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# Faculteit Revalidatiewetenschappen

## master in de revalidatiewetenschappen en de kinesitherapie

***Masterthesis***

***Multisite pain and pain-related cognitions in adolescents with obesity: a cross-sectional analysis***

**Jens Hermans**
**Rick Maes**

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

**COPROMOTOR :**
dr. Thomas MATHEVE

**BEGELEIDER :**
Mevrouw Lisa MENNENS

**2022**
**2023**

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## Acknowledgments

This investigation constituted the latter and final component of the master's thesis within the framework of the Rehabilitation Sciences and Physiotherapy program. The first part of the paper investigates differences in pain-related cognitions between adolescents with and without obesity. The second part further explores the domain of multisite pain in adolescents with obesity.

This observational, cross-sectional study was undertaken and documented under the guidance of Professor Dr. Kenneth Verboven, our promotor. We sincerely thank our supervisor for his invaluable assistance and for facilitating the realization of this research endeavor. Additionally, we express our appreciation for his constructive feedback, guidance, and suggestions. Moreover, we extend our gratitude to Dr. Thomas Matheve for his invaluable support and assistance while developing our thesis.

We are indebted to our participants and their parents/guardians for their unwavering dedication and flexibility throughout this study. All measurements were conducted at the rehabilitation research center of Hasselt University (REVAL) and Jessa Hospital (Hasselt). With the provision of this infrastructure and its accompanying facilities, the execution of this study was possible.

## Situating the Master's Thesis

This duo master's thesis, conducted by Rick Maes and Jens Hermans, examines differences in functioning between adolescents with and without obesity and mainly explores different aspects of musculoskeletal pain within these specific populations. The master's thesis is thus situated both in the research domain of internal diseases and in the research domain of musculoskeletal pain.

Research on musculoskeletal pain in adolescents with obesity, including multisite pain and pain-related cognitions, is critical. By examining these aspects, we can gain a deeper understanding of the unique challenges faced by adolescents with obesity. Understanding how these adolescents experience pain, with specific attention to multisite pain and pain-related maladaptive cognitions, allows us to develop (more) effective interventions that not only target weight loss but also reduce pain, promote functional recovery, and improve their overall well-being. This study aimed to identify the difference in functioning between adolescents with and without obesity, focusing on the subjective pain experience. In doing so, maladaptive pain-related cognitions have been explored, as well as multisite pain.

This master's thesis is part of the ongoing research project of Professor Kenneth Verboven: "Ultrasound for quantification of subcutaneous adipose tissue in obese adolescents: an exploratory feasibility study and associations with metabolic health." For this study, data were already collected from eleven adolescents with and fourteen adolescents without obesity at the REVAL research center and Jessa Hospital (Department of Child and Adolescent Medicine - Endocrinology for Children and Adolescents), respectively. All available data (study currently ongoing) were provided by Professor Verboven and his research team, in which a whole range of outcome measures were collected from both groups of adolescents, from which several side projects could later emerge, including this thesis. This dataset was provided to us, and we were free to develop our research questions.

The following research questions were devised by the students in consultation with their promotor:

- What is the prevalence of multisite pain in adolescents with obesity, and how does it manifest?
- What are the differences between adolescents with and without obesity regarding pain experience, pain-related cognitions, and degree of impairment experienced daily?

The work was divided evenly between the two students to conduct the research and prepare the thesis. Rick mainly took care of situating the importance of the research and identifying gaps in the current literature in the introduction. At the same time, Jens was responsible for the methodology and data processing. Finally, both students processed the results together and formulated a discussion based on them.

## Abstract

Background:

Understanding how adolescents with obesity experience musculoskeletal pain, with specific attention to multisite pain (simultaneous pain in two or more locations) and pain-related maladaptive cognitions, is critical to develop effective and tailored interventions.

