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Predictive Factors for Pressure Injury Risk in Individuals with Spinal Cord Injury

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Abbreviations

CA – Contact Area

AIS – ASIA Impairment Scale

ASIA – American Spinal Injury Association

DI – Dispersion Index

BMI – Body Mass Index

PI – Pressure Injuries

SCI – Spinal Cord Injury

FIM – Functional Independence Measure

WHO – World Health Organization

OT – Occupational Therapist

Resumo

Introdução: A lesão medular é uma condição neurológica central resultante da lesão da medula espinal, que provoca défices nas funções motoras, sensitivas e autonómicas, podendo levar ao desenvolvimento de lesões por pressão.

Objetivo: Identificar os fatores preditores sociodemográficos, clínicos e funcionais para o risco de desenvolvimento de lesões por pressão em indivíduos com lesão medular, considerando as medidas do mapeamento de pressões na posição de sedestação.

Métodos: Estudo quantitativo, observacional, analítico e transversal, com 79 participantes selecionados por conveniência. Utilizaram-se o Questionário Sociodemográfico, a ASIA Impairment Scale, a Medida de Independência Funcional e o BodiTrak2 Lite®. Os dados foram analisados na versão 29 do Statistical Package for the Social Sciences®, com nível de significância de 0.05.

Resultados: O modelo de regressão múltipla explicou 32 % da área de contacto (R^2 ajustado=0.32) e 35 % do índice de dispersão (R^2 ajustado=0.35). A idade (B=-2.22; p=0.004) e o índice de massa corporal (B=20.74; p<0.001) foram preditores significativos da área de contacto. O género (B=5.69; p<0.001), o índice de massa corporal (B=-0.66; p=0.002), a atividade física (B=3.25; p=0.035) e a Medida de Independência Funcional (B=0.09; p=0.014) influenciaram significativamente o índice de dispersão.

Conclusão: Fatores sociodemográficos e funcionais demonstraram-se preditores do risco de lesões por pressão, ao contrário dos clínicos que não apresentaram significância. Destaca-se a importância de sensibilizar os profissionais de saúde, incluindo terapeutas ocupacionais, para a presença destas variáveis em indivíduos com lesão medular, prevenindo lesões por pressão.

Palavras-chave: Lesão Medular; Lesões por Pressão; Funcionalidade; Área de Contacto; Índice de Dispersão.

Abstract

Introduction: Spinal cord injury is a central neurological condition resulting from an injury in the spinal cord, which causes deficits in motor, sensory and autonomic functions, and may lead to the development of pressure injuries.

Aim: To identify the sociodemographic, clinical and functional predictive factors regarding the risk of development of pressure injuries in individuals with spinal cord injury, considering the pressure mapping measurements in the sitting position.

Methods: Quantitative, observational, analytical and cross-sectional study, with 79 participants selected by convenience. The Sociodemographic Questionnaire, the ASIA Impairment Scale, the Functional Independence Measure and BodiTrak2 Lite® were used. The data was analyzed in version 29 of the Statistical Package for the Social Sciences®, with a significance level of 0.05.

Results: The multiple regression model explained 32 % of the contact area (adjusted R^2 =0.32) and 35 % of the dispersion index (adjusted R^2 =0.35). The age (B=-2.22; p=0.004) and the body mass index (B=20.74; p<0.001) were significant predictors of the contact area. The gender (B=5.69; p<0.001), the body mass index (B=-0.66; p=0.002), physical activity (B=3.25; p=0.035) and the Functional Independence Measure (B=0.09; p=0.014) significantly influenced the dispersion index.

Conclusion: Sociodemographic and functional factors have proven to be predictors of the risk of pressure injuries, unlike clinical factors, which were not significant. The importance of awareness among health professionals is emphasized, including occupational therapists, regarding the presence of these variables in individuals with spinal cord injury, to prevent pressure injuries.

Keywords: Spinal Cord Injury; Pressure Injuries; Functionality; Contact Area; Dispersion Index.

Contents

CHAPTER I: INTRODUCTION

1. Introduction

1.1. Spinal Cord Injury (SCI)

SCI is a central neurological condition[1] resulting from a permanent or temporary spinal cord injury, which causes deficits in motor, sensory and autonomic functions, in whole or in part[2]. The physiopathology has acute and chronic phases[2] and motor recovery occurs six to nine months after the injury, with a faster rate throughout the first three months[3]. In this way, an early intervention is fundamental to prevent the development of associated complications[4,5].

According to the World Health Organization (WHO)[6], currently, the prevalence of this pathology worldwide is around 40 to 80 cases per one million inhabitants, with a global rate of 250 thousand to 500 thousand new cases per year[6]. In Portugal, the incidence is around 57.8 thousand per one million, with an increase in the elderly, mainly due to falls[7]. Moreover, according to Berg et al.[8], SCI is more common in male individuals[8] and has a bimodal distribution, with the first peak between the ages of 15 and 29 and the second over 50[7,9]. Although there is no sufficient data to demonstrate that gender has an impact on neurological recovery, advanced age is a predictor of a negative impact on recovery[3].

In accordance with recent studies from 2024, the incidence rate of this pathology is higher in community settings than in hospital settings. It is also notoriously higher in developing countries[10].

According to the literature, the etiology of SCI is classified as traumatic or non-traumatic[11]. The first one occurs due to an external physical impact, as in the case of road accidents, falls or impacts associated with physical exercise, while the second occurs due to distinct pathologies, such as tumor processes, infection or degenerative diseases of the intervertebral discs[11]. Data from 2024 indicates that, globally, there is an average of 26.48 new cases of traumatic SCI per year and 17.93 of the non-traumatic type, per one million inhabitants[10]. In young people, high-energy injuries are more frequent, such as road accidents, sports injuries and injuries caused by bladed weapons and firearms, whereas in adults and the elderly low-energy injuries are more frequent, such as falls[1].

