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Faculteit Revalidatiewetenschappen

master in de revalidatiewetenschappen en de kinesitherapie

Masterthesis

Multi-site pain in individuals with morbid obesity: prevalence and associations with functional tests and performance

Griet Hertogs
Vincent Schildermans

Scriptie ingediend tot het behalen van de graad van master in de revalidatiewetenschappen en de kinesitherapie, afstudeerrichting revalidatiewetenschappen en kinesitherapie bij musculoskeletale aandoeningen

PROMOTOR :
Prof. dr. Kenneth VERBOVEN

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Acknowledgments

This observational, cross-sectional study was conducted and authored under the supervision and collaboration of Prof. dr. Kenneth Verboven, our promotor. We would like to extend our sincere gratitude for his invaluable support and facilitation of this research endeavor. Furthermore, we would like to express our appreciation for his constructive feedback, guidance, and suggestions. Additionally, we acknowledge the contributions of the first-year master's students from Prof. dr. Kenneth Verboven's research team for their assistance in participant recruitment and subsequent assessments. Moreover, we extend our gratitude to Dr. Wim Bouckaert and his team for their assistance and support during the recruitment process.

We are grateful to our participants for their unwavering dedication and flexibility throughout this study. All measurements were conducted at the Obesity Center of Ziekenhuis Oost-Limburg (ZOL) in Genk. The provision of this infrastructure and its accompanying facilities was instrumental in successfully executing this study.

Bree 3960, 2024 G.H.

Pelt 3910, 2024 V.S.

Context

This master's thesis is situated within internal diseases and musculoskeletal pain research domains. While extensive knowledge exists regarding pain (and pain-related psychological factors) and disability in the population without obesity, there is, to the author's knowledge, a lack of literature about pain and performance on functional tests in individuals with obesity. Therefore, this thesis aims to investigate the prevalence of multi-site MSP and its manifestation in individuals with morbid obesity undergoing bariatric surgery. Additionally, this thesis examines the relationship between performance on functional tests and multi-site MSP. Furthermore, the association between multi-site MSP and activities of daily living is assessed. By investigating these factors, a more profound comprehension of how multi-site MSP affects physical function in individuals with obesity can be achieved. This will contribute to the development of more effective treatment strategies and interventions. Multi-site MSP will be defined as pain simultaneously experienced in more than one anatomical location (Brady et al., 2015; Butera et al., 2019).

This observational, cross-sectional study is part of the ongoing research project led by Prof. dr. Kenneth Verboven and Prof. Thomas Matheve, entitled the "Sarcopenic Obesity and Musculoskeletal Pain (SOMP) study." All measurements are carried out at the Obesity Center of Ziekenhuis Oost-Limburg (ZOL) in Genk. The SOMP study constitutes a longitudinal, observational investigation wherein male and female adults with morbid obesity are being assessed for both pre- and post-bariatric surgery.

Griet Hertogs and Vincent Schildermans, second-year master's students of Rehabilitation Sciences and Physiotherapy, formulated the research question in consultation with promotor Prof. dr. Kenneth Verboven. Griet primarily focused on contextualizing the importance of the research, methodology, formatting, and data visualization, while Vincent took principal responsibility for identifying gaps in existing literature and conducting statistical analysis. Subsequently, both students developed the introduction and method section, analyzed the results, and formulated a comprehensive discussion and conclusion.

Abstract

Background: Musculoskeletal pain (MSP) is common in individuals with obesity. Obesity isan important risk factor for multi-site MSP, which is pain in more than one anatomical location, thereby potentially impacting physical function and well-being. However, the prevalence of multi-site MSP and its relationship with performance on functional tests is not well-documented in individuals with morbid obesity.

Objectives: This observational, cross-sectional study aims to examine the prevalence and presentation of multi-site MSP and its relationship with functional performance in individuals with morbid obesity.

Methods: Twenty-five adults with a mean BMI of 41.5 ± 4.8 kg/m², an average age of 44 ± 14 years, among whom 10 (40%) were male, were assessed. Evaluations included anthropometric measurements, body composition analysis, isometric muscle strength evaluation, and functional assessment using the Timed Up and Go (TUG) and Short Physical Performance Battery (SPPB). The Multi-Site Pain Questionnaire assessed pain symptoms over the past week and the impact on daily life was assessed using the Pain Disability Index (PDI).

Results: Among the participants, 8% reported pain at two sites, 12% at three sites, and 36% at four or more sites. Only 44% (n = 11) had no or single-site pain. The lower back was the most common pain site (52%). A significant positive correlation was found between the number of pain sites with the SPPB walking speed test ($\rho = 0.60$; $p = .002$). Multi-site MSP was related with lower body weight ($p = .015$) and waist circumference ($p = .012$). Moreover, a higher pain intensity ($\rho = 0.50$; $p = .011$) was found in individuals with multiple pain sites.

Conclusion: People with morbid obesity exhibit a high prevalence of multi-site MSP. Factors associated with multi-site pain include lower body weight and waist circumference, higher bilateral pain incidence, and more intense pain over the past seven days. Finally, the number of painful sites is positively related to walking speed.

Keywords: Morbid obesity; adults; multi-site musculoskeletal pain; functional tests

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1. Introduction

The World Health Organisation (WHO) describes obesity as an unusual or extreme buildup of body fat, posing significant risks to one's health. In 2022, a total of 890 million adults worldwide were classified as having obesity (Body Mass Index (BMI) ≥ 30 kg/m²), accounting for 16% of the global population (World Health Organization: WHO, 2024). In Belgium, overweight affects 49.3% of adults (BMI ≥ 25 kg/m²), and 15.9% of the population suffers from obesity (Cijfers, n.d.). In a recent review, Lin and Li (2021) identified food intake and energy balance, family history and lifestyle, micro environment and gut microbiome, genetics, and epigenetic modification as primary contributors to obesity. Morbid obesity, defined as a BMI ≥ 40 kg/m² or a BMI ≥ 35 kg/m² in combination with obesity-associated comorbidities (Professional, n.d.), is related to various health complications, including diabetes mellitus, cardiovascular diseases, certain types of cancer, sleep apnea, asthma, musculoskeletal disorders and psychological issues such as anxiety and depression (Fortunato et al., 2021; Yumuk et al., 2015). These complications exert a sizeable economic impact (Hecker et al., 2022), with combined direct medical and indirect non-medical costs amounting to an annual sum of 4.5 billion euro (Gorasso et al., 2022). Therefore, addressing primary and secondary prevention with multidisciplinary treatment approaches is essential, considering individuals' phenotype, functional status, and perspectives to specifically target cardiometabolic risk and physical fitness (Verboven & Hansen, 2020).