Objectives:

This study investigates the prevalence and pattern of multisite pain in adolescents with obesity and identifies the differences in pain-related cognitions between adolescents with and without obesity. By gaining insights into obesity-related pain mechanisms, we can enhance our understanding of the complex relationship between obesity, musculoskeletal pain, and its impact on adolescents' health-related quality of life.

Methods:

This cross-sectional, observational study included 24 adolescents aged twelve to seventeen years, divided into three groups based on their BMI Z-score and the prevalence of multisite pain. All participants underwent clinical measurements and completed pain-related questionnaires (FDI, PCS, and FOPQ).

Results:

Eight adolescents with obesity (72.7%) reported experiencing pain during the last week, and six (54.5%) experienced multisite pain. Adolescents with obesity and multisite pain experienced significantly more functional disabilities, a higher degree of pain catastrophizing, and more pain-related fears than their lean counterparts.

Conclusions:

Over 50% of adolescents with obesity experienced multisite musculoskeletal pain within the past seven days. These adolescents demonstrated higher levels of functional disability than their lean counterparts. Adolescents with obesity and multisite pain exhibited greater pain catastrophizing tendencies than those without, regardless of obesity status. Adolescents with obesity and multisite pain reported higher levels of fear of pain than their lean counterparts. These results emphasize the need for interventions targeting pain-related cognitions and multisite pain to improve the overall well-being and quality of life of adolescents with obesity.

Keywords: adolescents, obesity, multisite musculoskeletal pain, pain catastrophizing, fear of pain, functional disability.

## Introduction

In Belgium, as many as 19% of adolescents (2-17 years old) are overweight, and 6% are obese (S. Drieskens, 2018). Overweight-related health problems, such as type 2 diabetes mellitus, sleep apnea, or cardiovascular disease, are already seen in 80% of adolescents with obesity (Biro & Wien, 2010; Inchley et al., 2017). Consequently, overweight and obesity significantly impact health-related quality of life and social costs (Hecker et al., 2022) accounting for an annual cost of €4.5 billion in Belgium (Gorasso et al., 2022). Addressing obesity early in life significantly affects healthcare costs later in life (Wang et al., 2010), demonstrating the crucial need for targeted strategies.

Obesity is widely recognized as a significant risk factor for developing musculoskeletal pain during adolescence, as supported by previous studies (Smith et al., 2014). It has been reported that as many as 60% of adolescents with obesity experience recurrent or chronic musculoskeletal pain (Zeller et al., 2020), defined as pain persisting or recurring for a duration exceeding three months (Treede et al., 2019). This association between obesity and musculoskeletal pain becomes crucial as it has been identified as a significant predictor for developing chronic pain in adulthood (Tumin et al., 2020). The adverse effects of (chronic) musculoskeletal pain on the health-related quality of life of adolescents with obesity are well documented (Hainsworth et al., 2009; Theriault et al., 2023). However, there is still a need to explore and understand the underlying mechanisms that can contribute to this association. By gaining insights into obesity-related pain mechanisms, we can enhance our understanding of the complex relationship between obesity, musculoskeletal pain, and its impact on adolescents' health-related quality of life.

One proposed mechanism suggests that excess weight, as in obesity, exerts mechanical pressure on spinal discs, weight-bearing joints, and skeletal muscle tissue (S.-H. Chin et al., 2020). This directly affects the musculoskeletal system, limiting adolescents' mobility and physical activity behavior (Guthold et al., 2018), leading to reduced physical fitness (Petrovics et al., 2020) and exercise intolerance (Franssen et al., 2021). Another potential mechanism contributing to obesity-related pain is the association between obesity and chronic low-grade inflammation, defined as the chronic production of inflammatory factors (e.g., TNF-alpha,

