of 45 seconds to 1 minute between sets in the first two weeks, reducing to 30 seconds in subsequent weeks.

The training was designed to be performed entirely in the wheelchair, minimizing the need for adaptation. It included eight exercises: Elbow flexion with shoulder extension and scapular adduction; shoulder abduction in the neutral arm position; elbow flexion with forearm supination; elbow extension with shoulder adduction (participants facing away from the apparatus); wrist flexion with forearm supination; wrist flexion with forearm pronation; elbow flexion and extension with shoulder abduction and adduction in a vertical pressing movement; and horizontal shoulder adduction with elbows in flexion.

The training load was controlled through the subjective perception of effort (SPE) (ROBERTSON et al., 2003), with intensity varying between 7 and 9 on the SPE using the OMNI-RES scale (ROBERTSON et al., 2003). Intensity control was achieved by adjusting repetitions, sets, and training sessions, so when the individual's SPE fell below the set level, intensity would be adjusted to always be above 7 on the SPE.

To quantify and compare the total training load, the total mass moved in all eight exercises by all individuals was summed and multiplied by the weekly training volume for each of the 12 intervention weeks.

An undulatory periodization was adopted, characterized by greater variation in volume and intensity of the training session, providing frequent changes in stimuli, thereby stimulating the neuromuscular system's adaptation to each training session, and avoiding stagnation in strength gains (SPINETI et al., 2013).

The DT in this study occurred due to the interruption of the exercise program, which was prolonged due to the COVID-19 pandemic. During this interruption period, the participants were not monitored regarding the maintenance of their physical activities. Considering the context of the pandemic, it is plausible to believe that physical activity levels were restricted to performing essential daily life activities, given the restrictions and limitations imposed by the sanitary situation.

2.2 Procedures

To ascertain the effects of DT on the variables of interest, a 33-month interruption of the exercise program was observed. Assessment tests were conducted before and after the DT period to evaluate different manifestations of MS, functional agility, perception of MH status, and BC.

2.2.1 Muscle Strength

To evaluate isometric strength, the Maximum Voluntary Isometric Contraction (MVIC) test of the upper limbs was used, employing a load cell or strain gauge (MK, model CSL/ZL-1T) with a sampling frequency of 1000Hz. The load cell was placed on a Scorpions Fitness CrossOver machine, Brazil, such that one end was attached via a chain to the lower part of a stirrup handle and the other end fixed to the steel cable, which is pulled when the lever arm of the machine is moved. Before performing the test, the device was adjusted so that the elbow of the participants was at a 90° flexion angle. On the evaluator's command, the participant performed a maximum isometric tension of the biceps brachii for 5 seconds. During execution, verbal encouragement was given to induce greater tension and maintain maximum levels throughout the test. Two attempts were made, separated by a 2-minute interval, with the highest value obtained in the two attempts considered (MOREIRA et al., 2022).

For the evaluation of dynamic strength, the one-repetition maximum (1RM) test was used, through the elbow flexion exercise on a Scorpions Fitness CrossOver machine, Brazil. The initial position was sitting with the back supported by the apparatus, one hand holding the side support of the chair and the other holding a stirrup handle with the elbow extended to 0°. The volunteer was asked to flex the elbow to approximately 160° and return to the initial position. Before determining 1RM, a warm-up was performed consisting of 4 repetitions with a load of 50% of MVIC. After the warm-up, the volunteer's effort perception was assessed using the OMNI-RES scale from 0 to 10 (GEARHART JÚNIOR et al., 2011; ROBERTSON et al., 2003). The load was increased based on the evaluator's discretion, according to the ease of execution and the participant's perceived effort, and the volunteer was asked to perform two repetitions with the new load. The load was increased until the participant could only perform one repetition. A maximum of 5 attempts were made to determine 1RM, with a 2-minute rest interval between each attempt (GRGIC et al., 2020; MOREIRA et al., 2022).

Upper limb power was also assessed using the same machine used for the 1RM evaluation. Three different loads were used for power assessment, derived from percentage values of 1RM (40%, 60%, and 80% of 1RM), where the participant was asked to perform the elbow flexion movement (concentric phase of the movement) as fast as possible. The return of the elbow to the initial position was controlled, with a 1 to 2-second micro-pause, to prevent the effect of accumulated elastic force from interfering in the subsequent execution. The loads for this test were randomized for each subject to control potential bias related to learning effects or cumulative fatigue action. In each load, three repetitions were performed with a 2-minute rest interval between the loads, using the highest measure of the 3 repetitions (MOREIRA et al., 2022).

A linear position transducer or Encoder (Chronojump Boscosystem, Barcelona/Spain), with a sampling frequency of 1000Hz, and the Chronojump software, version 1.6.2 (Chronojump Boscosystem, Barcelona/Spain), were used to determine power values. Through this instrument, information on average power (AP) and peak power (PP) was obtained.

2.2.2 Functional state

To assess functional agility in wheelchairs, the adapted zigzag test (Texas Fitness Test) was performed (GREGUOL; SILVEIRA BÖHME, 2003). The aim of the test was to traverse the total distance of a 6 x 9-meter rectangle, requiring changes in direction, with the highest possible speed and efficiency. Each participant, using their own wheelchair, navigated the test course marked by five cones. On the evaluator's signal, the participant propelled the chair through the course as quickly as possible. Five attempts were made, with a five-minute interval between them. The first attempt was for course recognition and was performed at a slow speed. The second was a high-speed recognition run. The following three attempts were considered valid for the test. A stopwatch with hundredth of a second precision was used, and the result was the shortest time out of these three attempts.

2.2.3 Perception of mental state: anxiety, depression and mental distress.

To assess the presence of anxiety symptoms, the Beck Anxiety Inventory (BAI) was used, which consists of 21 items where the individual must indicate the severity level of the symptom on a four-point scale. The total score ranges from 0 to 63, and allows for the assessment of the intensity level of anxiety symptoms. The classification described in the manual recommends that the level of anxiety be classified as minimal (0-7), mild (8-15), moderate (16-25), or severe (26-63) (BAPTISTA; CARNEIRO, 2011).