Contiguous to obesity-related cardiovascular and metabolic diseases, research indicates a remarkably high prevalence of chronic musculoskeletal pain (MSP) among individuals with obesity (Okifuji & Hare, 2015). Chronic pain is defined as persistent or recurring pain lasting more than three months (Treede et al., 2019). A recent cross-sectional study showed an overall chronic MSP prevalence of 90.3% in patients with morbid obesity (Rosa et al., 2021). Of interest, a considerable portion of individuals with obesity experiencing MSP report pain in various body regions, hereafter referred to as multi-site MSP (Kamaleri et al., 2008; MacLellan et al., 2017). This thesis will describe multi-site MSP as pain simultaneously experienced in more than one anatomical location (Brady et al., 2015; Butera et al., 2019). In a study conducted by Mendonça, Noll, Rodrigues et al. (2020), it was revealed that 53.3% of the 150 participants diagnosed with severe to morbid obesity experienced pain across four or more body regions. The areas exhibiting the highest prevalence and severity of MSP included the ankles/feet, lower and upper back, and knees, all of which are regions susceptible to significant weight-bearing and, therefore, have to withstand the most mechanical loads (Chin et al., 2019; Mendonça, Noll, De Carvalho Santos et al., 2020). Additionally, a cross-sectional study by Costa et al. (2020) indicated that MSP extends to non-weight-bearing sites among individuals with obesity. This observation suggests the potential involvement of chronic low-grade inflammation alongside mechanical mechanisms (Chin et al., 2019; Costa et al., 2020) with the secretion of pro-inflammatory cytokines such as IL-6, TNF-α, resistin, leptin, adiponectin, and plasminogen activator inhibitor 1 (Ion et al., 2023; Khanna et al., 2022). Among these factors, TNF-α, leptin, ghrelin, and galanin might have a potential implication on MSP in people with obesity (Chin et al., 2019). Moreover, central adiposity, particularly visceral fat, is associated with chronic, low-grade inflammation and activation of the immune system, making it more relevant to health outcomes (Ion et al., 2023). As such, MSP is also related to fat distribution, where central adiposity (abdominal obesity, assessed by waist circumference or waist-hip ratio) is strongly associated with both lower extremity pain (Peiris et al., 2021) and upper extremity pain (Vehmas et al., 2013).

Given the high prevalence of chronic MSP among individuals with obesity, it is reasonable that pain and pain-related psychological factors (such as fear of movement) could impact physical performance, as evidenced in chronic pain cohorts (Matheve et al., 2022; Zale et al.,2013). Recent research shows that individuals with chronic low back pain demonstrate decreased performance on physical tasks when expecting pain (Matheve et al., 2022). To understand the relationship between body composition and physical performance, it is essential to consider both pain and pain-related psychological factors. Additionally, multi-site MSP is associated with reduced physical function and overall disability in individuals aged 65 and older (Butera et al., 2019). Despite the high prevalence of multi-site MSP, the current literature needs to gain knowledge regarding the performance on functional tests in individuals with morbid obesity. Hence, this thesis aims to investigate the impact of multi-site MSP on functional test performance among individuals with severe obesity undergoing bariatric surgery. Furthermore, the study aims to assess the prevalence of multi-site MSP and identify the predominant pain sites.

2. Methods

2.1. Study design

The Sarcopenic Obesity and Musculoskeletal Pain (SOMP) study is being conducted at the Obesity Center of Ziekenhuis Oost-Limburg (ZOL) in Genk, Belgium. SOMP is comprised of a longitudinal, observational study. Male and female adults with morbid obesity are being evaluated before and after bariatric surgery. This research started in March 2023 after the study was approved by the Committee on Medical Ethics of the University of Hasselt and ZOL on 21/02/2023 with reference code Z2022122. The current thesis is part of the SOMP study, focusing solely on the cross-sectional part of pre-operative assessments of bariatric patients with morbid obesity.

2.2. Participants

This thesis involves 25 participants (refer to inclusion and exclusion criteria) who were recruited under the supervision of an abdominal surgeon at the Obesity Center of ZOL in Genk. Adults eligible for the study were informed about the research by the surgeon. Following a thorough explanation by the local researcher, informed consent was provided by all interested individuals. The inclusion criteria were: (1) adults between 18 and 65 years old; (2) BMI ≥ 40kg/m² or BMI ≥ 35kg/m² in combination with obesity-related comorbidities; (3) proficiency in the Dutch language; and (4) undergoing bariatric surgery. The exclusion criteria were: (1) the presence of any form of oncologic disease; (2) pregnancy; (3) recent acute myocardial infarction within the last six months; (4) the presence of a pacemaker or Implantable Cardioverter Defibrillator (ICD); and (5) inability to walk six meters without the assistance of third parties. To be able to analyze the data from a specific participant, they must have filled out the entire questionnaire, and all measurements must be available.

2.3. Procedure

During their final consultation at the Obesity Center before bariatric surgery, all participating adults were assessed. This last pre-operative consultation focused on clinical assessment, anthropometric measurements, body composition analysis, isometric muscle strength evaluation, and physical performance assessment. The participants were digitally provided with the questionnaires through Qualtrics software. Anthropometric measurements were conducted using a stadiometer, digital-balanced weighing scale, and tape measure. Body composition was analyzed using Bioelectrical Impedance Analysis (BIA), isometric muscle strength was measured using Microfet for lower extremities and Jamar Hand Dynamometer for upper extremities, and physical performance was assessed using the Timed Up and Go (TUG) and the Short Physical Performance Battery (SPPB).

2.3.1. Measurements and tests

2.3.1.1. Anthropometric measurements

The participants' height is determined to the nearest 0.1cm (without footwear) using a stadiometer. A digital-balanced weighing scale determines body weight to the nearest 0.1kg(minimal clothing). BMI (kg/m^2) was calculated accordingly. Abdominal, hip, and calf circumferences were determined to the nearest 0.1cm (exposed skin, standing position) using a flexible (non-elastic) tape measure (NIHR Southampton Biomedical Research Centre, n.d.). Abdominal circumference was assessed by measuring the circumference between the highest point of the patient's crista iliaca and the lowest point of the most caudal rib. Hip circumference was determined at its widest point (between the trochanter major and the horizontal gluteal fold). Waist-to-hip ratio was calculated accordingly. Each measurement was performed three times, and subsequently, the mean of these measurements was calculated.

2.3.1.2. Body composition

The participant lies on their back with their hands and feet exposed. Two positive and negative electrodes are placed on their right hand and foot, respectively, to connect with the Bodystat (Bodystat 1500, Bodystat Ltd.). Body fat percentage (%), absolute fat mass (kg), lean body mass (kg), water content (%), impedance (Ohm), and basal metabolism (kcal) were estimated.

2.3.1.3. Isometric muscle strength

The maximum isometric muscle strength of the quadriceps and the hamstrings were assessed using a standardized protocol employing Microfet. To measure quadriceps strength, the Microfet was placed at the anterior border of the tibia, 2cm above the malleoli, and kept in place with a traction band by the assessor while the participant was seated. Similarly, for the hamstrings, the Microfet was positioned at the posterior border of the tibia, 2cm above the malleoli, and secured with a traction band by the assessor while the participant was seated. Three measurements were performed, and the highest peak force was documented in Newtons (N) (Sentanin et al., 2021).

Maximum isometric grip strength was assessed using a standardized protocol employing a Jamar Hand Dynamometer. The dynamometer was positioned at the level of the proximal interphalangeal joint, with the arms against the body and elbows flexed at 90° while the participant was seated. Three measurements were performed, and the highest peak force was documented in kilograms (kg) (Mutalib et al., 2022).

2.3.1.4. Physical Performance

Timed Up and Go (TUG) assesses the duration (seconds) it takes for a subject to stand up from a chair (potentially with the use of the chair's armrest), walk a distance of 3 meters, pivot, return to the chair, and resume sitting, all without the assistance of third parties (Meetinstrumenten in de zorg, 2022).

The Short Physical Performance Battery (SPPB) is a functional test battery that consists of three parts. Firstly, it assesses balance in a standing position. Secondly, it measures walking speed over a distance of four meters, and lastly, it estimates muscle strength using the Timed Chair Stand test (TCS). The balance component consists of three positions (bipedal stance, semi-tandem stance, and tandem stance), which participants must maintain for ten seconds.The bipedal and semi-tandem stances are worth one point. The tandem stance is worth 2 points. For the walking speed test, participants are instructed to walk four meters at a regular pace. The researcher records the best attempt of the two trials. The TCS measures the time, in seconds, it takes to repeatedly stand up and sit down from a chair as quickly as possible without using the arms, performed five times. The researcher stops the time when the participant stands up for the fifth time. The times of the final two tests are converted into points utilizing the scoring form (Meetinstrumenten in de zorg, 2024).