leptin, ghrelin, and galanin) but at a low-grade state (Khanna et al., 2022). Lastly, psychosocial factors may play an essential role in directly and indirectly aggravating musculoskeletal pain among adolescents with obesity. Unfortunately, these individuals often face stigmatization, social isolation, and reduced self-esteem (Haqq et al., 2021) which may hamper motivation and participation in physical activities (Bevan et al., 2021) Furthermore, adolescents with obesity are more likely to deal with anxiety and depression (Lindberg et al., 2020). This ultimately leads to a downward spiral of inactivity and further weight gain, increasing the mechanical load on the musculoskeletal system and promoting the release of inflammatory factors. In this manner, psychosocial factors (in)directly contribute to musculoskeletal pain. Of interest, studies in adults have demonstrated that the experience of chronic musculoskeletal pain in adults can be mediated by psychological factors (de Heer et al., 2014; Murillo et al., 2022; Rayner et al., 2016). However, whether this holds true for adolescents remains uncertain. Current literature lacks knowledge about possible differences in pain-related cognitions in adolescents, either with or without obesity, which could also directly affect the pain experience. Pain-related cognitions include adolescents' thoughts, beliefs, and perceptions regarding their pain experiences. Even though these cognitions may influence pain occurrence, intensity, and management (Sánchez-Rodríguez et al., 2020), there has been limited research on pain-related cognitions in adolescents with obesity (Santos et al., 2017).

There has recently been a shift in musculoskeletal pain research from single-site to multisite pain, which occurs simultaneously at more than one anatomical site, since it is more prevalent than single-site pain (Butera et al., 2019). It has a more significant impact on health-related quality of life, is associated with more functional limitations, and appears more persistent than single-site pain (Heikkala et al., 2019). To the authors' knowledge, no research has been conducted on multisite pain in adolescents with obesity thus far. This study aims to be the first to investigate the prevalence of multisite pain in adolescents with obesity and explore the patterns in which it manifests (i.e., the specific locations involved). Understanding how adolescents with obesity experience (multisite) pain, allows us to develop effective interventions that may reduce pain, promote functional recovery, and improve their quality of life. This study aims to identify the difference in functioning between adolescents with and without obesity, focusing on the subjective pain experience. As such, maladaptive pain-related cognitions will be explored, as well as multisite pain in adolescents with obesity.

## Methods

The primary research questions for this study are:

- What is the prevalence of multisite pain in obese adolescents, and how does it manifest?
- What are the differences between adolescents with and without obesity regarding pain experience, pain-related cognitions, and degree of impairment experienced daily?

### Study design

The current study includes a cross-sectional, observational study design. It evaluates female and male adolescents with or without obesity. The Ethical Review Committee of Jessa Hospital approved the study application on 13/08/2021 after positive advice from the Committee on Medical Ethics of Hasselt University. The study has the Belgian reference number B2432021000022.

### Participants

The current study includes eleven adolescents with obesity (see inclusion criteria for definition), recruited at the Department of "Child and Adolescent Medicine - Endocrinology for Children and Adolescents" of the Jessa Hospital (Hasselt). Overweight adolescents who were eligible for the study and met the in- and exclusion criteria were informed about the study by the pediatrician. If interested, the local investigator provided the complete information and consent form to the potential participant and its legal representative. Initial questions and concerns regarding the content and conduct of the study measurements were clarified during a phone call. If the participant and his/her parent(s)/guardian(s) consent to participate in the study, participation was confirmed by mutually signing the informed consent form. Also, a lean control group of thirteen adolescents will be included (matched for age and gender) for this study. These individuals will be recruited by word of mouth.

The following inclusion criteria were applied:

Adolescents with obesity

1. age between 12 and 17 years old
2. the presence of overweight or obesity as defined by a BMI z-score above 1 (85 percentile) and 1.64 (95 percentile), respectively; scores are calculated based on height, weight, gender, and age (Centers for Disease Control and Prevention, 2022)
3. free of known chronic diagnosed conditions (cardiovascular, renal, or respiratory)
4. adequate command of the Dutch language (also applicable to their legal representatives)

Adolescents without obesity (lean control group)