The American Spinal Injury Association (ASIA) developed the ASIA Impairment Scale (AIS)[12] and, according to this scale, SCI are subdivided into five grades, from A to E, according to the impairment and preservation of motor and sensory functions of the segments below the injury level[13]. Therefore, grade A is classified as complete, implying the total loss of motor and/or sensory function below the injury level, including segments S4-S5. Grade B is referred to as incomplete, and the motor function, unlike the sensory function, is compromised below the neurological level, including segments S4-S5. Grade C is known as incomplete, with preservation of the motor function below the neurological level and a muscle grade of less than three in more than half of the muscles below the injury. Grade D is also designated as incomplete, with preservation of the motor function below the neurological level and a muscle grade equal or greater than three in at least half of the muscles below the injury. Finally, grade E is considered "normal", since motor and sensory functions are preserved[14,15]. Consequently, clinical pictures classified with grades A and B are considered of greater severity, with individuals showing more deficits and lower recovery capacity, when compared with neuromotor conditions of grades C and D[16].

In terms of the clinical picture, SCI is classified as paraplegia or tetraplegia, according to the impairment of the function of the different body segments[13,17]. As such, it is considered paraplegia when there is a partial or total loss of motor and/or sensory functions of the thoracic, lumbar or sacral segments[17], causing impairment of the torso, pelvic organs and lower limbs, with preservation of the cervical region and upper limbs function[13]. Alongside this, studies indicate that, in cases of full paraplegia, when the injury occurs above vertebra T9, the possibility of recovering lower limb function is limited, in comparison with injuries below T9[1]. In the case of tetraplegia, there is a partial or total loss of motor and/or sensory function in the cervical segments of the spinal cord[13], with consequent loss of function of the upper limbs, torso, pelvic organs and lower limbs, including the four extremities[17]. Additionally, there is an impairment of the respiratory function. The higher the level of injury, the greater the loss of respiratory capacity[18]. Thus, when the injury occurs above C3, the diaphragm is paralyzed, hindering effective inspiration and requiring continuous mechanical ventilation. Between C4 and C5, the diaphragm is partially preserved, allowing for spontaneous ventilation, although insufficient without assisted ventilation, especially in acute phases or during sleep. In injuries at the C5 level, although the diaphragm is functional, paralysis of the intercostal and abdominal muscles compromises forced expiration, reducing lung capacity and the effectiveness of coughing. Between C6 and C7, ventilation becomes independent, albeit with increased effort, with the recruitment of the pectoralis major as an accessory muscle of inspiration. Between T1 and T5, there is activity of the intercostal muscles, increasing inspiratory and expiratory capacity, although coughing may still be compromised. Lastly, between T6 and T12, there is a progressive improvement in the strength of the respiratory muscles, with respiratory function generally preserved below T6, with an effective contribution from the abdominal muscles and normalization of breathing patterns[18].

After a SCI, cell death occurs by different mechanisms, which originates neurological dysfunctions and affects the progression of the pathology[19], being generally associated with a decrease in average life expectancy[16]. However, in recent years there has been an increase over time[20], although there is still a high mortality rate, mainly in individuals with traumatic SCI[20] and of the tetraplegic type[21]. In addition, secondary complications may arise, such as chronic pain, incontinence, urinary infections, gastrointestinal problems, spasticity, cardiovascular and respiratory complications, orthostatic hypotension, deep vein thrombosis and/or autonomic dysreflexia[9,17,22–24].

As a consequence of SCI, there is a reduced autonomy, independence and functionality of the person in their everyday life, leading to a negative impact on their occupational participation and involvement[25], and affecting the person's satisfaction with their life[26]. Furthermore, there are negative impacts on a financial level[27], on sleep quality and, consequently, on physical, social and emotional well-being[28], which might even contribute to a sedentary lifestyle[29], to the manifestation of mental illnesses, such as post-traumatic stress disorder[30,31] and to the development of pressure injuries[32,33]. As such, monitoring by a multidisciplinary team is essential, which includes the occupational therapist (OT),[34] in the implementation of different types of intervention, among them: selection of suitable support products and training in their use, home adaptations, development of significant activities to build meaning and purpose in life, and the implementation of mindfulness practices[35–42]. Besides, in the past decades, interventions related to the formation of neural networks and the promotion of regeneration have been studied[43–46]. Nevertheless, despite improvements, there is still no fully effective treatment[47–49].

1.2. Pressure Injuries (PI)

Since 2016, the National Pressure Injury Advisory Panel[50], a professional organization founded in 1986 and dedicated to the prevention and treatment of PI, has released new terminology guidelines. As such, the nomenclature "pressure ulcers" was replaced by "pressure injuries", with the aim of including all forms of tissue damage, including the stage before skin rupture[50,51]. This organization defines PI as localized skin and soft tissue injuries, resulting from pressure and/or intense or prolonged shear, usually exerted on bony prominences[50]. However, they may also occur due to medical devices, such as oxygen masks, nasogastric tubes, urinary catheters, cervical collars and splints[52,53].

According to a study conducted in 2020 by Chen et al.[54], it is estimated that around one in five individuals with SCI develops a PI throughout life, with around 40 % developing at least one PI in the first two years after hospital discharge[55]. In addition, Shiferaw et al.[32] demonstrate that, globally, the prevalence of PI as a consequence of SCI is higher in the African continent (41.94 %), followed by the European continent (37.47 %).

Recent data shows that, one year after SCI, around 59.2 % of individuals resort to using a wheelchair, mostly manual ones, for locomotion, remaining in the sitting position for more than 40 hours a week. This number tends to increase as the years go by[56]. As a consequence, more than 100 thousand new PI are recorded every year[57]. Approximately 70 % of those injuries occur in the sacral regions, greater trochanter, calcaneus and lateral malleoli in the supine and lateral positions, while those acquired in the sitting position generally affect the ischial tuberosity, calcaneus and feet[58]. Nevertheless, although less common, they may also occur in the occipital region, ears, shoulders, shoulder blades and elbows[59].

These injuries differ in terms of their severity and characteristics, and tissue tolerance to pressure may be affected by nutrition[60], micro-climate, perfusion and other associated pathologies[52].

In 2018, WHO developed one of the PI classifications, mainly aimed at the medical field, featured in the eleventh edition of the International Classification of Diseases[61]. However, the classification developed by the National Pressure Injury Advisory Panel, in 2016, is currently the most used in clinical practice[62]. This classification consists of four main stages: Stage 1 – non-blanchable erythema (intact skin, but with a change in temperature, consistency or sensitivity); Stage 2 – partial thickness loss of the skin (partial loss of the epidermis and/or dermis, with a superficial injury); Stage 3 – total loss of skin thickness (total loss of skin, with exposed subcutaneous fat and necrosis); Stage 4 – total loss of tissue thickness (total loss of skin, with exposure of muscle, bone and/or tendon)[52,62].