2.3.2. Pain-related questionnaires: Dutch versions

Multi-Site Pain Questionnaire. The Multi-Site Pain Questionnaire evaluates the places where participants have experienced pain over the past seven days and three months. Participants identify the areas where they felt pain using a body chart derived from the Dutch Musculoskeletal Questionnaire (Meetinstrumenten in de zorg, 2021a). This chart divides the anatomical body into distinct locations, including the head, neck, upper and lower back, shoulder, elbow, hand and wrist, hip, knee, and ankle and foot. This thesis will only focus on the pain experienced over the past seven days to limit the risk of recall bias. Furthermore, the average pain intensity experienced over the past seven days is recorded on a 0-10 numeric scale (0 = no pain, 10 = worst imaginable pain). This thesis interprets the concept of multi-site MSP as pain experienced in more than one anatomical location simultaneously (Brady et al., 2015; Butera et al., 2019). Additionally, the number of pain locations is classified into four categories (pain at 0-1 place, pain at 2 places, pain at 3 places, and painat 4 or more places).

Pain Disability Index. The Pain Disability Index (PDI) evaluates the impact of pain on daily life. It comprises seven items: family/household responsibilities, recreation, social activities, occupation, sexual activities, self-care, and basic living needs. Participants rate each item on a scale of 0 to 10, where 0 indicates no limitations, and 10 signifies complete limitation (Meetinstrumenten in de zorg, 2021b).

2.4. Outcomes

The main aim of this research is to investigate the prevalence of multi-site MSP and its presentation. Additionally, secondary objectives include exploring the relationship between performance measures obtained from the Timed Up and Go (TUG) and the Short Physical Performance Battery (SPPB) in the context of multi-site MSP. Furthermore, the association between multi-site MSP and activities of daily living, as assessed by the Pain Disability Index (PDI), is examined.

2.5. Data-Analysis

Two independent researchers conducted data analyses using JMP® Pro 17 software (JMP®, Version Pro 17. SAS Institute Inc., Cary, NC, 1989–2023). Results are expressed as mean ± standard deviation (SD) and frequencies (%) unless indicated otherwise. Figure 1 illustrates the statistical decision-making process. Given the multiple levels applied in the data analysis of continuous data (four categories based on the number of pain locations), several criteria must be met to continue data processing: (1) independence of measurements, (2) normality of the residuals (Shapiro-Wilk test), and (3) equality of variances (Brown-Forsythe test). A one-way ANOVA (parametric) was conducted if all criteria were met. Alternatively, if normality of the residuals could not be assumed, a Kruskal-Wallis test (non-parametric) was performed. Additionally, the Tukey post-hoc test was utilized to compare means across different groups. When processing the categorical data, the expected values of each cell were checked. Fisher's exact test (non-parametric) was employed if all expected values were <5; otherwise, the Pearson test (parametric) was the appropriate statistical test. Furthermore, correlations were computed among specific variables, with correlation coefficients interpreted as follows: 0.00-0.25 indicating a weak to negligible relationship; 0.25-0.50 suggesting a fair relationship; 0.50-0.75 implying a moderate to good relationship; and 0.75-1.00 indicating a good to excellent relationship (Portney & Watkins, 2015). If normality of the residuals could be assumed, the Pearson correlation was employed. In cases where normality could not be assumed, Spearman's rho correlation was the appropriate statistical choice. Moreover, a two-sample t-test was used to analyze the relationship between continuous variables divided into two groups, with p-values derived from the left-sided test. Statistical significance was set at the conventional threshold of five percent ($p \leq .05$) for all analyses.

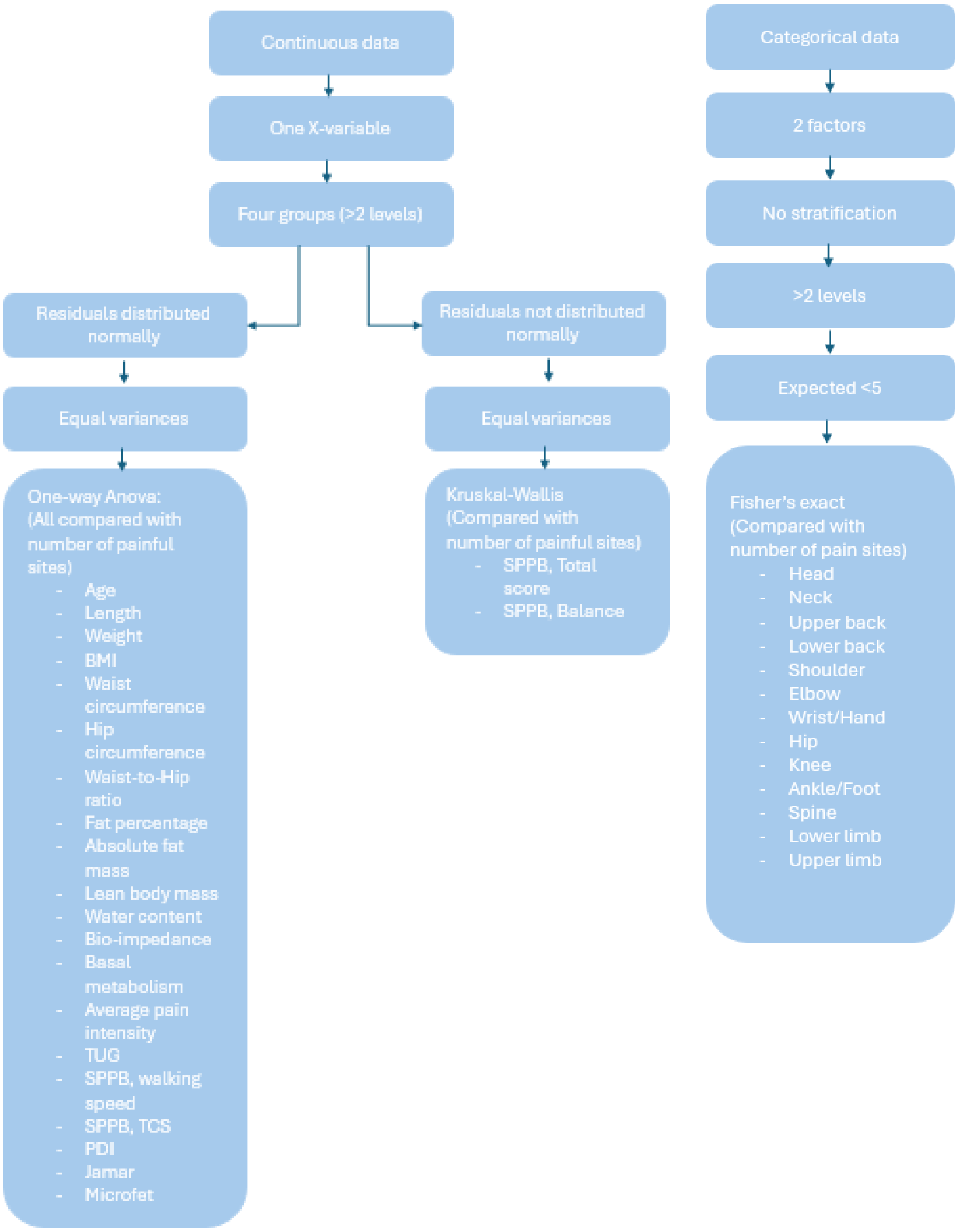

Figure 1

Visual Presentation of the Statistical Decision Process

Note. BMI = Body Mass Index; TUG = Timed Up and Go; SPPB = Short Physical Performance Battery; TCS; Timed Chair Stand test; PDI = Pain Disability Index.