For the evaluation of depression, the Beck Depression Inventory (BDI) was employed. This inventory consists of 21 items, including symptoms and attitudes, with intensity varying from 0 to 3. The items pertain to sadness, pessimism, feeling of failure, lack of satisfaction, guilt, sense of punishment, self-depreciation, self-accusations, suicidal thoughts, crying spells, irritability, social withdrawal, indecisiveness, body image distortion, work inhibition, sleep disturbance, fatigue, loss of appetite, weight loss, somatic concern, decreased libido (GORENSTEIN; HELENA; GUERRA, 1998; OLIVEIRA ET AL., 2011).

For the assessment of mental disorder, the Self Report Questionnaire (SRQ) was used to evaluate the suspicion of psychiatric disorder symptoms through questions about the patient's life. The Portuguese version of the SRQ 20 determines the cutoff point for not presenting psychotic morbidity as ≤8 for women and ≤6 for men (JACOBS et al., 2011).

2.2.4 Body composition

BC was assessed with a full-body Dual-Energy X-ray Absorptiometry (DXA) scan (GE Healthcare Lunar Prodigy Advance DXA System, software version 13.31). The equipment was calibrated prior to conducting the scan. The precision presented by a similar device (MOREIRA; OLIVEIRA; DE PAZ, 2018) was 2.3% for Total Body Mass (TBM), 1.6% for FM, 0.3% for LM, and less than 0.1% for Bone Mineral Content (BMC).

Each volunteer's evaluation was conducted after a 30-minute wait and under the same conditions. During the DXA measurements, the volunteer lay supine on the device, with upper limbs extended and parallel to the trunk, hands pronated and resting on the device. The lower limbs were also extended, with a standard separation at hip width and secured by a strap holding the ankles. They were instructed to remain as still as possible for the duration of the scan (HIRSCH et al., 2017; MOREIRA et al., 2015). Each scan took about seven minutes, and through them, an automatic calculation of the DXA outcome parameters (TBM, FM, LM, and BMC) was obtained.

2.3 Statistical analysis

For the analysis of the data obtained in the present study, the Jacobson and Truax (JT) Method, proposed by Jacobson and Truax (1991), was employed. This statistical method has been used in research and interventions with single subjects or small samples (AGUIAR ET AL., 2009). The JT Method is an alternative for research/interventions that lack a control group design and aim to investigate the Reliability of Change Index (RCI) pre and post-intervention and the Clinical Significance (CS), which checks if the impacts observed in the last evaluation had an effect in the participant's daily life, contributing to the application of these acquired behaviors in other environments (AGUIAR ET AL., 2009).

For the calculations of the JT Method, the global score from the first evaluation (EV2019) of all participants was considered. To identify the cutoff point for CS, Criterion A was used, which is indicated when normative data of the functional population are not available (JACOBSON; TRUAX, 1991). To understand the results regarding the RCI, the central diagonal line that separates the positive differences (post > pre) above and the negative differences (post < pre) below should be observed. There are also two dashed diagonals that delimit the area of uncertainty, indicating that participants located in this range had no reliable change (NC). These lines are drawn according to mathematical formulas based on the variability of the results (standard deviation, standard error, reliability of the instrument).

Regarding CS, the analysis of the graphs is performed through four quadrants formed by the crossing of the vertical and horizontal lines. To assert that there was a clinically significant change, participants must be situated in the quadrant above the horizontal line and to the left of the vertical line. The cutoff point calculation for CS was based on Criterion A and is used when there is no normative population data, allowing for estimation of mean and standard deviation according to a dysfunctional sample.

In addition to the JT Method, the effect size (ES) was calculated using Cohen's d test to verify the magnitude of the result of the DT period on the analyzed variables, the standard error of measurement (SEM), and the minimal detectable difference (MDD), with the purpose of enhancing the analysis of the changes promoted by DT. The effect values were based on Cohen's proposal, being classified as "small" (< 0.2), "medium" (0.2 to 0.8), and "large" (> 0.8) (LINDENAU; GUIMARÃES, 2012).

The calculation of the SEM was necessary to obtain the MDD, and then, the MDD with a 95% confidence level was verified. All calculations were performed in Microsoft® Excel version 2010.

3 RESULTS

The sample of the present study consisted of five individuals with chronic phase SCI with an average age of 46.2 ± 13.9 years, 60% of whom were women (n=3). The injuries of all study participants were in the thoracic region. The causes of the injuries were varied, and the average duration of the injury was 19.6 ± 17.0 years.

Table 2 presents the descriptive analysis for each of the variables analyzed in the group of evaluated volunteers.

Table 2 – Descriptive analysis of variables assessed to verify the effect of DT between 2019 and 2022 in individuals with SCI.