1. age between 12 and 17 years old
2. the absence of under or overweight as defined by a BMI z-scores between -1.65 (5 percentile) and 1 (85 percentile); scores are calculated based on height, weight, gender, and age (Centers for Disease Control and Prevention, 2022)
3. free of chronic diagnosed conditions (cardiovascular, renal, or respiratory)
4. adequate command of the Dutch language

**Procedure**

The evaluation of participants with obesity included one assessment visit, taking place at Jessa Hospital (Department of Child and Adolescent Medicine - Endocrinology for Children and Adolescents) by an experienced researcher. The performance of the measurement moment has a duration of approximately 45 minutes. Before effectively starting the measurements, the following sociodemographic data of the participants were collected using a questionnaire: gender, age, family situation, medical antecedents (global), medication use, and smoking behavior. Furthermore, the Dutch-language versions of the following pain-related questionnaires were used. These questionnaires have been validated for adolescents and can be administered to both adolescents with and without pain:

- Musculoskeletal Pain Questionnaire: This is a questionnaire in which the participant can indicate in which body parts (shoulder, elbow, wrist/hand, neck, upper back, lower back, hip/pelvis, knee, and ankle/foot) and how frequently the pain has been present during the past seven days and three months. The intensity of pain is questioned using a scale with eleven scores (0-10) (0="no pain"; 10="worst imaginable pain"). To assess the presence of chronic pain, defined as pain that has been continuously present or recurring for at least three months, participants were asked whether they are currently dealing with chronic pain and if they have previously encountered episodes of chronic pain. To investigate multisite pain, participants were asked in which locations they had experienced pain in the past seven days. This study focused on the past seven days because this period includes all participants with chronic pain but fewer with recurrent or episodic pain. Also, the risk of recall bias is reduced.

- Functional Disability Inventory: This questionnaire assesses pain-related functional limitations in school, home, leisure, and social interactions. The various items are scored on a 5-point Likert scale (0="no difficulty"; 4="impossible"). The maximum score is 60, with higher scores corresponding to a higher degree of perceived pain-related functional impairment (Walker & Greene, 1991).

- Pain Catastrophizing Scale: This self-assessment questionnaire gauges catastrophizing (an overly negative orientation toward harmful stimuli). The PCS consists of 13 items further divided into three domains: rumination, magnification, and helplessness. The various items are scored on a 5-point Likert scale (0="not at all"; 4="very much"). The maximum score is 52, with higher scores corresponding to a higher degree of pain catastrophizing (Crombez et al., 2003).

- Fear of Pain Questionnaire for Adolescents: This questionnaire consists of 24 items subdivided into two sub-scales (fear and avoidance) and looks to what extent the experienced pain affects this. The different items are scored on a 5-point Likert scale (0 = "strongly disagree"; 4= "strongly agree"). The maximum score is 96, with higher scores corresponding to higher pain-related fear and avoidance levels (Dekker et al., 2017).

The estimated time investment for completing these questionnaires is 40 minutes. Several standard clinical measurements (totaling approximately 30 minutes) were performed next where participants needed to be sober:

- Height: determined to the nearest 0.1 cm (without footwear) using a stadiometer
- Weight: determined to the nearest 0.1 kg (minimal clothing) using digital scales
- Circumference measurements: abdominal and hip circumferences were determined to the nearest 0.1 cm using a flexible (non-elastic) measuring tape. Measurements (in duplicate) were taken on bare skin in a standing position as prescribed in the guidelines (ACSM).
- Body composition: the participant lies on a bed with his hands and feet uncovered. Then, two band-aids are applied on the right hand and right foot to link the impedance scale (Bodystat 1500, Bodystat Ltd.). The following variables were recorded:

The evaluation of participants from the lean adolescents without obesity included one assessment visit on an individual basis (body composition and clinical measurements only). Taking place at the REVAL research center (Faculty of Rehabilitation Sciences, Hasselt University (at Diepenbeek)), conducted by an experienced researcher. The performance of the measurement moment has a duration of approximately 30 minutes. Before effectively starting the measurements, the following sociodemographic data of the participants will be collected digitally (Qualtrics) using a questionnaire: gender, age, family situation, medical antecedents (global), and medication use. Furthermore, the Dutch-language versions of the above-mentioned pain-related questionnaires were used. Finally, the same protocol will be applied to determine body composition via bioimpedance, as described for the group of adolescents with obesity.