3. Results

3.1. Patient characteristics

Table 1 presents the overall characteristics of the participants. The study involved 25 participants with an average age of 44 ± 14 years, among whom 10 (40%) were male. The mean BMI among all participants was 41.5 ± 4.8 kg/m² at baseline. The mean body weight recorded was 120.6 ± 16.6 kg, with absolute fat mass and lean body mass averaging 55.4 ± 13.0 kg and 65.8 ± 12.0 kg, respectively. The mean waist-to-hip ratio (WHR) resulted in 0.97 ± 0.14 (Table 1).

Table 1

Patient Characteristics

Characteristics	N = 25
Male (n, %)	10 (40)
Age (years)	44 ± 14
BMI (kg/m²)	41.5 ± 4.8
Length (cm)	170.4 ± 7.6
Weight (kg)	120.6 ± 16.6
Waist circumference (cm)	126 ± 12
Hip circumference (cm)	131 ± 15
Waist-to-hip ratio	0.97 ± 0.14
Body fat (%)	45.6 ± 8.1
Absolute fat mass (kg)	55.4 ± 13.0
Lean body mass (kg)	65.8 ± 12.0
Water content (%)	40.1 ± 6.0
Impedance (Ohm)	466 ± 71
Basal metabolism (kcal)	1967 ± 273

Note. Values are expressed as mean ± standard deviation (SD) and frequencies (%). BMI = Body Mass Index.

The baseline characteristics of participants categorized by the number of painful sites are presented in Table 2. Forty-four percent of participants reported either no pain (n = 5) or single-site pain (n = 6), while 8% experienced pain in two anatomical body locations, 12% in three sites, and 36% experienced pain in four or more sites. Length, weight, waist circumference, lean body mass, and basal metabolism significantly differed among groups (Table 2).

Table 2

Patient Characteristics by Number of Painful Sites at Seven Days

Characteristics	Number of painful sites				p-value
	0 - 1 n = 11	2 n = 2	3 n = 3	≥ 4 n = 9	
Male (n, %)	7 (28)	0 (0)	0 (0)	(12)	0.164[a]
Age (years)	47 ± 15	45 ± 4	40 ± 9	42 ± 16	0.867[b]
BMI (kg/m^2)	42.7 ± 5.2	43.7 ± 3.1	39.7 ± 5.8	40.0 ± 4.4	0.529[b]
Length (cm)	175.6 ± 6.9[1,2]	162.6 ± 0.6[2]	161.6 ± 3.2[1]	168.8 ± 5.2	**0.002**[b]
Weight (kg)	131.4 ± 14.2[1,2]	115.6 ± 9.1	104.1 ± 18.5[1]	114.0 ± 12.4[2]	**0.015**[b]
Waist circumference (cm)	134 ± 10[1]	125 ± 6	118 ± 8	119 ± 10[1]	**0.012**[b]
Hip circumference (cm)	130 ± 16	147 ± 2	132 ± 9	129 ± 15	0.479[b]
Waist-to-hip ratio	1.05 ± 0.15	0.85 ± 0.06	0.90 ± 0.07	0.93 ± 0.13	0.111[b]
Body fat (%)	43.8 ± 7.7	54.1 ± 1.6	50.1 ± 3.0	44.4 ± 9.3	0.282[b]
Absolute fat mass (kg)	58.0 ± 13.7	62.7 ± 6.9	54.1 ± 9.4	51.1 ± 14.3	0.580[b]
Lean body mass (kg)	73.7 ± 10.8[1,2]	53.1 ± 2.5[1]	53.5 ± 3.9[2]	63.0 ± 9.5	**0.005**[b]
Water content (%)	41.7 ± 6.1	34.8 ± 1.3	37.3 ± 1.9	40.5 ± 6.9	0.413[b]
Impedance (Ohm)	445 ± 80	512 ± 18	495 ± 49	471 ± 72	0.531[b]
Basal metabolism (kcal)	2142 ± 243[1,2]	1600 ± 54[1]	1682 ± 71[2]	1930 ± 200	**0.003**[b]

Note. Values are expressed as mean ± standard deviation (SD) and frequencies (%). BMI = Body Mass Index.

[a]Fisher's Exact Test

[b]One-way ANOVA

[1]Tukey post-hoc test: between-group differences [2]Tukey post-hoc test: between-group differences

*p ≤ .05

3.2. Multi-Site Pain Questionnaire

3.2.1. Average pain intensity

The average pain intensity scored on a scale ranging from 0 to 10 is not significantly different between different groups of multi-site pain (p = .055, one-way ANOVA) (Figure 2).

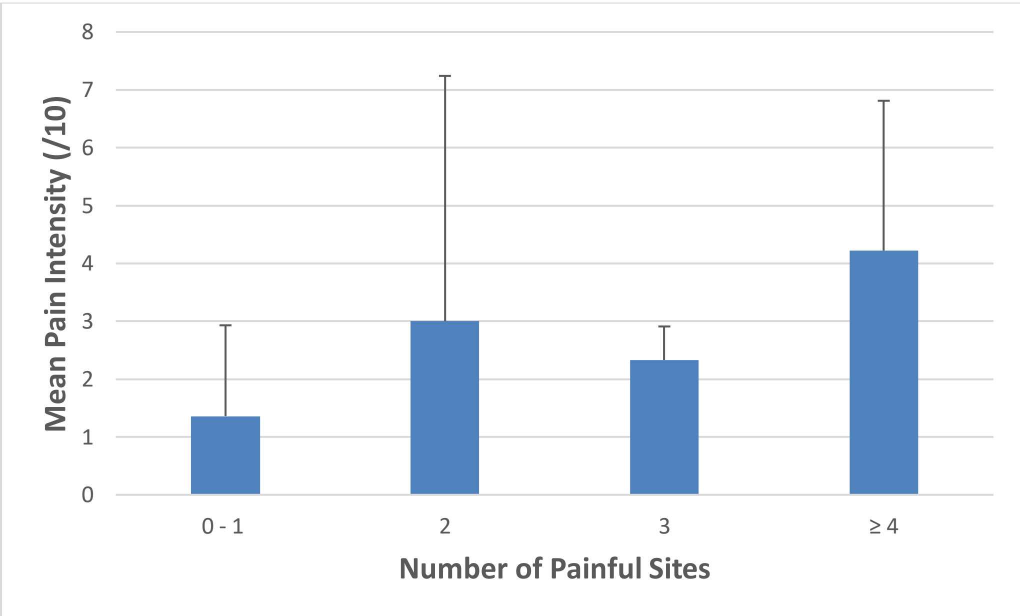

Figure 2

Mean Pain Intensity Experienced over the Past Seven Days

Note. Bar graph represents mean pain intensity expressed by a scale of 0-10, and error bars indicate SDs.

There are some significant correlations between mean pain intensity over the past seven days and sociodemographic, anthropometric, body composition, and multi-site pain variables. Lean body mass was negatively correlated with mean pain intensity (ρ = -0.43; p = .032) and number of pain sites was positively correlated with mean pain intensity (ρ = 0.50; p = .011) (Table 3).

Table 3

Correlation between Mean Pain Intensity Experienced over the Past Seven Days and Sociodemographic, Anthropometric, Body Composition, and Multi-Site Pain Variables

Variables	Mean Pain Intensity Experienced over the Past Seven Days (/10)			
	Correlation coefficient[a]	95% Confidence Interval		p-value
		Lower Bound	Upper Bound	
Age (years)	-0.16	-0.44	0.35	0.459
BMI (kg/m²)	-0.20	-0.56	0.20	0.343
Waist-to-hip ratio	-0.17	-0.52	0.25	0.403
Absolute fat mass (kg)	-0.10	-0.50	0.28	0.644
Lean body mass (kg)	-0.43	-0.70	-0.03	**0.032**
Number of pain sites	0.50	0.131	0.748	**0.011**

Note. BMI = Body Mass Index.