The treatment of PI requires a multidisciplinary intervention, to determine and correct the injury causes, according to the severity and stage[58]. As such, the role of the OT is fundamental[63] in the implementation of pressure relief strategies, by recommending postural adjustments, studying support products, and properly assessing wheelchair seats and backrests[64]. Moreover, these health professionals are essential for promoting prevention of PI, through the therapeutic education of the individual, which includes the recommendation of adequate wheelchairs and seats, the use of pressure relief cushions[64], teaching frequent repositioning, monitoring the injured area[65] and training in transfer techniques, as well as promoting nutritional optimization, physical activity, weight control and smoking cessation[58]. Nevertheless, despite preventive measures, the progression of PI to a more advanced stage might require surgical intervention using fasciocutaneous or myofasciocutaneous flaps, followed by adequate post-operative care[58,66].

1.3. Relation between Positioning, Functionality, Sociodemographic Factors and Risk of PI

According to Vecin et al.[58], PI result from prolonged immobility, when soft tissues are compressed between bony prominences and external surfaces, generating tissue hypoxia which, in turn, originates ischemia and, consequently, necrosis. Therefore, the risk of injury is higher in individuals that use a wheelchair, due to prolonged periods of time in the sitting position, without pressure relief. In addition, individuals with motor and/or sensory deficits are subject to constant and sustained pressure, increasing the risk of developing PI. Conversely, in individuals without changes in mobility and sensitivity, the pressure increase in certain body areas triggers a feedback response, leading to posture adjustment[58].

According to the literature, there is a relation between positioning and PI, with a notorious 25 % reduction in the risk of developing those types of injuries, because of frequent repositioning from two to three hours, compared to the time interval of four to six hours[67]. Thus, the creation of a repositioning schedule adapted to the clinical condition of each individual is recommended, as it was found that the higher the daily frequency of repositioning, the lower the risk of developing PI[68]. Additionally, the incidence of PI also tends to reduce by using positioning systems[67], such as pressure relief wedges and pads[58]. Consequently, the wheelchair's characteristics must be adjusted to each user, including the seat's width, so that it is neither narrow nor wide, to not cause instability or postural imbalances; the depth, so that it is neither long nor causes forward sliding, nor short so that it causes an increase in pressure; and the height, to allow full support of the feet and knees at 90 degrees, maintaining stability. Furthermore, the backrest must be adjusted to increase the contact area (CA), provide uniform support and reduce pressure on body segments. Finally, the inclination of the seat must be adjusted from 0 degrees to 40/60 degrees, to relieve pressure and reduce the risk of injuries[58].

In addition to this, studies also demonstrate a relation between the individual's functionality in everyday activities and the risk of developing PI, as the reduction of independence in eating increases the risk of those injuries due to the lack of nutrition[69]. Nutrition is often associated with weight loss and loss of muscle mass, reducing the cushioning effect on bony prominences. Moreover, dehydration, in turn, weakens skin resistance, increasing predisposition to the development of PI[70]. Consequently, there is a decrease in the score of the Functional Independence Measure[71], with limited autonomy in everyday activities being a factor that increases the risk of PI[70]. This risk can be reduced by using products to support activities of daily living, such as adapted cutlery and glasses, shower chairs, grab rails, toilet risers and shoe rails[58].

Finally, there is also a relation between sociodemographic factors and the risk of PI, with advanced age[71], the male gender[71,72], the presence of an ASIA-A traumatic SCI[73], the presence of comorbidities such as obesity[74], smoking and excessive consumption of alcohol[74] associated with a high risk of developing PI.

1.4. Aim of the Study

The aim of the study was to identify the sociodemographic, clinical and functional predictive factors regarding the risk of development of PI in individuals with SCI, considering the pressure mapping measurements in the sitting position. Due to the scarcity of studies about the relation between SCI and PI, and to the existing gaps with respect to the assessment of risk factors, the aim was to contribute to increase scientific evidence about this topic.

CHAPTER II: ARTICLE

2. Article

2.1. Introduction

Spinal cord injury (SCI) is a central neurological condition[1] resulting from a permanent or temporary spinal cord injury, which causes deficits in motor, sensory and autonomic functions, in whole or in part[2].

According to the World Health Organization (WHO)[6], the worldwide prevalence is 40 to 80 cases in one million and in Portugal it is 57.8 thousand per million[7]. It is more common in the male gender[8], between the ages of 15 and 29, and over 50[7,9], in community settings and in developing countries[10].

The ASIA Impairment Scale (AIS)[12] classifies SCI in grades from A to E, considering the motor and sensory functions below the injury level[13]. SCI is also classified as traumatic or non-traumatic[11] and in paraplegia or tetraplegia[13,17]. Although there is still no fully effective treatment[47–49], early intervention is essential to prevent pressure injuries (PI)[32,33].

According to the National Pressure Injury Advisory Panel[50], PI are localized skin and soft tissue injuries, caused by pressure and/or shear on bony prominences[50].

It is noted that, one year after SCI, 59.2 % of individuals use a wheelchair for more than 40 hours a week[56]. Every year, more than one hundred thousand PI are reported[57] on the ischial tuberosity, calcaneus and feet[58], in the sitting position, making it essential to adopt pressure relief strategies, frequent repositioning, support products[64] and therapeutic education[58,64,65] to reduce the risk of PI[58,67]. There is a relation between sociodemographic factors and functionality with the risk of PI, which means advanced age[71], the male gender[71,72], the presence of obesity[74] and the reduction of independence[69] increase the risk of PI.

As such, the aim of the study was to identify the sociodemographic, clinical and functional predictive factors regarding the risk of development of PI in individuals with SCI, considering the pressure mapping measurements in the sitting position.

2.2. Methods

2.2.1. Study Design

Quantitative, observational, analytical and cross-sectional study. Structured assessment instruments were used for objective data collection[75], without intervention on the participants[76], with relations between the variables[77,78] and recording only at a single moment in time[79].