**Data-analysis**

Results are presented as mean ± standard deviation (SD), and the level of statistical significance was set at five percent ($p < 0,05$). Figure 1 depicts the statistical decision process. For continuous data, three conditions must be met before proceeding to data processing: normality (Shapiro-Wilk test), equality of variances (homoscedasticity using Brown-Forsythe test), and independence of measurements. If these conditions were met, a two-sample t-test (parametric, two groups) or one-way ANOVA (parametric, three groups) was used. If normality could not be assumed, Wilcoxon's Rank Sum Exact test (nonparametric) was used when variances were equal. When both normality and equality of variances could not be assumed, Welch's ANOVA test (nonparametric) was used. Before processing the categorical data, the expected values for each cell were checked. If sufficiently large (each >5), the chi-square test (parametric) was used; if not (one or more <5), Fisher's exact test (nonparametric) was used. All analyses were carried out using JMP software (v. JMP PRO 16.2, SAS Institute Inc., Cary, NC, 1989–2023) by two independent statisticians.

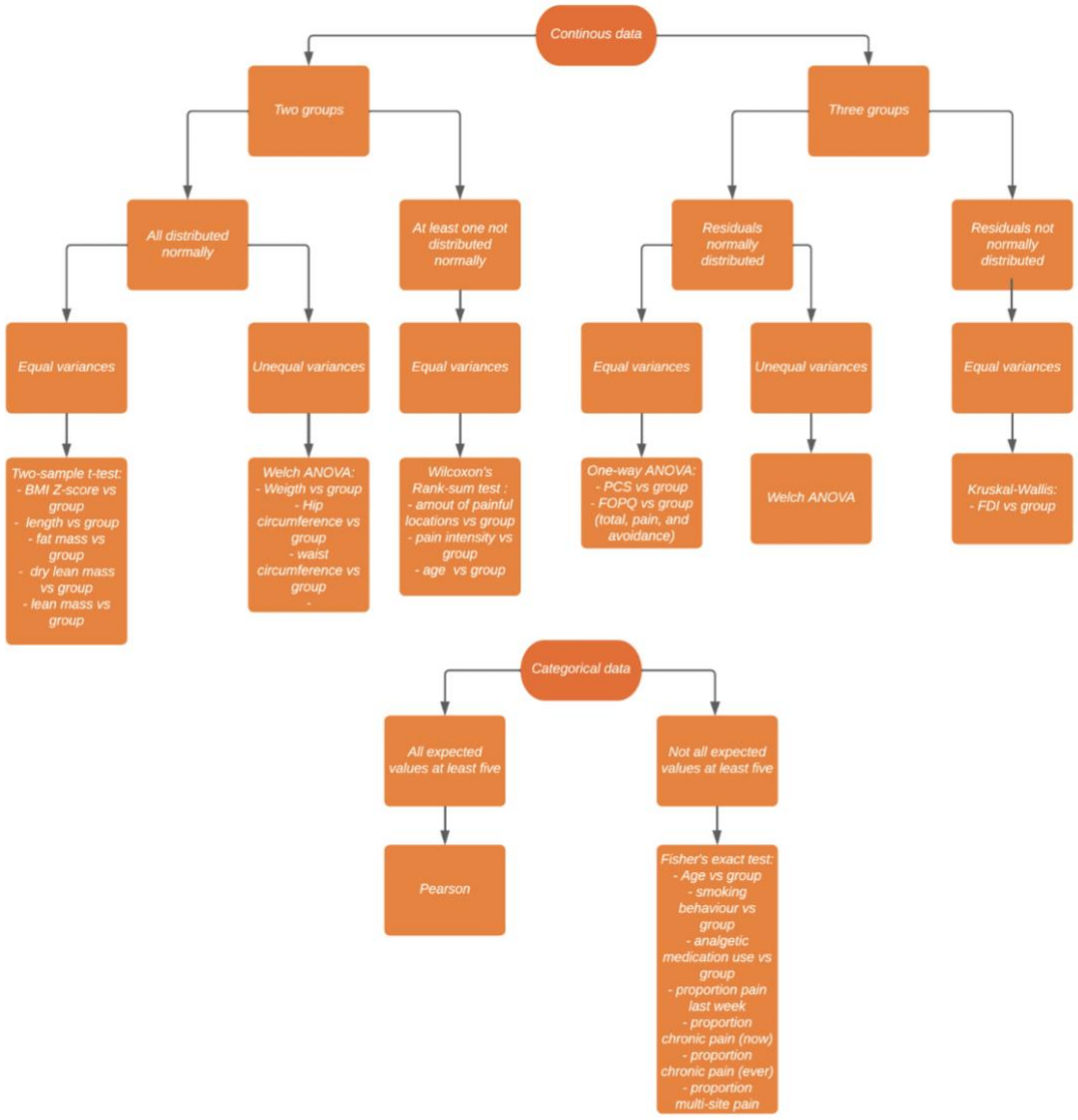


***Figure 1: visual presentation of the statistical decision process***

*Note*. BMI = Body Mass Index; PCS = Pain Catastrophizing Scale; FOPQ = Fear Of Pain Questionnaire; FDI = Functional Disability Inventory.