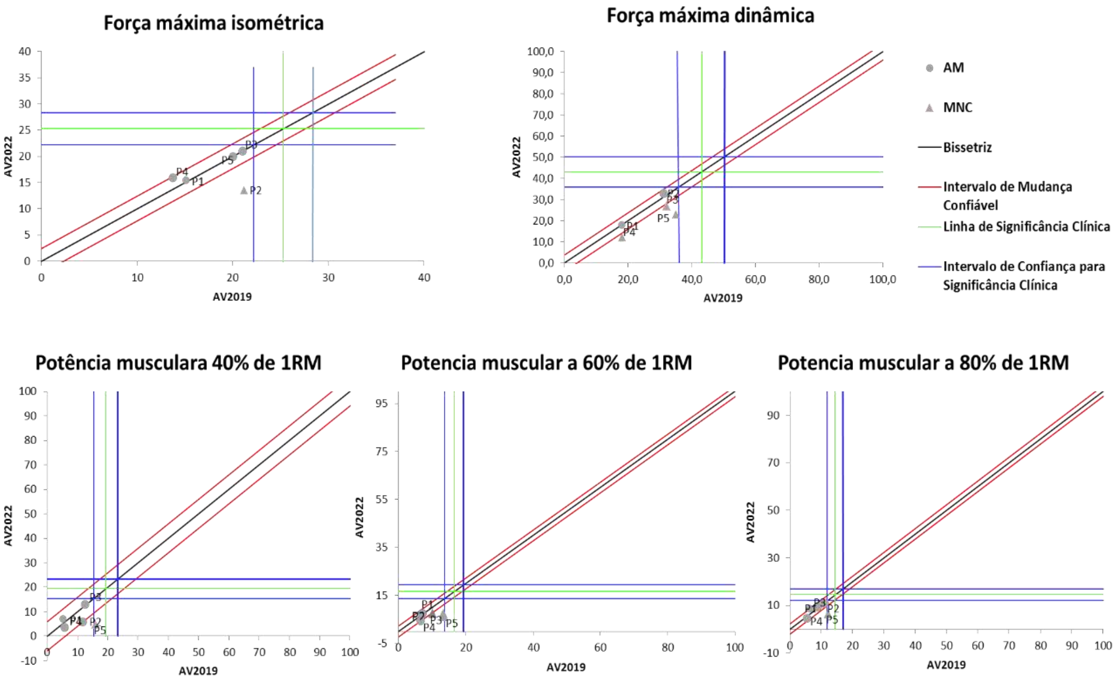
	EV2019					EV2022				
	Mean	SD	Median	Míni mum	Maxi mum	Mean	SD	Media n	Minim um	Maxi mum
MVIC (Kg)	16,70	5,03	17,75	8,80	21,20	19,00	6,14	16,00	13,60	28,80
1RM (Kg)	24,50	9,22	24,50	13,00	35,00	22,60	8,08	23,00	12,00	33,00
MP40 (Watts)	89,24	51,59	86,86	26,18	159,35	69,38	38,57	59,18	35,76	134,32
MP60 (Watts)	88,12	42,17	85,48	26,07	134,45	66,24	13,19	74,62	44,67	74,87
MP80 (Watts)	77,35	37,78	77,29	20,98	122,03	80,55	26,31	86,43	45,63	111,69
Zigzag (s)	32,55	5,17	30,41	29,45	42,93	27,10	4,81	24,68	23,10	34,46
Anxiety	5,40	4,39	4,00	1,00	11,00	8,50	4,12	8,00	4,00	14,00
Depression	6,00	3,39	8,00	1,00	9,00	4,75	3,86	4,50	1,00	9,00
TBM (Kg)	63,57	15,22	59,50	45,00	87,20	67,30	10,48	67,10	57,50	82,40
LM (Kg)	37,53	10,14	36,29	27,23	53,22	39,87	8,76	37,54	28,11	50,08
FM (kg)	23,77	56,00	24,58	16,28	30,93	24,86	4,42	26,81	18,35	29,31
BMC (Kg)	2,28	0,59	2,36	1,47	3,09	2,36	0,52	2,37	1,64	3,03
T-score (sd)	-1,50	1,04	-1,85	-2,50	0,30	-1,22	0,82	-1,50	-2,20	0,00
Z-score (sd)	-0,82	0,90	-1,20	-1,50	0,90	-0,64	1,06	-1,30	-1,50	0,80

EV2019: Evaluation in 2019, EV2020: Evaluation in 2020, SD: Standard Deviation, MVIC: Maximum Voluntary Isometric Contraction, 1RM: Maximum Voluntary Dynamic Contraction, PM40: Muscle Power at 40% of 1RM, PM60: Muscle Power at 60% of 1RM, PM80: Muscle Power at 80% of 1RM, TBM: Total Body Mass, LM: Lean Mass, FM: Fat Mass, BMC: Bone Mineral Content.
Source: Author

Figure 3 presents the effects of DT that occurred between the two evaluations (2019 and 2022) on the results of isometric, dynamic, and power MS. It is observable that the DT period did not cause significant losses in maximum isometric strength in most of the study participants. On the other hand, three out of the five participants showed a significant reduction in maximum dynamic strength after the DT period.

Regarding muscle power (MP), Figure 3 demonstrates that there was no change in it after the DT period when measured at 40% of 1RM. When measured at 60% of 1RM, MP experienced a significant reduction in four of the five study participants. As for MP measured at 80% of 1RM, only one participant showed a significant reduction, while the others did not demonstrate changes with the DT period.

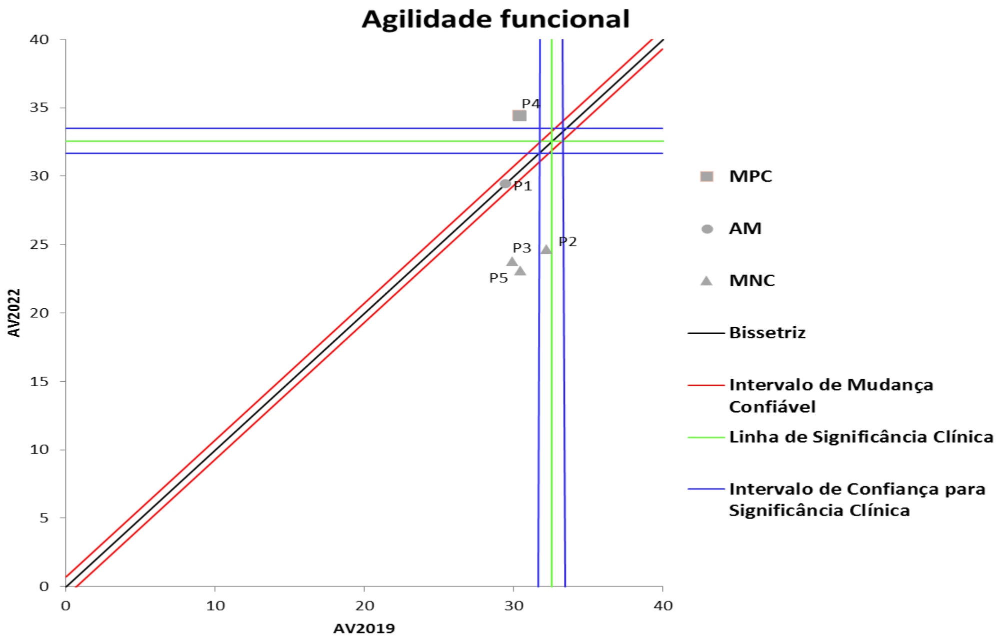
Figure 3 – Dispersion of the differences between the EV2019 and EV2022 evaluations, measuring the effect of DT on the test results for assessing different manifestations of MS in individuals with SCI.



Source: Author.