[a]Spearman's rho

*p ≤ .05

3.2.2. Prevalence of painful body locations

The predominant pain location among all individuals was the lower back (52.0%), followed by the shoulders, knees, and ankles/feet (respectively 40.0%, 32.0%, and 28.0%). Conversely,the upper back, elbows, and wrist/hand exhibited the lowest frequency of pain (Table 4; Figure 3).

Table 4

Prevalence of Pain in Specific Anatomical Sites by Number of Painful Sites at Seven Days

Pain sites	Number of painful sites				p-value[a]
	0 - 1 n = 11	2 n = 2	3 n = 3	≥ 4 n = 9	
Head (n, %)	0 (0.0)	0 (0.0)	0 (0.0)	4 (44)	**0.050**
Neck (n, %)	0 (0.0)	0 (0.0)	0 (0.0)	5 (55.6)	**0.012**
Upper back (n, %)	0 (0.0)	0 (0.0)	0 (0.0)	3 (33.3)	0.159
Lower back (n, %)	4 (36.4)	1 (50.0)	1 (33.3)	7 (77.8)	0.236
Shoulder (n, %)	1 (9.1)	1 (50.0)	1 (33.3)	7 (77.8)	**0.002**
Elbow (n, %)	0 (0.0)	0 (0.0)	0 (0.0)	3 (33.3)	0.159
Wrist/hand (n, %)	0 (0.0)	0 (0.0)	0 (0.0)	2 (22.2)	0.487
Hip (n, %)	0 (0.0)	0 (0.0)	1 (33.3)	4 (44.4)	**0.050**
Knee (n, %)	1 (9.1)	0 (0.0)	1 (33.3)	6 (66.7)	**0.027**
Ankle/foot (n, %)	0 (0.0)	1 (50.0)	2 (66.7)	4 (44.4)	**0.012**

Note. Values are expressed as frequencies (%).

[a]Fisher's Exact Test

*p ≤ .05

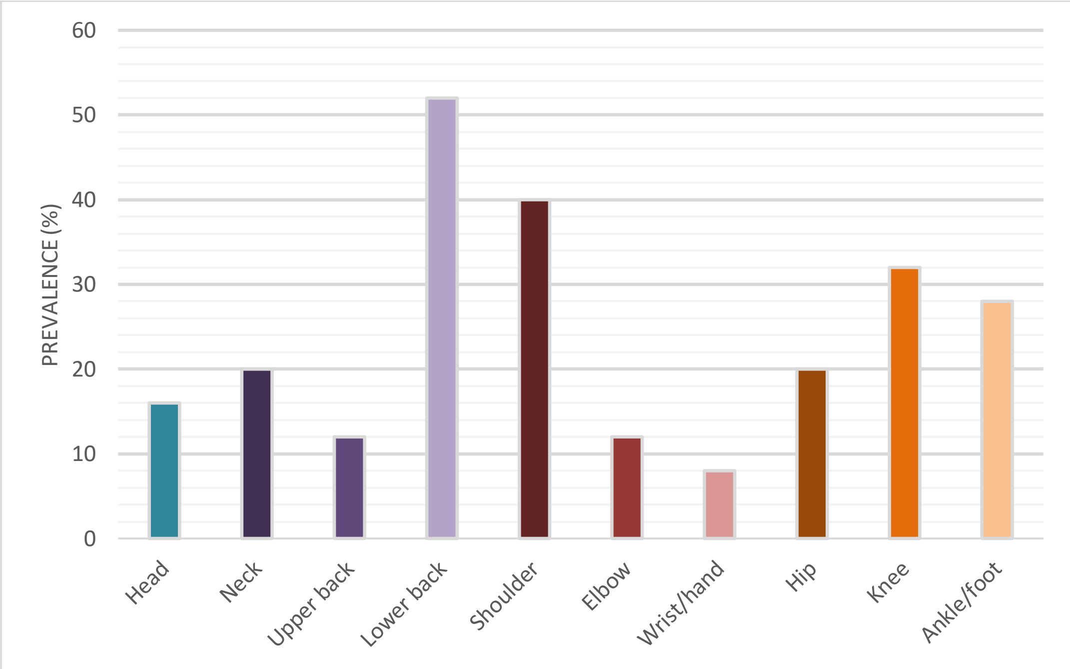

Figure 3

Prevalence of Painful Body Locations across Participants Not Divided by Number of Painful Sites

Note. Bar graph represents prevalence expressed by percentage (%).

3.2.3. Prevalence of pain sites per body region

The spine was the most frequently reported region (56.0%) (Figure 4).

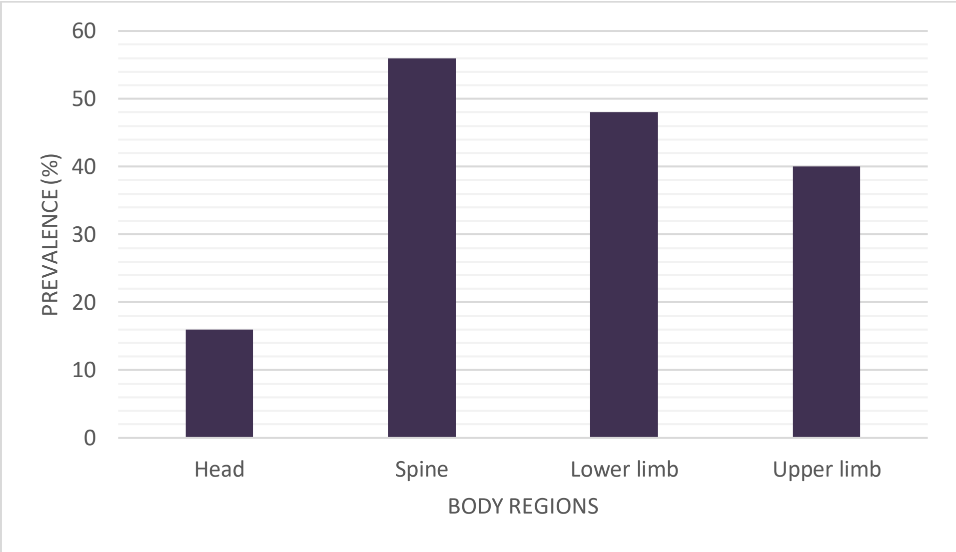

Figure 4

Prevalence of Pain Sites per Body Region

Note. Bar graph represents prevalence expressed as frequencies (%).

3.2.4. Presence of bilateral pain

Bilateral pain is present in both upper and lower limbs. Bilateral pain is generally seen more in individuals experiencing pain in three or more painful areas (Table 5; Figure 5).