## Results

### Participants characteristics

The sample consists of 24 participants further divided into two groups based on their BMI Z-score. The first group comprised 11 adolescents with obesity (OB), while the second group consisted of 13 lean controls (LA). Participants' characteristics are shown in Table 1. Both groups were similar regarding sex, age, smoking behavior, analgesics use, and body height. Groups significantly differed regarding BMI Z-score ($p = 0.001$), weight ($p = 0.001$), hip and waist circumference ($p = 0.001$ and $p = 0.001$ respectively), fat mass ($p = 0.001$), dry lean tissue mass ($p = 0.001$), and lean tissue mass ($p = 0.001$) (Table 1).

**Table 1**

*Participants characterization*

| | Obese (n=11) | Lean (n=13) | P-value |
|---|---|---|---|
| **Demographics** | | | |
| Male (n, %) | 5 (45.45) | 5 (38.50) | 1.000[a] |
| Age (y) | 14.3 ± 0.5 | 15.4 ± 0.4 | 0.097[d] |
| **Substance use** | | | |
| Smoking (n,%) | 1 (7.7) | 1 (9.1) | 1.000[a] |
| Analgetics (n,%) | 0 (0) | 0 (0) | 1.000[a] |
| **Anthropometry** | | | |
| BMI Z-score | 2.3 ± 0.2 | -0.3 ± 0.2 | 0.001*[b] |
| Length (cm) | 166.5 ± 2.8 | 168.5 ± 2.6 | 0.606[b] |
| Weigth (kg) | 101.3 ± 4.8 | 57.4 ± 4.4 | 0.001*[c] |
| Hip circumference (cm) | 115.4 ± 3.0 | 75.1 ± 2.8 | 0.001*[c] |
| Waist circumference (cm) | 113.5 ± 3.1 | 70.1 ± 2.8 | 0.001*[c] |
| Fat (kg) | 37.9 ± 2.0 | 20.0 ± 1.8 | 0.001*[b] |
| Dry lean tissue mass (kg) | 21.2 ± 1.4 | 14.2 ± 1.2 | 0.001*[b] |
| Lean tissue mass (kg) | 64.02 ± 3.4 | 46.2 ± 3.0 | 0.001*[b] |