Figure 4 shows the effects of DT that occurred between the two evaluations (2019 and 2022) on the results of functional agility assessed by the wheelchair zigzag test. It can be observed that the DT period resulted in significant losses in functional agility in three out of the five participants evaluated.

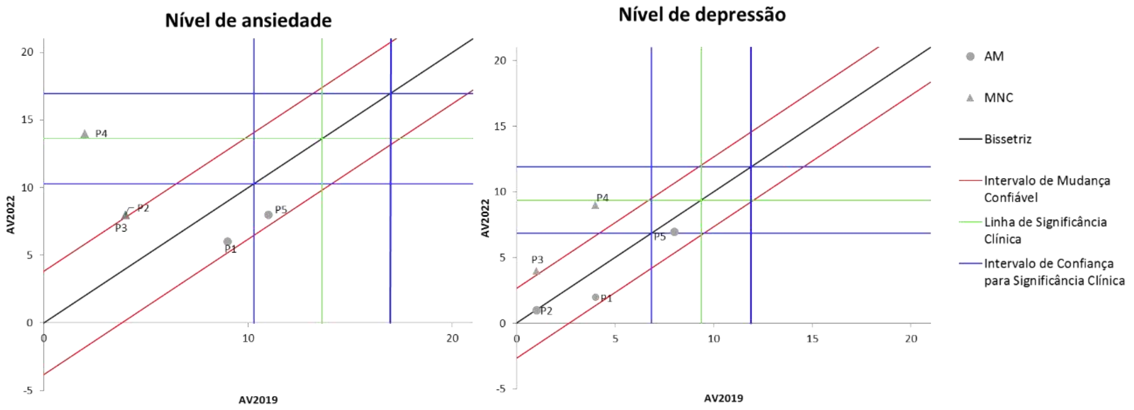
Figure 4 – Dispersion of the differences between the EV2019 and EV2022 evaluations, measuring the effect of DT on the results of the Zigzag test for assessing functional agility in individuals with SCI.



Source: Author.

Figure 5 illustrates the effects of DT that occurred between the two evaluations (2019 and 2022) on the results of MH, assessed by anxiety and depression questionnaires. It is observable that the DT period led to significant worsening of anxiety symptoms in three volunteers, while the other two showed no change. Regarding depression symptoms, two participants exhibited a significant worsening of symptoms, while the remaining three did not demonstrate any significant change.

Figure 5 – Dispersion of the differences between the EV2019 and EV2022 evaluations, measuring the effect of DT on the results of anxiety and depression for assessing MH in individuals with SCI.

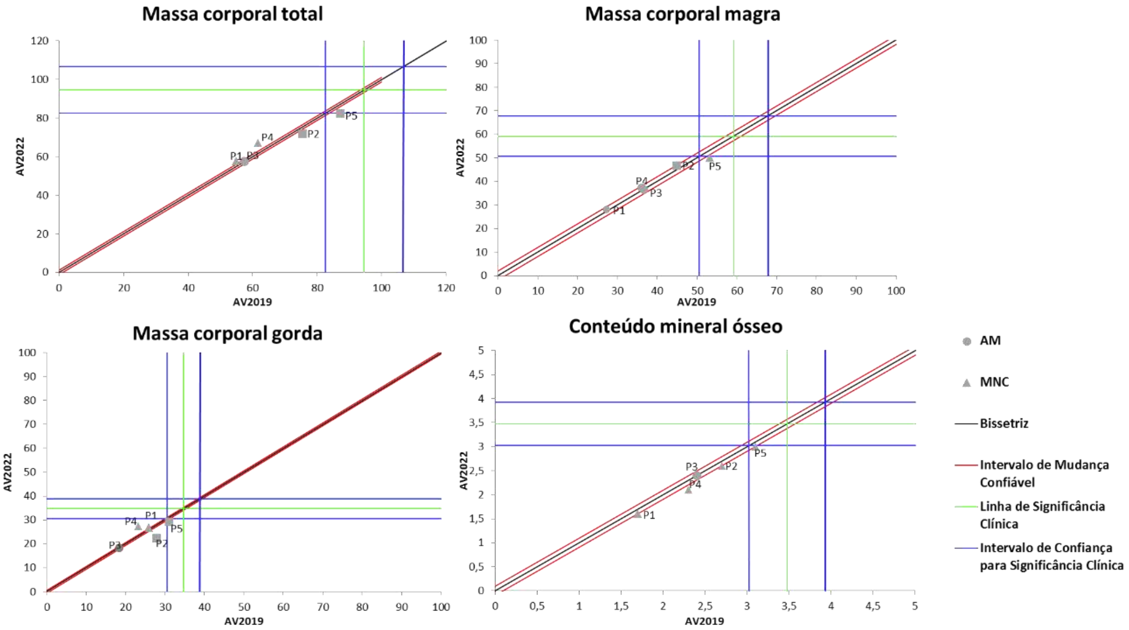


Source: Author.

Figure 6 shows the effects of DT that occurred between 2019 and 2022 on the results of BC measured by the DXA method. It was identified that the total body mass behaved heterogeneously during the DT period among the study participants (1 increased, 2 remained unchanged, and 2 lost total body mass).

Regarding LM, four out of the five participants showed no changes due to the DT period, while one participant experienced a significant loss of LM during this time. For the variable of FM, a similar pattern to total body mass was observed, i.e., one participant increased FM, two remained unchanged, and two lost FM. Finally, for BMC, four out of the five evaluated individuals showed no significant change, while one individual exhibited a significant increase in this variable.