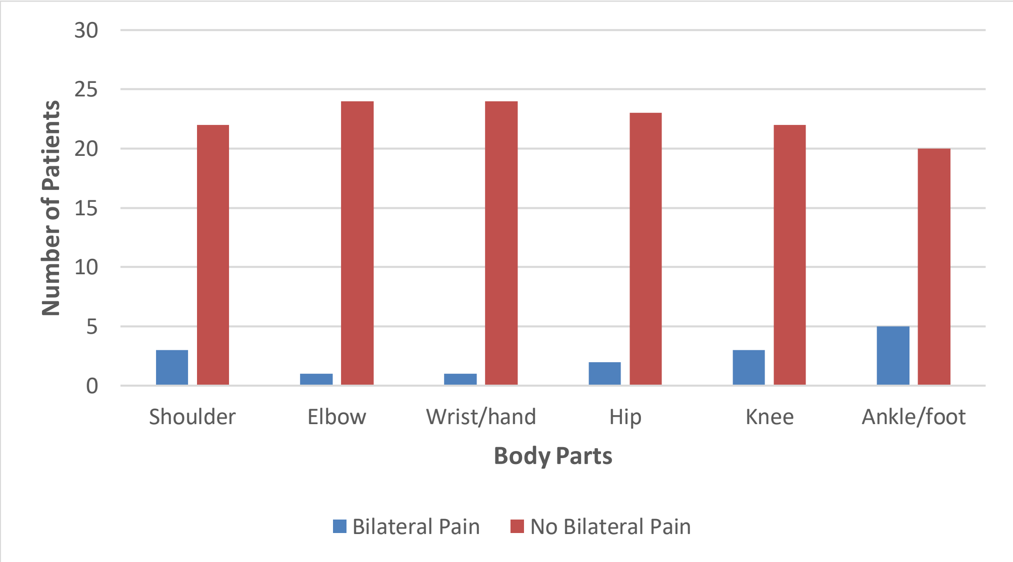

Figure 5

Distribution of Bilateral Pain by Body Part

Table 5

Distribution of Bilateral Pain with Multi-Site Pain

Number of painful sites	Shoulder n = 3	Elbow n = 1	Wrist/hand n = 1	Hip n = 2	Knee n = 3	Ankle/foot n = 5
0 – 1	0	0	0	0	0	0
2	0	0	0	0	0	1
3	1	0	0	0	0	2
≥ 4	2	1	1	2	3	2

Note. Values are expressed as fraction of the entire group.

3.3. Functional tests

3.3.1. Upper and lower limb muscle strength

Isometric muscle strength measurements for the quadriceps and hamstrings did not reveal any significant differences between groups. There is a significant association between grip strength left and right and the number of painful sites, respectively. However, only significant differences were found in grip strength right between individuals experiencing either no or single-site pain and those reporting pain across four or more locations, yielding a p-value of p = .048 (Table 6).

Table 6

Association of Isometric Muscle Strength and Grip Strength by Number of Painful Sites at Seven Days

Strength test	Number of painful sites				p-value[a]
	0 - 1 n = 11	2 n = 2	3 n = 3	≥ 4 n = 9	
Isometric muscle strength left quadriceps (N)	483.1 ± 110.1	240.5 ± 67.2	333.7 ± 79.3	322.4 ± 169.9	0.136
Isometric muscle strength right quadriceps (N)	428.9 ± 119.9	334.3 ± 138.2	301.3 ± 115.4	351.6 ± 134.0	0.341
Isometric muscle strength left hamstring (N)	201.8 ± 61.7	163.5 ± 48.8	156.3 ± 31.8	197.7 ± 48.6	0.521
Isometric muscle strength right hamstring (N)	207.5 ±67.7	170.3 ± 66.0	200.3 ± 29.7	199.0 ± 39.3	0.854
Grip strength left (kg)	43 ± 9	29 ± 4	29 ± 2	32 ± 3	**0.025**
Grip strength right (kg)	45 ± 9[12]	29 ± 5	29 ± 6[1]	34 ± 8[2]	**0.009**

Note. Values are expressed as mean ± standard deviation (SD). N = Newton.

[a]One-way ANOVA

[1]Tukey post-hoc test: between-group differences [2]Tukey post-hoc test: between-group differences

*p ≤ .05

In individuals experiencing pain in the lower and upper limbs, no statistically significant differences were observed in the mean muscle strength of the quadriceps and hamstrings and grip strength, respectively (Table 7; Table 8).

Table 7

Comparison of Muscle Strength between Groups with and without Pain in the Lower Limb

Variables	Pain LL n = 12		No pain LL n = 13		t-Ratio	p-value[a]
	Mean ± SD	95% CI	Mean ± SD	95% CI		
Isometric muscle strength left quadriceps (N)	344.9 ± 154.1	[259.9, 429.8]	389.5 ± 130.5	[307.7, 471.2]	-0.78	0.220
Isometric muscle strength right quadriceps (N)	382.4 ± 158.6	[304.8, 460.1]	374.3 ± 96.6	[299.7, 448.9]	0.16	0.562
Isometric muscle strength left hamstring (N)	198.7 ± 56.2	[166.4, 230.9]	185.5 ± 51.9	[154.5, 216.4]	0.61	0.726
Isometric muscle strength right hamstring (N)	213.1 ± 50.6	[181.8, 244.4]	189.0 ± 54.0	[159.0, 219.1]	1.15	0.869

Note. LL= lower limb; N = Newton; SD = standard deviation; CI = confidence interval.

[a]Two-sample t-test

*p ≤ .05

Table 8

Comparison of Muscle Strength between Groups with and without Pain in the Upper Limb

Variables	Pain UL n = 10		No pain UL n = 15		t-Ratio	p-value[a]
	Mean ± SD	95% CI	Mean ± SD	95% CI		
Grip strength left (kg)	34 ± 8	[27, 41]	38 ± 11	[32, 43]	-0.95	0.177
Grip strength right (kg)	36 ± 8	[29, 42]	39 ± 11	[33, 44]	-0.75	0.229

Note. UL= upper limb; N = Newton; SD = standard deviation; CI = confidence interval.

[a]Two-sample t-test

*$p \leq .05$

3.3.2. TUG and SPPB in relation to multi-site pain

No statistically relevant differences were found for TUG, SPPB total, SPPB balance, and SPPB walking speed compared with different groups of increasing pain sites (Table 9).

Table 9

Association of the Timed Up and Go and Short Physical Performance Battery (total score, balance, walking speed, Timed Chair Stand test) by Number of Painful Sites at Seven Days

Functional test	Number of painful sites				p-value
	0 - 1 n = 11	2 n = 2	3 n = 3	≥ 4 n = 9	
TUG (sec)	7.4 ± 1.7	6.4 ± 0.7	6.1 ± 0.8	7.6 ± 1.6	0.418[a]
SPPB, total score (/12)	10.9 ± 1.1	10.0 ± 2.8	12.0 ± 0.0	10.7 ± 1.7	0.373[b]
SPPB, balance (/4)	3.9 ± 0.3	3.5 ± 0.7	4.0 ± 0.0	3.9 ± 0.3	0.375[b]
SPPB, walking speed (sec)	3.4 ± 0.7	3.8 ± 0.3	3.8 ± 0.7	4.0 ± 0.3	0.546[a]
SPPB, Timed Chair Stand test (sec)	12.0 ± 3.2[1]	4.6 ± 5.0[1,2]	8.0 ± 1.0	12.1 ± 3.6[2]	**0.022**[a]

Note. Values are expressed as mean ± standard deviation (SD). TUG = Timed Up and Go; SPPB = Short Physical Performance Battery.

[a]One-way ANOVA

[b]Kruskal-Wallis Test

[1]Tukey post-hoc test: between-group differences [2]Tukey post-hoc test: between-group differences

*p ≤ .05

No significant correlation was found between TUG and sociodemographic, anthropometric, body composition, and multi-site MSP variables (Table 10).

Table 10

Correlation between the Timed Up and Go and Sociodemographic, Anthropometric, Body Composition, and Multi-Site Pain Variables

Variables	Timed Up and Go (sec)			
	Correlation coefficient[a]	95% Confidence Interval		p-value
		Lower Bound	Upper Bound	
Age (years)	-0.03	-0.46	0.32	0.878
BMI (kg/m²)	0.30	0.05	0.71	0.152
Waist-to-hip ratio	-0.17	-0.54	0.22	0.420
Absolute fat mass (kg)	0.29	-0.00	0.68	0.163
Lean body mass (kg)	0.24	-0.32	0.47	0.256
Number of pain sites	0.09	-0.23	0.54	0.663

Note. BMI = Body Mass Index.