2.2.2. Participants and Eligibility Criteria

The sample possesses 79 participants, selected through a non-probability convenience sampling method[80,81]. The sample size was calculated in advance using the G*Power 3.1 software, considering a multiple linear regression test, with moderate effect size (f^2=0.2), a significance level (α) of 0.05, statistical power of 95 % and six predictive variables[82]. The result indicated the need of a minimum sample of 68 participants. Therefore, the 79 individuals included guarantee the adequate statistical power for the proposed analyses.

Volunteer individuals of both genders were included. They were capable of giving their informed, free and voluntary consent to participate, aged 18 or over, in an inpatient or outpatient setting in Centro de Reabilitação do Norte, with ambulation exclusively in a wheelchair and a diagnosis of complete and incomplete SCI. Individuals with active PI, other neuro-musculoskeletal pathologies associated with the diagnosis of SCI, able to walk and with severe postural changes were excluded.

2.3. Assessment Instruments

2.3.1. Sociodemographic Questionnaire and AIS Scale

The sociodemographic questionnaire, created by the researchers, allowed the characterization of the participants and the verification of compliance with the inclusion criteria. The questionnaire was completed by self-report, with questions designed to collect sociodemographic data – age, gender, body mass index (BMI), household, marital status, academic qualifications and professional situation –, clinical data – clinical picture, origin of the injury, injury type and time, treatment time, type of wheelchair and positioning systems – and functional – physical activity practice. The AIS scale, developed by the ASIA[13], was also included to determine the classification of the injury as complete or incomplete, in accordance with the grades from A to E and considering the level of the injury. In this way, neuromotor conditions were classified depending on severity, considering the impairment and preservation of motor and sensory functions below the injury level[16].

2.3.2. Functional Independence Measure (FIM)

The FIM was developed in 1987 in the United States of America, by Keith et al.[83] and validated in Brazil in 2000 by Riberto et al.[84], following the guidelines of WHO. It has good reproducibility and cultural equivalence[85] and, even though there is still no validation for the Portuguese population, there are studies that demonstrate favorable results of its applicability in Portugal[86,87].

The instrument makes it possible to assess the individual's motor and cognitive dependence, based on direct observation of their functional performance(84), through 18 questions grouped into six domains: "self-care", "sphincter control", "mobility", "locomotion", "communication" and "social cognition". Each one is scored from 1 (full assistance) to 7 (complete independence)(83). The total score is obtained by adding up all the items, varying from 18 points (maximum dependence) to 126 points (full independence). The higher the score, the greater the individual's independence and performance(84). In this way, scores between 18 and 60 represent high dependence, between 61 and 90 moderate dependence, between 91 and 105 mild dependence and between 106 and 126 full independence(83).

Reliability was rated as "very good" by the internal consistency measure of Cronbach's Alpha, presenting a total ranging from 0.87 to 0.98(85), making the instrument reliable(88).

2.3.3. Pressure Mapping System

The BodiTrak2 Lite® software was used. It was developed by Vista Medical Ltd. in 2020, which is designed to map pressures(89) with measurements up to 200 mmHg(90). The system is simple, with no wires and even though it does not allow data to be stored permanently, the results are immediate and can be compared with each other and saved in portable document format(89).

This system collects variables such as the CA and the dispersion index (DI)(91). The CA is defined by the total body area in contact with the surface, being measured by the number of activated sensors. The larger the area, the lower the pressure at each point, as it is better distributed. Therefore, values lower than 1000 cm^2 represent a higher risk of injury(91). In turn, the DI is expressed as a percentage and represents pressure concentration, between the minimum peak and the maximum peak, in the areas of greatest risk, being an indicative of the concentration of pressures in the ischial and sacrococcygeal regions(91). Thus, the lower the value, the lower the concentration of pressure is in the areas of greatest risk and the better its distribution will be in the offloading regions. Values higher than 50 % are indicative of a higher risk of injury(92).

2.4. Procedures

Firstly, bibliographical research was carried out, with the latest available literature, to define the topic and carry out the respective state of the art analysis.

Hereinafter, the aim, the investigation protocol, the eligibility of the sample, and the dependent (CA and DI) and independent variables (age, gender, BMI, physical activity practice, clinical picture and FIM scores) were defined for the study. For implementation, Centro de Reabilitação do Norte was selected. A request was filled in and submitted to the Ethics Committee of ULS de Gaia e Espinho, together with the developed protocol, to obtain permission to investigate. Once the ethical approval process was completed (ULSGE 40/2023), data collection began, which took place between 27/03/2023 and 09/05/2025. Throughout all the process, the ethical principles present in The European Code of Conduct for Research Integrity, developed in 2013 by the All European Academies[93] were respected.

Initially, each volunteer's consent to participate in the study was verified, by signing the Informed, Free and Voluntary Consent, according to the Declaration of Helsinki[94] and the Oviedo Convention[95]. Afterwards, the sociodemographic questionnaire and the FIM were filled in. Lastly, BodiTrak2 Lite® was used to map pressures. Each one of the participants was positioned and kept, throughout the entire assessment, in a medium-active light-alloy wheelchair, with tension-adjustable backrest, of the Invacare® Action 3 NG type and an Invacare® Flo-Tech Contour Cushion, as a positioning system. The position adopted was that of static sitting, in which they remain for seven minutes, to calibrate the measurement system[96]. That calibration allowed the software to compensate for natural changes in sensors over time, as well as pressure variations and physiological changes of the participants, ensuring the accuracy of the results[91].

After the calibration period, the collection was carried out in the same position, recording the data at times of 30, 60 and 120 seconds, with three repetitions, allowing the final mean of the values to be calculated[90].

Finally, a statistical analysis of the collected data was carried out, followed by the interpretation and discussion of the results, with the subsequent conclusion of the study.

2.5. Statistical Analysis

The data was inserted manually in Microsoft Office Excel®, and the document was imported to version 29 of the Statistical Package for the Social Sciences® software, where it was statistically analyzed, with a α of 0.05.

The variables were coded, followed by their descriptive analysis, for the sociodemographic, clinical and functional characterization of the sample, considering the scores of the applied assessment instruments. In this way, absolute (n) and relative (%) frequency tables were used to describe nominal and ordinal qualitative variables, and measures of central tendency and dispersion, namely the calculation of means (M), standard deviations (SD), minimums and maximums for continuous and discrete quantitative variables[97,98].