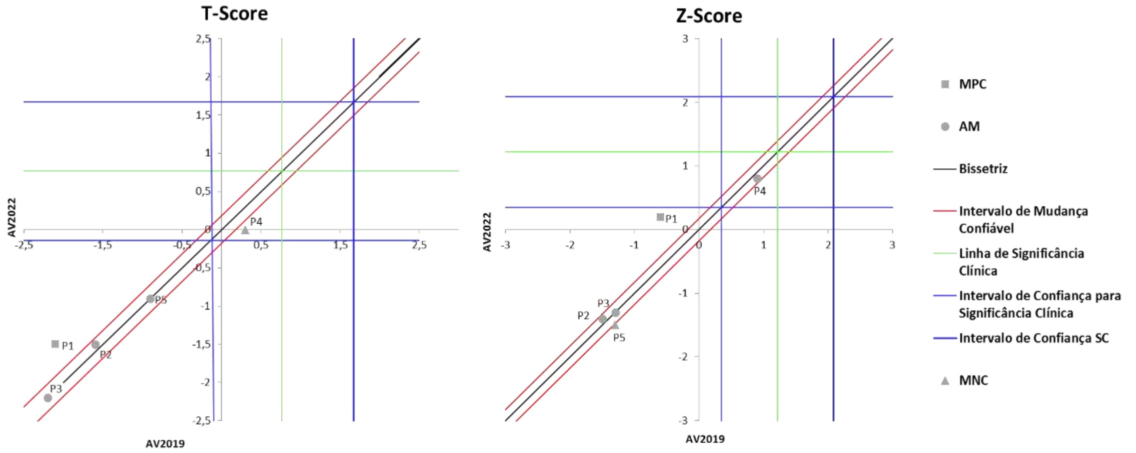
Figure 6 – Dispersion of the differences between the EV2019 and EV2022 evaluations, measuring the effect of DT on the DXA results for assessing BC in individuals with SCI.



Source: Author.

Figure 7 displays the effects of DT that occurred between the two evaluations (2019 and 2022) on the results of BMD. It can be observed that the DT period did not alter the T-score in four out of the five individuals with Spinal Cord Injury (SCI) evaluated, although one participant exhibited a significant decline in T-score values. Similarly, the Z-score also remained unchanged in the majority of the evaluated individuals (three volunteers), while two participants showed distinct results: one with significant improvement and another with a decline.

Figure 7 – Dispersion of the differences between the EV2019 and EV2022 evaluations, measuring the effect of DT on the DXA results for assessing BMD in individuals with SCI.



Source: Author.

4 DISCUSSION

The present study investigated the long-term impacts of DT, over a period of 33 months, on measures of physical performance, MH, and BC parameters in individuals with SCI. The findings indicated a decline in various components such as MS, functional agility, anxiety, depression, and BC, demonstrating that DT has a considerable impact on the lives of this population.

MS plays a crucial role in the health and QoL of individuals with SCI (ALVES et al., 2021). The results of this study identified that isometric strength, the ability to generate muscle tension without movement, remained stable during the DT period. There appears to be a scarcity of studies that seek to identify the effects of DT on the strength of individuals with SCI, particularly regarding the evaluation of active musculature not affected by the injury. Thus, considering the changes caused by SCI, it can be compared to an accelerated model of aging (O'BRIEN et al., 2017).

The results corroborate the findings of Chen et al. (2018), where elderly women with sarcopenia maintained isometric strength derived from 8 weeks of kettlebell training, even after 4 weeks of DT. Considering other populations, Araujo et al. (2021) found that healthy individuals and those with HIV/AIDS who underwent 15 weeks of concurrent training (strength and aerobic) and 5 weeks of DT maintained isometric strength without significant losses. Although the results of these studies point in the same direction, it is important to note that the training methodology and especially the sample were different from the present investigation, as this study worked with individuals with SCI, while the cited studies investigated the elderly and patients with HIV/AIDS.

Contrary to these results, Häkkinen et al., (2022) investigated a group of healthy women for 10 weeks in resistance training followed by 5 weeks of DT and observed decreases in isometric strength -6.6 ± 3.6% ($p < 0.01$). Similarly, Gomez-Illan et al., (2020) investigated individuals with multiple sclerosis for 8 weeks in high-intensity resistance training, 90% 1RM, and reported losses in isometric strength after 10 weeks of DT.

It is important to highlight that the studies mentioned varied between 5 and 8 weeks of DT period. In contrast, the present investigation conducted a period of 33 months, aiming to fill a gap in the literature, as this is a long period of DT, thus adding originality to the work.

To explain these results regarding isometric strength, it should be considered that individuals with SCI benefit from the effects of training with a lower volume than individuals without SCI (PEEV et al., 2020; MARTIN GINIS et al., 2018). Therefore, it is believed that the movements of supporting and suspending one's own body during moments of transfer and movement with the wheelchair serve as sufficient stimuli for the maintenance of isometric strength, given the need to support one's own body weight in various activities such as bathing, moving from bed to chair and vice versa, among other tasks.

Upper limb MS is considered a relevant physical capacity for wheelchair propulsion and, therefore, for performing locomotion and transfer activities (ITURRICASTILLO et al., 2022). Furthermore, MS contributes to the prevention of secondary complications, such as pressure ulcers, respiratory, and postural problems (HWANG; KWON, 2023; SANTOS et al., 2022; ALVES et al., 2021).

In relation to dynamic strength, the capacity to generate muscle tension with movement, the results showed a decline in this variable. These findings are in line with the study by Schott; Johnen and Holfelder (2019), which identified reductions in 10RM dynamic strength ($p < .001$ for all measures) in older adults after 6 weeks of DT, following 26 weeks of resistance training with 3 sets of 10-12RM at intensities between 70-80% of 1RM. Additionally, in a controlled randomized clinical trial in which 95 elderly women were randomly allocated to 4 experimental resistance training groups (strength, power, absolute strength, and relative strength) and 1 control group, undergoing 20 weeks of training with intensity controlled between 6 to 8 points of SPE and equalized volume between 25 to 30 repetitions for each group, Mazini Filho et al. (2022) observed, after 4 weeks of DT, significant losses in MS ($p<0.05$) for all groups, even though strength values did not return to baseline.

Furthermore, two groups of healthy women, eccentric training vs. concentric training, subjected to 10 weeks of resistance training and undergoing 5 weeks of DT, showed declines in dynamic strength of -6.6 ± 3.6% ($p < 0.01$) for the eccentric group and -8.0 ± 4.5% ($p < 0.001$) for the concentric group in the 1RM bench press test (HÄKKINEN et al., 2022). Additionally, in a systematic review with older adults and middle-aged individuals, it was observed that when the DT period exceeded the duration of resistance training, the benefits of resistance training were not maintained in relation to MS (YANG et al., 2022). Since the results indicated stability in LM and a reduction in dynamic strength, it is believed that the reduction in the ability to generate voluntary force is due to neural changes (FRIZZIERO et al., 2016).