[a]Spearman's rho

*p ≤ .05

A significant negative correlation was observed between total score on the SPPB and age ($\rho = -0.48$; $p = .015$) and waist-to-hip ratio (WHR) ($\rho = -0.42$; $p = .034$), respectively (Table 11).

Table 11

Correlation between the Short Physical Performance Battery (total score) and Sociodemographic, Anthropometric, Body Composition, and Multi-Site Pain Variables

Variables	Short Physical Performance Battery, total score (/12)			
	Correlation coefficient[a]	95% Confidence Interval		p-value
		Lower Bound	Upper Bound	
Age (years)	-0.48	-0.75	-0.13	**0.015**
BMI (kg/m²)	0.26	-0.23	0.54	0.211
Waist-to-hip ratio	-0.42	-0.65	0.07	**0.034**
Absolute fat mass (kg)	0.32	-0.17	0.58	0.119
Lean body mass (kg)	-0.32	-0.58	0.16	0.116
Number of pain sites	-0.03	-0.53	0.24	0.899

Note. BMI = Body Mass Index.

[a]Spearman’s rho

*p ≤ .05

No significant correlation was found between SPPB balance test and sociodemographic, anthropometric, body composition, and multi-site MSP variables (Table 12).

Table 12

Correlation between the Short Physical Performance Battery (balance test) and Sociodemographic, Anthropometric, Body Composition, and Multi-Site Pain Variables

Variables	Balance (/4)			
	Correlation coefficient[a]	95% Confidence Interval		p-value
		Lower Bound	Upper Bound	
Age (years)	-0.14	-0.53	0.24	0.515
BMI (kg/m²)	0.05	-0.30	0.48	0.808
Waist-to-hip ratio	-0.03	-0.45	0.34	0.871
Absolute fat mass (kg)	0.15	-0.29	0.49	0.463
Lean body mass (kg)	0.19	-0.23	0.54	0.369
Number of pain sites	0.01	-0.40	0.40	0.967

Note. BMI = Body Mass Index.

[a]Spearman's rho

*p ≤ .05

A significant positive correlation for the TCS is observed for age (ρ = 0.40; p = .049), WHR (ρ = 0.44; p = .029), and lean body mass (ρ = 0.53; p = .007) (Table 13).

Table 13

Correlation between the Short Physical Performance Battery (Timed Chair Stand test) and Sociodemographic, Anthropometric, Body Composition, and Multi-Site Pain Variables

Variables	Timed Chair Stand test (sec)			
	Correlation coefficient[a]	95% Confidence Interval		p-value
		Lower Bound	Upper Bound	
Age (years)	0.40	0.00	0.69	**0.049**
BMI (kg/m²)	-0.10	-0.48	0.31	0.633
Waist-to-hip ratio	0.44	0.05	0.71	**0.029**
Absolute fat mass (kg)	-0.23	-0.57	0.19	0.277
Lean body mass (kg)	0.53	0.17	0.76	**0.007**
Number of pain sites	0.09	-0.31	0.47	0.663

Note. BMI = Body Mass Index.

[a]Pearson correlation

*p ≤ .05

A significant positive correlation for the walking speed test is observed for number of pain sites (ρ = 0.60; p = .002) (Table 14).

Table 14

Correlation between the Short Physical Performance Battery (walking speed) and Sociodemographic, Anthropometric, Body Composition, and Multi-Site Pain Variables

Variables	Walking speed (sec)			
	Correlation coefficient[a]	95% Confidence Interval		p-value
		Lower Bound	Upper Bound	
Age (years)	0.04	-0.36	0.42	0.865
BMI (kg/m²)	0.04	-0.36	0.42	0.866
Waist-to-hip ratio	0.05	-0.35	0.44	0.799
Absolute fat mass (kg)	-0.09	-0.47	0.32	0.673
Lean body mass (kg)	0.07	-0.34	0.45	0.750
Number of pain sites	0.60	0.26	0.80	**0.002**

Note. BMI = Body Mass Index.

[a]Pearson correlation

*p ≤ .05

3.4. PDI in relation to multi-site pain

No statistically significant differences were seen among the groups (Table 15).

Table 15

Association of the Pain Disability Index by Number of Painful Sites at Seven Days

Questionnaire	Number of painful sites				p-value
	0 - 1 n = 11	2 n = 2	3 n = 3	≥ 4 n = 9	
PDI (/70)	13 ± 10	36 ± 0	25 ± 13	20 ± 15	0.081[a]

Note. Values are expressed as mean ± standard deviation (SD). PDI = Pain Disability Index.

[a]One-way ANOVA

*$p \leq .05$

A significant negative correlation is observed between the score on the PDI and lean body mass ($\rho = -0.42$; $p = .039$) (Table 16).

Table 16

Correlation between the Pain Disability Index and Sociodemographic, Anthropometric, Body Composition, and Multi-Site Pain Variables

Variables	Pain Disability Index (/70)			
	Correlation coefficient[a]	95% Confidence Interval		p-value
		Lower Bound	Upper Bound	
Age (years)	0.03	-0.37	0.42	0.890
BMI (kg/m²)	-0.01	-0.40	0.39	0.962
Waist-to-hip ratio	-0.18	-0.54	0.23	0.377
Absolute fat mass (kg)	-0.01	-0.41	0.38	0.955
Lean body mass (kg)	-0.42	-0.70	-0.03	**0.039**
Number of pain sites	0.32	-0.08	0.64	0.117

Note. BMI = Body Mass Index.

[a]Pearson correlation

*p ≤ .05

4. Discussion

To the best of our knowledge, this is the first study to investigate the relationship between multi-site MSP and performance on functional tests among individuals with morbid obesity. Among the noteworthy contributions of this study, we highlight several key findings in individuals with morbid obesity: a high prevalence of multi-site MSP; lower weight and waist circumference observed in the group experiencing pain in four or more regions compared to the group experiencing no or single-site MSP; a negative correlation between average pain intensity over the past seven days and lean body mass, and a positive correlation between average pain intensity over the past seven days and the number of painful sites; the lower back emerged as the most common site of pain; a higher incidence of bilateral pain among those with a greater number of painful sites; a positive correlation between the walking speed test and the number of pain sites; and a negative association identified between the PDI and lean body mass. These results may offer valuable insights for the development of clinical interventions tailored to individuals with severe obesity and multi-site MSP.

Summarizing the prevalence and interpreting the consequences of multi-site MSP in individuals with morbid obesity is highly beneficial in terms of understanding and developing novel treatment strategies. In this cross-sectional study involving 25 adults with morbid obesity, the results revealed a multi-site MSP prevalence of 56%, as defined by Butera et al. (2019) and Brady et al. (2015), denoting pain experienced in at least two different anatomical regions within the past seven days. This high prevalence of multi-site MSP aligns with prior research studies, ranging from 37% to 80.49% (Calenzani et al., 2017; MacLellan et al., 2017; Magnusson et al., 2013; Mendonça, Noll, Rodrigues et al., 2020). These findings suggest that pain in adults with morbid obesity should not be overlooked and that preventing and managing this pain should be integrated into the treatment strategies.