Subsequently, the dependent variables were modeled, based on the independent ones, the assumptions of the multiple linear regression were assessed, by graphically inspecting the residuals and the adequacy of the model by plotting expected/predicted and observed/actual values, as well as the adjusted R^2 [98], for the CA (Appendix 1, Figure 1) and the DI (Appendix 1, Figure 2) variables. Consequently, there was no clear violation of the assumptions for applying multiple linear regression for both dependent variables. The presence of a linear relation between the variables, and the absence of evident patterns and outliers in the residuals graph were observed, as well as no deviations from the straight line in the P-P plot of standardized residuals. As such, two multiple linear regressions were carried out, to predict the value of each of the dependent/response variables, according to the independent/predictor variables under study[98]. However, since linear regression can only be applied to numerical variables, dummy variables were created, by converting categorical into numerical, with values of 0 and 1. Therefore, in each categorical variable, one of the categories was omitted, being considered the reference category, while the others were included in the model, to make comparisons[99]. According to the literature, the regression coefficient is represented by the letter B and is expressed in the same unit as the dependent variable, indicating the effect that a one-unit increase in the independent variable has on the dependent one, keeping the others constant. As such, a positive B value indicates an increase in the dependent variable, while a negative value shows a decrease. Lastly, the "adjusted R^2" is measured as a percentage and represents the quality of the fit of the regression model, adjusted to the number of variables being analyzed. As such, it indicates the proportion of the variability of the dependent variable that is explained by the model. Therefore, the closer the value is to 1, the better the model fits and explains the observed data[98].

2.6. Results

2.6.1. Sociodemographic Characterization of the Sample

By analyzing the sociodemographic data in Table 1, it can be observed that the sample presents a mean of 58.13 (15.40) years old, with a variation between 18 and 80 years old. It presents a predominance of participants of the male gender (74.70 %), married or in a de facto union (65.80 %) and that live with someone else (84.80 %). The mean of academic qualifications is 7.95 (3.98) years, with 3 years as the minimum and 19 the maximum, also emphasizing a higher prevalence of professionally inactive individuals (87.30 %). Furthermore, it is noteworthy that most of the individuals have normal BMI parameters (60.80 %), ranging from 17.30 kg/m^2 to 30.50 kg/m^2, with a mean of 24,40 (3,03) kg/m^2.

Table 1: Sociodemographic characterization of the sample.

Sociodemographic Variables		n (%)	M (SD)
Age (years)			58.13 (15.40)
Gender	Male	59 (74.70)	
	Female	20 (25.30)	
BMI (kg/m²)	Underweight	1 (1.30)	24.40 (3.03)
	Normal Weight	48 (60.80)	
	Overweight	28 (35.40)	
	Obesity	2 (2.50)	
Household	Living alone	12 (15.20)	
	Living with someone else	67 (84.80)	
Marital Status	Single	15 (19.00)	
	Married or in a de facto union	52 (65.80)	
	Divorced	4 (5.10)	
	Widowed	8 (10.10)	
Academic Qualifications (years)			7.95 (3.98)
Professional Situation	Active	10 (12.70)	
	Inactive	69 (87.30)	

(n – absolute frequency; % – relative frequency; M – mean; SD– standard deviation; BMI – Body Mass Index)

2.6.2. Clinical Characterization of the Sample

By observing the clinical data collected in Table 2, the sample has a predominance of participants with the clinical picture of tetraplegia (53.20 %) and incomplete injury (77.20 %), according to ASIA's classification. Besides, there is a higher prevalence of individuals with traumatic SCI (55.70 %), mostly due to falls (31.60 %) and road accidents (19.00 %). It is also possible to note that the predominant level of injury is between the C1 and C7 vertebrae (53.20 %), the SCI time ranges from 30 to 293 days, with a mean of 111.96 (60.24) days and treatment time ranges from 0 to 90 days, presenting a mean of 37.58 (25.27) days. Moreover, most of the participants have a standard wheelchair (81.00 %) with a cushion (94.90 %), as a positioning system.

Table 2: Clinical characterization of the sample.

Clinical Variables		n (%)	M (SD)
Clinical Picture	Paraplegia	37 (46.80)	
	Tetraplegia	42 (53.20)	
ASIA's Classification	Complete (A)	18 (22.80)	
	Incomplete (B, C, D)	61 (77.20)	
SCI Type	Traumatic	44 (55.70)	
	Non-traumatic	35 (44.30)	

Table 2: Cont.

Clinical Variables		n (%)	M (SD)
SCI Level	C1 – C7	42 (53.20)	
	T1 – T9	16 (20.30)	
	T10 – T12	13 (16.50)	
	L1 – L5	8 (10.10)	
Time of SCI (days)			111.96 (60.24)
Treatment Time (days)			37.58 (25.27)
Wheelchair	Standard	64 (81.00)	
	Comfort/Positioning	7 (8.90)	
	Medium-Active	3 (3.80)	
	Active	5 (6.30)	
Positioning	With cushion	75 (94.90)	
	Without cushion	4 (5.10)	

(n – absolute frequency; % – relative frequency; M – mean; SD – standard deviation).

2.6.3. Functional Characterization of the Sample

According to the data of the functional profile presented in Table 3, it can be observed that most of the sample has a moderate dependence profile (54.40 %), with a mean of FIM scores of 78.58 (18.42) points, with a recorded minimum score of 47 points and a maximum of 116 points. Besides, it is possible to verify that most of the participants do not practice physical activity (79.70 %). Lastly, by using the BodiTrack2 Lite® software it can also be observed that the CA presents a mean of 1608.58 (116.32) cm², with a minimum of 1286.56 cm² and a maximum of 1857.33 cm² and the mean of the DI is of 48.01 (6.34) %, represented by a minimum of 34.11 % and a maximum of 61.89 %.

Table 3: Functional characterization of the sample.

Functional Variables		n (%)	M (SD)
Physical Activity	Practice	16 (20.30)	
	Do not practice	63 (79.70)	
FIM	High Dependence	15 (19.00)	78.58 (18.42)
	Moderate Dependence	43 (54.40)	
	Mild Dependence	14 (17.70)	
	Full Independence	7 (8.90)	
BodiTrack2 Lite	CA		1608.58 (116.32)
	DI		48.01 (6.34)

(n – absolute frequency; % – relative frequency; M – mean; SD– standard deviation; FIM – "Functional Independence Measure" scale; CA – contact area; DI – dispersion index).