Perceiving the negative impact of DT on the analyzed variable, it is essential that individuals with SCI engage in specific training programs to maintain and improve MS. These programs can include progressive resistance exercises, strength training with weights or resistance machines, functional electrical stimulation, and other therapeutic interventions aimed at muscle strengthening (SANTOS et al., 2022; PEEV et al., 2020;).

The product of muscle force and movement velocity results in MP (SAPEGA; DRILLINGS, 1983). Regarding this variable, a reduction in MP at 60% of 1RM was observed. The behavior of MP observed during DT periods tends to show a decrease in performance levels, as observed by Mazini Filho et al. (2022) in their study with elderly women, where 4 weeks of DT were sufficient to reduce upper and lower limb MP (all $p < 0.05$) generated by 20 weeks of resistance training. Another study in which elderly men underwent 12 weeks of resistance training followed by an equal DT period also observed reductions in MP (-5 to -15%, $p \leq 0.004$). However, these reductions were not sufficient to return to pre-training baseline values in both studies (MAZINI FILHO et al., 2022; BLOCQUIAUX et al., 2020).

Additionally, wheelchair basketball athletes who achieved better results in the MP test, in the flat bench press exercise at ~50% of 1RM, showed superior physical performance (ITURRICASTILLO et al., 2019). Thus, it is possible to consider that MP is essential for performing explosive movements and wheelchair maneuvers (ALVES et al., 2021). In this sense, resistance training focusing on MP can increase movement efficiency and functional independence in individuals with SCI (FERREIRA DA SILVA et al., 2022). On the other hand, DT, by reducing MP, negatively affects movement efficiency and functional independence in people with SCI.

One of the abilities directly linked to MP is agility, the ability to change direction rapidly, which is a crucial factor for the independence and mobility of individuals with SCI, allowing them to perform daily activities and move more easily (ALVES et al., 2021). The reduction of this capacity leads to mobility restrictions, preventing individuals with SCI from moving autonomously and freely (ALVES et al., 2021).

Resistance circuit training (RCT) has proven to be effective in improving upper limb MP and functional capacity in individuals with SCI, as evidenced by a wheelchair-adapted agility test (ALVES et al., 2021). Furthermore, RCT is a low-cost and highly ecologically valid strategy that can be performed in the individual's own wheelchair without the need for specific adaptations. By incorporating movements that mimic activities of daily living and training stations that require agility and rapid changes of direction, RCT also stands out as a practical approach to improving functional agility (ALVES et al., 2021).

During the training interruption period, there was a loss of functional agility measured by the adapted wheelchair agility test. Studies that conducted wheelchair agility tests were associated with the evaluation of this variable for the functional classification of wheelchair basketball athletes (FRÉZ; SOUZA; BIM, 2015; OZMEN et al., 2014) and wheelchair handball (SILVEIRA et al., 2012). This makes it difficult to compare the results found within this population. Therefore, when investigating the effect of DT on functional agility in different populations, the following can be found: Leitão et al. (2022) observed that 1 year of DT led to a loss of functional agility (-4.24% $p < 0.01$) in hypertensive elderly women, stemming from 9 months of multicomponent training. The same authors also identified losses in agility ($p < 0.05$) after 3 months of DT in elderly women with high cholesterol and triglycerides (LEITÃO et al., 2021). In line with these findings, Park and Lee (2015) observed that 8 weeks of DT led to a significant loss of agility ($p < 0.01$) in elderly individuals with type 2 diabetes, although the results still remained high compared to pre-training baseline. Similar to this result, Blasco-Lafarga et al. (2020) found that the agility of elderly individuals, after 7.5 months of DT, was the variable that, despite showing losses, exhibited greater retention compared to other physical components ($p < 0.001$).

As agility demands factors such as strength and speed, it is directly associated with anaerobic power and functional physical performance (RIBEIRO NETO et al., 2022). In this sense, the loss of agility in most participants may perhaps be explained by the alteration from fast-twitch white type II fibers to slow-twitch red type I fibers (ALVES et al., 2021), due to a possible reduction in physical activity levels and lack of anaerobic stimuli caused by the interruption of resistance training during the COVID-19 pandemic quarantine.

MH plays a significant role in the lives of individuals with SCI (SANTOS et al., 2022). Adapting to the injury, coping with physical limitations, and emotional challenges can negatively affect psychological well-being (SINGH; MITRA, 2022). A systematic review with meta-analysis documented a high risk of issues such as anxiety, depression, and stress in this population, emphasizing the importance of taking care of MH and providing adequate psychological support (WILLIAMS; MURRAY, 2015). Regular physical exercise is recommended due to its benefits for mental health and being a low-cost non-pharmacological alternative (SANTOS et al., 2022).

The present study showed a worsening of MH in individuals, both for anxiety and depression, during the DT period. There seems to be a significant relationship between DT and the worsening of depression and anxiety symptoms. This phenomenon is evident in different investigated groups, namely: elderly women with type 2 diabetes (DONYAEI et al., 2023), badminton athletes (SILVA et al., 2022), individuals affected by ischemic stroke (TOLLÁR et al., 2023), and patients diagnosed with Parkinson's disease (HORTOBÁGYI et al., 2021), revealing an increase in depressive indicators following periods of DT, with durations ranging from 8 weeks to 1 year. However, in other studies with healthy elderly individuals (SHAHTAHMASSEBI et al., 2022) and frail elderly individuals (CALDO-SILVA et al., 2021), healthy women (RUFO-TAVARES et al., 2020), women with fibromyalgia (SAÑUDO et al., 2012), and women with polycystic ovary syndrome (SANTOS, I. et al., 2022), no significant disparities in depressive and anxiety symptoms induced by DT were observed. Furthermore, in elderly individuals undergoing hemodialysis and those with multiple sclerosis, gains obtained during training in terms of MH, including depression management, were preserved even after the DT period (CORREALE et al., 2021; ROSA et al., 2020).

It is worth noting that the methodological discrepancies in the studies presented in the previous paragraph reflect the diversity of approaches in studying DT in different populations and conditions, such as training intensity and type, DT exposure time, and assessment instruments. In summary, while some studies indicate an improvement in anxiety and depression symptoms with training, the sustainability of these benefits after DT periods appears to vary, with some studies indicating a partial reversal of psychological benefits and others not finding significant changes.