In the present study, individuals with pain in four or more regions were found to have a lower weight and waist circumference compared to those experiencing no or single-site MSP. However, fat mass and BMI did not demonstrate a significant difference with multi-site MSP. This finding contradicts Pan et al. (2017), who reported a cross-sectional and longitudinal association between multi-site pain, higher fat mass, and increased BMI. Similarly, Walsh et al. (2018) observed a greater number of pain sites in individuals with higher total body fat mass. This discrepancy suggests that additional factors may influence pain. One such factor could be the presence of chronic low-grade inflammation (Chin et al., 2019; Costa et al., 2020). However, blood parameter data were not available in our study. Furthermore, individuals with multi-site MSP exhibited lower lean body mass and basal metabolism, although these differences did not reach statistical significance, presumably due to the small sample size. However, significant differences were observed in groups with two or three pain sites in comparison to individuals experiencing no or single-site MSP. This finding aligns with Raghupathy et al. (2023), who demonstrated a positive association between higher adiposity and greater lean mass. These results underscore the importance of muscle mass in supporting weight-bearing joints (Wu et al., 2024). To further investigate this relationship, a DEXA scan is required, which was not available for this study.

The average pain intensity demonstrates a negative correlation with lean body mass. No studies were found to support this association. Contrary to previous studies emphasizing the association between fat mass and pain intensity, particularly in the lower back (Brady et al., 2019; Hussain et al., 2017; Walsh et al., 2018), we did not find a correlation between pain intensity and absolute fat mass. Additionally, mean pain intensity was positively correlated with the number of reported pain sites. This finding aligns with the results of Finney et al. (2017), who reported a significant increase in average pain intensity with each additional joint reporting pain.

The high prevalence of pain, especially in areas subject to increased mechanical loads, such as the lower back, shoulders, knees, and ankles/feet, is in agreement with findings from prior research (Chin et al., 2019). The prevalence of lower back pain (52.0%) closely mirrors that reported in Brazilian studies (53.7%; 62.7%) (Calenzani et al., 2017; Mendonça, Noll, De Carvalho Santos et al., 2020). Conversely, the prevalence of knee pain (32.0%) in our study was lower than that documented in Brazilian investigations (46.3%; 53.3%) (Calenzani et al., 2017; Mendonça, Noll, De Carvalho Santos et al., 2020). Similarly, the prevalence of ankle/foot pain (28.0%) was also lower compared to the rates reported in Brazilian studies (70.7%; 68.7%) (Calenzani et al., 2017; Mendonça, Noll, De Carvalho

Santos et al., 2020). These prior studies were performed among individuals with morbid obesity. Additionally, 16.0% reported head pain, 56.0% reported pain in the spine, 48.0% reported lower extremity pain, and 40.0% reported pain in the upper extremities, underscoring the high frequency of pain in the spine and lower extremities. However, the prevalence of upper extremity pain, particularly in the shoulders (40.0%), warrants attention as it cannot be solely attributed to mechanical stress (Pan et al., 2017). As proposed by Chin et al. (2019), physiological mechanisms, such as inflammation, may play a potential role. Evidence suggests that inflammation, especially TNF-α, ghrelin, and galanin, may induce hypersensitivity (Chin et al., 2019). Unfortunately, due to the absence of data on blood parameters, an in-depth analysis of this aspect is precluded. This area remains largely unexplored in thorough investigations, and comprehensive studies in this domain could provide valuable insights into these issues.

The greater the number of painful sites reported, the higher the incidence of bilateral pain. No studies have specifically examined the relationship between bilateral pain and multi-site MSP. However, Coggon et al. (2013) investigated bilateral pain in isolation and found that pain in one body area often correlated with pain on the opposite side or in a neighboring area. This connection can be attributed to the diffuse nature of pain, which may not be confined to a single location as outlined in the Multi-Site Pain Questionnaire (Coggon et al., 2013). Additionally, bilateral pain may be linked to the chronic low-grade inflammatory state associated with obesity (Khanna et al., 2022), which can induce hypersensitivity, as previously noted (Chin et al., 2019). Moreover, it is believed that psychosocial factors, including low emotional state, adverse health beliefs, a propensity for somatization, and job demands, significantly contribute to the determination of MSP (Vargas-Prada & Coggon, 2015).

In the analysis of the walking speed component of the SPPB, a significant positive correlation was found between walking speed test and the number of pain sites. Specifically, individuals with a greater number of pain sites showed an increased time to walk four meters at a regular pace, indicating a slower walking speed. This finding is consistent with the study by Sawa et al. (2017), which demonstrated that both pain intensity and the presence of pain in multiple sites are significantly associated with reduced gait speed. However, it is important to note that this study was conducted within an elderly population, which differs from the target population in this thesis.

A negative association was found between the score on the PDI and lean body mass, indicating that a higher amount of lean body mass corresponds to a lower PDI score and, consequently, a lower level of disability. This finding contradicts a study by Brady et al. (2019), which identified an association between fat mass, low back pain, and disability, but found no association between disability and lean body mass. No additional studies were found. No association was found between the number of painful sites and the score on the PDI.

A clear strength of the current study is the strict adherence to rules and procedures. Another strength is the detailed evaluation of MSP intensity and the assessment of pain across ten body parts. To avoid recall bias, multi-site pain was assessed over the past seven days. However, several limitations exist.

Firstly, given that the study commenced in March 2023 and therefore is still in its early phase, the relatively small sample size has yielded limited statistical power. Additionally, some participants failed to complete the entire questionnaire or to omit their patient ID, rendering some data unusable. Secondly, data collection was conducted by five researchers from the previous academic year and six researchers from the current year, totaling 11 different researchers. This raises concerns regarding interrater reliability. Furthermore, participants generally achieved high total scores on the SPPB, suggesting that the SPPB may not be an appropriate test for this population due to its low discriminatory power. This issue warrants further investigation in future studies. The study also faced challenges with varying definitions of multi-site MSP; it used the cut-off values from Butera et al. (2019) and Brady et al. (2015), which may lead to different results compared to other definitions for multi-site pain. Additionally, bio-impedance measurement, rather than the gold standard DEXA-scan, was used to assess body composition. However, bio-impedance measurements were found to be reliable for estimating fat mass and appendicular lean mass in people with severe obesity (Ballesteros-Pomar et al., 2022). Lastly, the results are strongly influenced by the participants' motivation to perform well on the functional tests.

As this study is cross-sectional, firm conclusions about causality cannot be drawn. Therefore, future research should focus on developing effective pain management and treatment strategies targeting individuals with obesity in longitudinal study designs. Based on our findings, as well as those from previous studies, clinical interventions should incorporate pain education to address the psychological factors influencing pain. Furthermore, lifestyle modifications should be considered, especially in light of the impact of chronic low-grade inflammation in people with obesity. Additionally, weight reduction and strengthening programs should be included in the treatment regimen for individuals with obesity, regardless of the presence of MSP. Moreover, research should investigate the role of psychosocial factors (for example emotional state, health beliefs, work-related factors…) in the experience of pain in obesity. Integrating the duration of obesity and blood markers could provide a more comprehensive understanding of multi-site MSP mechanisms. Finally, further research should explore alternative tests to the SPPB and develop a uniform definition of multi-site pain to facilitate comparisons across studies.

5. Conclusion

The results of this investigation indicate a high prevalence of multi-site MSP in individuals with morbid obesity, especially in the lower back, followed by the shoulders, knees, and ankles/feet. Factors associated with multi-site pain include lower body weight and waist circumference, a higher incidence of bilateral pain, and more intense pain over the past seven days. These findings suggest that obesity significantly contributes to the prevalence of multi-site MSP, emphasizing the need for effective treatment strategies. Additionally, a positive association was found between the number of painful sites and performance on the SPPB walking speed test. Future research should investigate performance on functional tests to explore underlying mechanisms and draw causal inferences through longitudinal study designs with larger sample sizes.

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