2.6.4. Multiple Linear Regression to predict the CA

Through the application of the statistical test presented in Table 4, it can be concluded that the model explains 32 % of CA's variability (adjusted R^2=0.32) and the statistically significant variables are age (B=-2.22; p=0.004) and BMI (B=20.74; p<0.001). Given the regression coefficients, for each additional year of life, the CA decreases on average 2.22 cm^2 and the increase of 1kg/m^2 in the BMI is associated with the increase of the CA, on average 20.74 cm^2. Although it is not significant, the "tetraplegia" variable presented a borderline significant value (B=-49.48; p=0.053), suggesting that, in comparison with paraplegia, tetraplegia is associated with a CA decrease of 49.48 cm^2. It can also be seen that, in addition to not being significant, the male gender (B=-47.97; p=0.062) and the FIM (B=-1.20; p=0.085) reveal a negative trend, with men presenting, on average, less 47.97 cm^2 of CA, compared to women, and, with each extra point in the FIM, there is an average reduction of 1.20 cm^2 in CA. Nevertheless, physical activity (B=2.13; p=0.940) did not prove to have any relevance in the CA's model.

2.6.5. Multiple Linear Regression to predict the DI

Based on statistical analysis, in Table 4 it can also be seen that the model explains 35% of the DI's variability (adjusted R^2 =0.35) and the statistically significant variables are the male gender (B=5.69; p<0.001), the BMI (B=-0.66; p=0.002), physical activity (B=3.25; p=0.035) and the FIM (B=0.09; p=0.014). Thus, taking into consideration the regression coefficients, men show, on average, more 5.69% of DI, compared to women; the increase of 1kg/m^2 of BMI decreases the DI by 0.66%; people who practice physical activity have a higher DI, on average 3.25%, compared to those who do not practice anything, and with each additional point in the FIM, the DI increases 0.09%. Although it is not significant, the "age" variable presented a borderline significant value (B=0.08; p=0.058) and a positive trend, suggesting that, for each additional year of life, the DI increases 0.08%. Nevertheless, tetraplegia (B=2.10; p=0.121), when compared to paraplegia did not prove to have any relevance in the DI's model.

Table 4: Multiple linear regression to predict the CA and the DI.

	Contact Area			Dispersion Index		
Variables	B	p-value	Adjusted R^2	B	p-value	Adjusted R^2
Constant	1387.32	<0.001		46.59	<0.001	
Age	-2.22	0004		0.08	0058	
Male Gender Reference: Female	-47.97	0062	0.32	5.69	<0.001	0.35
BMI	20.74	<0.001		-0.66	0002	
Physical Activity Reference: Do not practice	2.13	0940		3.25	0035	

Table 4: Cont.

	Contact Area			Dispersion Index		
Variables	**B**	**p-value**	**Adjusted R^2**	**B**	**p-value**	**Adjusted R^2**
Tetraplegia Reference: Paraplegia	-49.48	0053	0.32	2.10	0121	0.35
FIM	-1.20	0085		0.09	0014	

(B – regression coefficient; BMI - Body Mass Index; FIM - "Functional Independence Measure" scale).

2.7. Discussion

2.7.1. Evidence of the predictive factors of the risk of PI in individuals with SCI

This study aimed to identify the sociodemographic, clinical and functional predictive factors regarding the risk of development of PI in individuals with SCI, considering the pressure mapping measurements in the sitting position.

Based on the data presented, as the age increases, there is a decrease of the CA and an increase of the DI. According to Vecin et al.(58), this result is reflected in an increased risk of developing PI, since the body area is in contact with a smaller surface area and the concentration of pressure is located mainly in the ischial and sacrococcygeal regions. Corroborating these results, García-Rudolph et al.(71) defend that advanced age is a predictor of the risk of developing PI, because the older someone is, the greater the risk of injury. Therefore, aging usually causes sarcopenia and postural changes, reducing the body's CA with the surface and decreasing the cushioning effect on bony prominences, due to a reduction in the volume of muscle mass(100). Additionally, aging is associated with a decreased collagen and tissue perfusion, which reduces skin elasticity, favoring pressures more concentrated in the ischial and sacrococcygeal regions(101). Thus, advanced age, associated with the low level of education observed in this study's sample, undermines health literacy, which can make it difficult to adopt effective strategies to prevent PI(71).

Regarding gender, the data shows that the male gender, compared to the female gender, presents a smaller CA and a higher DI, which represents an increased risk of PI. These results can be explained due to the fact that men have, on average, less fat mass in the gluteal region, in relation to women(102), which might result in a smaller CA, especially in the sitting position and a higher concentration of pressure in the ischial and sacrococcygeal regions. Therefore, the difference between genders in terms of the distribution of adipose tissue through the distinct body areas, is reflected in an increase of the risk of PI in the male gender(102). Furthermore, according to the literature, men tend to have less skin elasticity, when compared to women(103), a more acidic pH(104) and lower capillary density, with lower baseline perfusion of the skin capillaries and lower blood flow(105). According to the authors, these factors decrease skin resistance, making tissues more vulnerable to pressure and with a lower tolerance to friction, leading to a difficulty in distributing pressure over the surface and a higher concentration in the higher risk areas, making it more likely to develop PI. In the same line of thought, the study conducted by Balasuberamaniam et al.[72] shows that the sociodemographic factors, namely the male gender, is associated with an increase of the risk of developing PI. Similarly, García-Rudolph et al.[71] also present this variable as a risk factor.