To explain the results of this study, it is interesting to highlight that there seem to be two effects affecting the MH status of the sample in this study. In addition to the effect of DT itself, one must consider the effects of the COVID-19 pandemic, which, according to systematic review studies (VINDEGAARD; BENROS, 2020; XIONG et al., 2020), increased anxiety symptoms (6.33% to 50.90%) and depression symptoms (14.6% to 48.3%) in the general population in various countries due to the social isolation protocols adopted to combat the pandemic.

BC is a determinant factor in the health and rehabilitation of individuals with SCI, as changes in FM and LM can directly influence functionality, the risk of secondary diseases, and

QoL (SHIN et al., 2022; VAN DER SCHEER et al., 2021; BUCHHOLZ; BUGARESTI, 2005). High FM is associated with an increased risk of cardiovascular complications, while adequate LM is crucial for maintaining MS and preventing atrophy, being essential for daily activities and independence (SANTOS et al., 2022; MCMILLAN et al., 2021; SPUNGEN et al., 2003).

The results of the present study show that there was no change in LM during the DT period. In this regard, it is worth noting some methodological limitations, such as the lack of monitoring of physical activity levels, dietary control, and pharmacological control of the subjects in the sample during the analyzed period. Comparing the effect of DT on LM in other populations, this variable tends to decrease in women survivors of breast cancer (DE JESUS et al., 2021), elderly women (AMARANTE DO NASCIMENTO et al., 2022), and elderly men with osteosarcopenia (KEMMLER et al., 2021). Furthermore, according to a systematic review by Del Vecchio et al. (2020), the literature suggests that BC tends to result in a reduction in LM and an increase in body fat accumulation after DT periods. In line with this statement, an increase in visceral adipose tissue was observed in individuals with SCI who underwent DT periods with monitored physical activity levels (GORGEY et al., 2021).

As individuals with SCI benefit from the effects of physical activity with lower volumes, it is believed that the activities performed in daily life may have been sufficient to maintain LM in most subjects in the present study (MARTIN GINIS et al., 2018; VAN DER SCHEER et al., 2017).

BMD, which results from a dynamic process of bone tissue formation and resorption, and cross-sectional muscle area (CSA) are other aspects that deserve attention, as they are important indicators of bone health (RODRIGUES FILHO et al., 2016). These aspects are often compromised in this population, leading to osteoporosis and a high risk of fractures (RAGUINDIN et al., 2021; BAUMAN; SPUNGEN, 2001).

The results found in this study did not observe changes in bone health variables during the DT period. However, individuals with SCI who underwent a period of 12 months of training followed by 12 months of DT showed a loss of the benefits generated by training in both BMD and CSA (FROTZLER et al., 2009). In line with the results of the present study, Gorgey et al. (2021) did not observe changes in BMD after 16 weeks of DT in individuals with SCI. It is worth noting that the results of the compared studies correspond to an analysis of the limbs affected by the injury through studies involving electrical stimulation.

Physical exercise promotes osteogenesis and increases BMD and CSA by imposing mechanical loads on the bones through muscle contractions (DE AVILA et al., 2019). Therefore, the lack of movement in the affected musculature can lead to a faster absorption of the bone content acquired through training compared to the still active limbs, which is the case in the present study's sample.

Analyzing the changes in LM, FM, BMD, and CSA, it can be considered that the evaluation and monitoring of BC are essential components of clinical management in individuals with SCI, aiming to optimize the results of intervention programs and promote a healthier lifestyle (VAN DER SCHEER et al., 2021).

The present study has limitations that should be considered when interpreting its results. The use of a small group of participants restricts the generalization of the findings to the broader population of individuals with SCI. The lack of monitoring of participants' physical activity levels may have influenced the results of BC and functionality. Additionally, the absence of comparative data with pre-training baseline data hinders a clear analysis of the participants' physical condition evolution or regression in response to DT. To strengthen the quality of evidence in future studies, it is essential to include a larger number of participants, adequate monitoring of physical activity, a more homogeneous group with detailed classifications of SCI, and comparisons with baseline data.

5 CONCLUSION

This study highlights the negative consequences of prolonged DT in individuals with SCI, demonstrating reductions in dynamic MS, functional agility, and MH, despite the preservation of isometric strength and BC. The stability of isometric strength suggests that daily activities may provide sufficient stimuli for its preservation, while the deterioration of MH underscores the importance of physical exercise for psychological well-being, especially during periods of isolation such as those imposed by the COVID-19 pandemic.

The findings reinforce the need for continuous and tailored training programs for individuals with SCI to improve functionality and MH and prevent secondary complications. The study's limitations, including the sample size and lack of physical activity monitoring, point to the need for more detailed future research to optimize intervention strategies for this population.

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GENERAL CONCLUSION

This thesis aimed to analyze the effects of detraining on health indicators in individuals with SCI. Based on the results obtained through the studies conducted in Chapters 1 and 2, it was possible to conclude that, individuals with SCI are vulnerable to negative health consequences when subjected to detraining periods. Detraining can lead to a loss of the benefits gained from regular physical exercise, including changes in BC, metabolic profile, and cardiorespiratory variables in Study 1. In Study 2, prolonged detraining results in reductions in dynamic MS, functional agility, and mental health.

Overall, these findings emphasize the importance of consistent engagement in regular physical activity for individuals with SCI to maintain their health, quality of life, and overall well-being. This underscores the need for continuous and tailored training programs to address the specific needs of this population and prevent secondary complications. However, further research with larger sample sizes and comprehensive physical activity monitoring is necessary to optimize intervention strategies for individuals with SCI.

ATTACHMENT

POSTGRADUATE IN PHYSICAL EDUCATION

Federal University of Viçosa Department of Physical Education	Federal University of Juiz de Fora Faculty of Physical Education and Sports

ACTIVITY SHEET DEVELOPED IN THE COURSE MASTERS/DOCTORATE IN PHYSICAL EDUCATION

Student: Lucas Barbosa Almada

1. PARTICIPATION IN FULL ARTICLES PUBLISHED IN JOURNALS

DA SILVA, T D; MORAIS, G. F. ; **ALMADA, L. B.** ;AGOSTINHO, P. A. G.; COTA, A. R. Obesidade infantil e hábitos alimentares: as consequências na vida adulta. **Revista Brasileira De Fisiologia Do Exercício**, v. 21, p. 322-328, 2023.