With respect to the BMI, this study revealed that an increase in this variable triggers an increase of the CA and a decrease of the DI, with a reduction of the risk of developing PI. Despite these results, within the literature, there is a controversy among authors. Corroborating the results of this study, Alipoor et al.[106] and García-Rudolph et al.[71] stated that the increase of the BMI is associated with a reduced risk of PI, while the decrease is related to an increased risk, since the individuals with a higher BMI generally have more adipose tissue, which increases the CA. As such, the existing fat mass also acts as a cushion, helping with pressure relief[107]. Conversely, a recent study from 2024, published by Huang et al.[108], shows data proving that the higher the BMI, the higher the probability of developing a PI. These authors relate the risk of PI to obesity, since this comorbidity increases the risk of diabetes and this, in turn, increases the risk of development of PI. Nevertheless, the highest percentage of participants of that study belongs to the population with obesity and the sample of this study is mostly made up of individuals within the normal parameters of the BMI, so it was not possible to predict the specific impact of obesity on the development of these injuries. Nonetheless, it is known that the metabolic syndrome in SCI, such as the presence of obesity, hypertension, type 2 diabetes mellitus and low high-density lipoprotein cholesterol values, is a factor that increases the likelihood of developing PI, due to decreased blood circulation, decreased cell regeneration capacity, increased chronic low-grade inflammation and decreased mobility[74]. As such, the importance of taking these data into account in the clinical approach of individuals with obesity is highlighted.

As for the clinical picture, although statistical evidence was not found to affirm the presence of predictive effects on the DI, the data presented reveals that tetraplegia, compared to paraplegia, shows a smaller CA and, consequently, a higher risk of developing PI. In line with these results, the study made by Valent et al.[109] shows that, in tetraplegia, there is a decreased muscle tone and postural control, more markedly than in paraplegia, leading to asymmetrical postures that reduce the CA with the surface and increase the risk of developing a PI. In addition, Balasuberamaniam et al.[72] defend that longer hospital stays are a predictive factor for the risk of developing PI. Thus, since individuals with tetraplegia usually present longer hospital stays compared to those with paraplegia, they might be subject to a greater risk of PI[110]. Moreover, the predominance of traumatic SCI in this study, combined with the high average injury time and the low treatment time, might have contributed to the adoption of incorrect postures in the long term.

With regard to the FIM, the increase in the score of this scale, which indicates a higher independence and functionality, predicts a decrease of the CA and an increase of the DI, being associated with an increase of the risk of PI. However, these data do not match the literature. According to García-Rudolph et al.[71], a lower FIM score, reflected in less independence, has a high predictive power of PI, so the greater the independence, the lower the risk of injuries is. This divergence can be explained by the fact that the more functional individuals, with higher FIM scores, have a greater postural control, which might result in a more active posture[111]. This reduces the CA with the surface and contributes for fixing pressure in critical areas, increasing the risk of injuries. Additionally, more functional individuals tend to have a lower BMI[112], which, as mentioned before, is a predictive factor for the risk of developing PI, as demonstrated by Alipoor et al.[106] and García-Rudolph et al.[71]. Besides, in addition to increased mobility, the more functional individuals also spend a long time in the sitting position, which increases the risk of developing PI[72]. Lastly, the practice of physical activity is also a factor that increases functional independence, which can contribute to an increase in the risk of PI[113]. Although this study did not demonstrate statistically significant predictive effects of physical activity in the CA, it was observed that its practice is associated with an increase of the DI. As such, there is an increased risk of developing a PI. According to Pooryamanesh et al.[114], individuals who practice physical activity present fewer pain complaints and can make more effective postural adjustments, adopting more dynamic and vertical postures in the sitting position. However, these factors may contribute to a repeated and sustained concentration of pressure in the higher risk areas, compromising blood flow to the skin, which is essential for tissue viability[115]. Additionally, increased movement intensifies the shear forces caused by clothing, which might compromise the integrity of the skin and underlying tissues, safeguarding the use of appropriate positioning systems[116], as in the case of pressure relief cushions used in most of the participants of this study. Nevertheless, the fact that the sample of this study mainly consists of physically and professionally inactive individuals, might have influenced the results.

2.7.2. Limitations and Suggestions for Future Studies

The study presented some limitations, including the sample selection method being non-probabilistic for convenience, which limited the generalization of the results for the population. In addition, the fact that the study is cross-sectional is also considered a limitation, since the assessment occurred only at a single moment in time, so the lack of longitudinal data made it impossible to observe the evolution of the risk of developing a PI over time.

In this way, to address the above-mentioned limitations, it is suggested that future studies about this topic be longitudinal, so the evolution of the risk of developing a PI over time can be observed. Additionally, it is proposed to carry out studies on the impact of factors such as mental health and quality of life of individuals with SCI in the development of PI, as well as experimental studies to assess the effectiveness of interventions to reduce the risk of these injuries.

2.7.3. Strengths of the Study

This study revealed several strengths. In addition to being an inexpensive type of study and one that can be carried out quickly, it presents high clinical relevance, addressing an innovative and highly pertinent topic for health professionals, including occupational therapists. In this way, it is an extremely important issue, since aspects related to the prevention of PI in individuals with SCI are not taken into consideration as often as is desirable in clinical practice. Furthermore, the fact that data collection was done in-person, allowed direct contact with the participants, which facilitated the exchange of information and the verification of the answers' veracity. Moreover, this study considers multiple predictive factors, providing a comprehensive overview of the risk of developing PI. Finally, the use of assessment instruments that are recognized in the scientific community, validated for the population with SCI and with a "very good" Cronbach's Alpha, was another strength, increasing the results' reliability.

2.8. Conclusion

2.8.1. Summary of Results and Final Considerations

The study contributed with a positive impact to the scientific community, increasing evidence on this topic. In addition, it highlighted the importance of awareness among health professionals, including occupational therapists, regarding the presence of the sociodemographic and functional variables predictive of PI, to prevent the development of those injuries in individuals with SCI.

The multiple linear regression model explained 32 % of CA's variability (adjusted R^2 =0.32) and 35 % of the DI (adjusted R^2 =0.35), with age (B=-2.22; p=0.004) and the BMI (B=20.74; p<0.001) demonstrating that they are significant predictors of the CA, while physical activity (B=2.13; p=0.940) was not a significant predictor. It was also seen that there is a statistically significant influence of gender (B=5.69; p<0.001), of the BMI (B=-0.66; p=0.002), of physical activity (B=3.25; p=0.035) and of the FIM (B=0.09; p=0.014) on the DI, and the clinical picture (B=2.10; p=0.121) was not a significant predictor of the DI.

In sum, the sociodemographic and functional variables proved to be predictors of the risk of developing PI, considering the CA and the DI in individuals with SCI in the sitting position, unlike the clinical variables that did not show statistically significant effects. As such, there is an emphasis on the need of a multidisciplinary approach and on the importance of awareness among health professionals regarding the presence of these variables in people with SCI, to prevent PI.