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Literature Review

Childhood obesity and food habits: the consequences in adult life

Obesidade infantil e hábitos alimentares: as consequências na vida adulta

Tárcilio Dias da Silva[1], Gessimara Ferreira Morais[1], Lucas Barbosa Almada[2], Pablo Augusto Garcia Agostinho[2], Amanda dos Reis Cota[2]

1. Colégio Claretiano, Batatais, SP, Brazil
2. Universidade Federal de Viçosa, Viçosa, MG, Brazil

ABSTRACT
Aim: To identify, through a literature review, the impact on the health of the individual as a result of childhood obesity, its impacts during the stages of life, describing the complications, and presenting the risks to the health of children as a result of bad habits of food. **Methods:** For the elaboration of the research, journals of scientific journals and scientific articles were analyzed, based on PubMed, Scielo, and Google Scholar, on the subject. The search was limited to English and Portuguese, and the articles analyzed were selected because they were highly relevant to the topic. **Results:** It was observed that overweight and obese children are more likely to develop various diseases in childhood, with repercussions throughout life, reducing quality and life expectancy. Low income, genetics, lack of physical exercise, bad eating habits, and socioeconomic problems are the main factors that contribute to the increase in childhood obesity. **Conclusion:** Health promotion strategies that have the most effect are improvements in lifestyle, such as healthy eating and physical activity.

Keywords: adolescent, nutritional status, pediatric obesity.

RESUMO
Objetivo: Identificar, por meio de uma revisão de literatura, o impacto na saúde do indivíduo em consequência da obesidade infantil, seus impactos durante as fases da vida, descrevendo quais as complicações e apresentando os riscos para a saúde das crianças em decorrência dos maus hábitos alimentares. **Métodos:** Para elaboração da pesquisa, foram analisados periódicos de revistas científicas e artigos científicos, tendo como base de dados PubMed, Scielo e Google Acadêmico, sobre o tema. A busca foi limitada à língua inglesa e portuguesa, e os artigos analisados foram selecionados por apresentarem grande relevância sobre o tema. **Resultados:** Observou-se que crianças com sobrepeso e obesidade apresentam maiores probabilidades de virem a desenvolver várias doenças na infância, repercutindo ao longo da vida, reduzindo a qualidade e expectativa de vida. Baixa renda, genética, a falta de exercícios físicos, maus hábitos alimentares e problemas socioeconômicos são os principais fatores que colaboram para o aumento da obesidade infantil. **Conclusão:** Estratégias de promoção de saúde que mais surtem efeitos são melhoras dos hábitos de vida, como, alimentação saudável e da prática de atividades físicas.

Palavras-chave: adolescente; estado nutricional; obesidade pediátrica.

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Correspondence:Tárcilio Dias da Silva, E-mail: tarciliodias@hotmail.com

2. BOOKS PUBLISHED IN JOURNALS

3. PARTICIPATION IN PUBLISHED BOOK CHAPTERS

4. PARTICIPATION IN NEWS NEWSPAPERS OR MAGAZINES

5. PARTICIPATION IN CONFERENCES, SEMINARS, COURSES, AND SYMPOSIA AS A SPEAKER

6. ABSTRACTS PUBLISHED IN CONFERENCE PROCEEDINGS

Lucas Barbosa Almada e Osvaldo Costa Moreira. Impacto do Treinamento Resistido na Capacidade Cognitiva de Idosos Frágeis. Health Conect Summit 2021 – Polo de Saúde de Londrina.

Lucas Barbosa Almada, Lucas Vieira Santos, Luís Felipe Moutinho Leitão, Mauro Lúcio Mazini Filho, Gabriela Rezende de Oliveira Venturini, e Osvaldo Costa Moreira. Impact of Detraining on the Health of Individuals with Spinal Cord Injury– SIFES II – II Simpósio Internacional de Fisiologia do Exercício e Saúde.

Mauro Lúcio Mazini Filho, **Lucas Barbosa Almada**, Pedro Lima Souza, Juliana Brandão Pinto de Castro, João Guilherme Vieira da Silva e Gabriela Rezende de Oliveria Venturini. Effects of Nutritional Interventions in Sarcopenic Older Adults: An Umbrella Review. SIFES II – II Simpósio Internacional de Fisiologia do Exercício e Saúde.

Lucas Vieira Santos, Osvaldo Costa Moreira, Karla Raphaela da Silva Ramos Freitas, Claudia Eliza Patrocinio de Oliveira, Eveline Torres Pereira, e **Lucas Barbosa Almada**. Efeito do destreinamento físico induzido pela pandemia de Covid-19 em indicadores de saúde física e mental de pessoas com lesão medular espinhal. Simpósio de Integração Acadêmica 2023 – Universidade Federal de Viçosa. 1º lugar na modalidade Pesquisa do Campus Florestal.

7. TECHNICAL VISITS, EXCHANGES, OR INTERNSHIPS

Instituição:
Data:
Local:
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8. GUIDANCE

9. PARTICIPATION IN EXAMINING COMMITTEES

Student name: Beatriz Silva Lopes Machado
Title of the work: “A Importância de se Trabalhar as Ações Hormonais nas Aulas de Educação Física, nos Últimos Anos do Ensino Fundamental e no Ensino Médio”

Date: 13/12/2022
Names of the Other Evaluation Committee Members: Neilton de Sousa Ferreira Júnior, Osvaldo Costa Moreira.
Promoting Organization: Federal University of Viçosa – UFV

Student name: Marcos Rosa Antonucci e Pedro Henrique Ramos da Silva Romanhol
Title of the work: "Níveis de Ansiedade e Depressão em Profissionais de Educação Física da Cidade de Cataguases-MG"
Date: 08/12/2023
Names of the Other Evaluation Committee Members: Carlos Gonçalves Tavares, Pedro Lima Souza.
Promoting Organization: Faculdade Sudamérica

10. UNDERGRADUATE CLASSES TAUGHT AT UFV OR UFJF

Course name: Human Physiology
Credit hours: 2hr

Course Name: Human Growth and Development
Credit hours: 2hr