CHAPTER III: CLINICAL FINDINGS

3. Summary of Clinical Findings

a) As the years of SCI increase, the worldwide prevalence of wheelchair use tends to expand, increasing the negative impact on the autonomy, independence and functionality of individuals with SCI, as well as the risk of developing PI;

b) The multiple linear regression model for the DI has a slightly better fit than for the CA;

c) Older individuals have a higher risk of suffering PI, due to a decrease in the CA, even though there are no predictive factors on the DI;

d) The increase of the BMI increases the CA and decreases the DI and the risk of PI, considering a sample that consists mostly of individuals with a BMI average within the normal parameters;

e) The clinical variables do not have predictive effects on the CA, or the DI;

f) The male gender has a higher DI, compared to the female, with a higher risk of PI. However, it does not have predictive effects on the CA;

g) Although it does not have predictive effects on the CA, the increase of the FIM score, associated with higher functional independence, predicts an increase in the DI, increasing the risk of PI. As such, independent individuals need as much supervision and prevention as the dependent ones;

h) Even though the practice of physical activity does not have predictive effects on the CA, it increases the DI and, consequently, the risk of developing PI. The investigation of this variable in more detail is recommended, through the assessment of the number of hours and the type of physical activity that is practiced;

i) There is an emphasis on the need of a multidisciplinary approach and on awareness among health professionals regarding the presence of the predictive variables for the risk of PI, to prevent PI in SCI;

j) There is a relation between sociodemographic and functional factors and the risk of developing PI, with the intervention of the OT being fundamental to the implementation of pressure relief strategies, support products and therapeutic education.

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5. Appendices

5.1. Appendix 1: Graphs of the Assessment of Multiple Linear Regression Assumptions

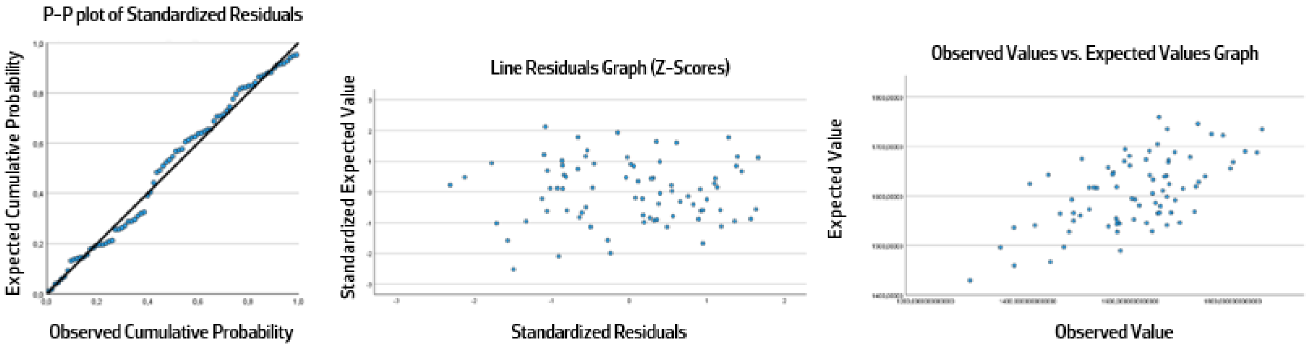

Figure 1: Assessment of the assumptions for the application of multiple linear regression, for the CA variable.

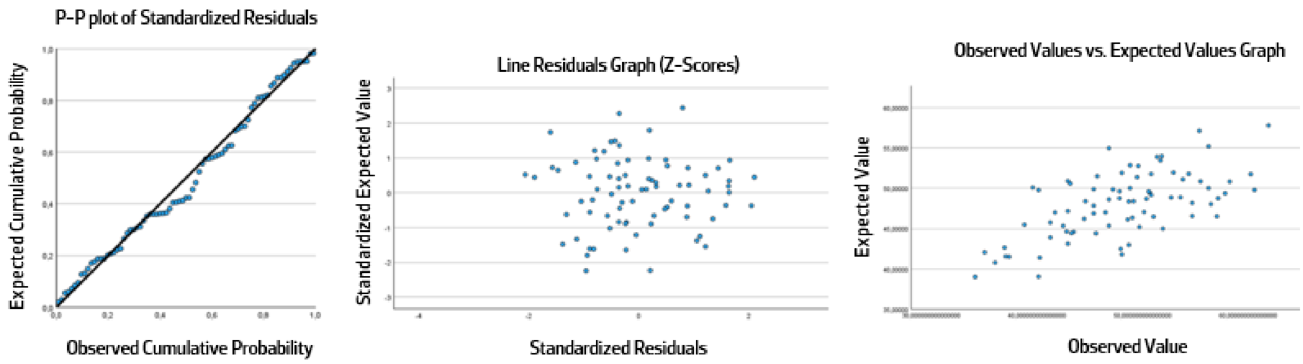

Figure 2: Assessment of the assumptions for the application of multiple linear regression, for the DI variable.

5.2. Appendix 2: Article Submission – Spinal Cord

Outlook

SC-2025-0228 Approved MS Received

De spinalcord@springernature.com <spinalcord@springernature.com>
Data qua, 25/06/2025 20:15
Para costainesm@outlook.pt <costainesm@outlook.pt>

Dear Ms Costa,

On 25th Jun 25, the manuscript entitled "Predictive Factors for Pressure Injury Risk in Individuals with Spinal Cord Injury " by Inês Costa, Ângela Fernandes, Carlos Almeida, Sara Sousa, Beatriz Bastos , Laura Oliveira, Raquel Pereira, Carina Coelho, Marta Marques, Nuno Machado, Maria Cunha, Fátima Gandarez, Margarida Rodrigues, and Ana Silva was submitted to Spinal Cord.

The manuscript has been assigned the Paper #: SC-2025-0228.

Sincerely,

Dr Michael Fehlings
Editor
Spinal Cord
spinalcord@springernature.com

Figure 1: Confirmation of submission.

ESCOLA SUPERIOR DE SAÚDE

P.PORTO

M

MASTER'S DEGREE

OCCUPATIONAL THERAPY – AREA OF SPECIALIZATION IN PHYSICAL REHABILITATION