*Note*. Values are expressed as mean ± standard deviation (SD) and frequencies (%). BMI = Body mass index.
[a]Fisher's Exact Test
[b]Two-sample t-test
[C]Welch's Anova
[d]Wilcoxon rank-sum test
*$p \leq 0.05$

**Musculoskeletal Pain Questionnaire**

Pain during the last week

In both the group with and without obesity, eight participants (72.7% and 61.5%, respectively; p = 0.679) reported experiencing pain during the last week (Figure 2). The mean pain intensity (score out of 10) in the last seven days was comparable for adolescents with obesity (OB) (4.5 ± 0.8) and (2.2 ± 0.8) for lean adolescents (LA) (p = 0.083) (Figure 3). In terms of pain location, OB reported the lower back as the most frequent painful location (five times), followed by the ankle/foot (four times), the knee and neck (three times), and the hand/wrist and hip/pelvis (two times). Both the shoulder and upper back were mentioned only once. In LA, the most frequent painful locations were the knee and shoulders (three times). The ankle/foot (two times) and the hand/wrist, neck, upper back, lower back, and hip/pelvis (once) were less frequently reported as painful. No one reported the elbow as a painful location (Figure 4).

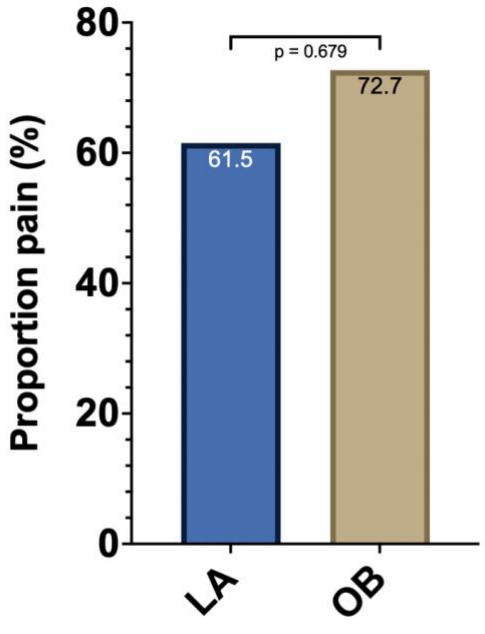


***Figure 2: Between-group differences in the proportion reporting pain in the last week***

*Note*. P-value represents the difference in the proportion of pain in the last week between adolescents with and without obesity. Data are reported as percentages. LA = adolescents without obesity (n = 13); OB = adolescents with obesity (n = 11).

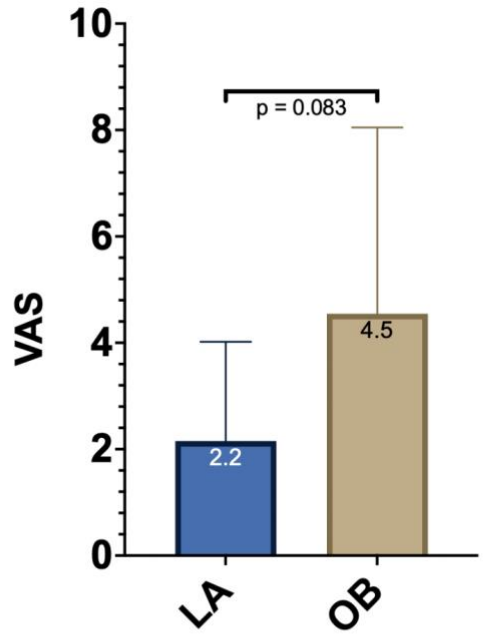


***Figure 3: Between-group differences in Visual Analogue Scale (VAS) pain scores during the last week***

*Note*. P-value represents the difference in Visual Analogue Scale (VAS) pain scores between adolescents with and without obesity. Data are reported as mean ± SD. A higher score indicates greater pain intensity. VAS = Visual Analogue Scale. LA = adolescents without obesity (n = 13); OB = adolescents with obesity (n = 11).

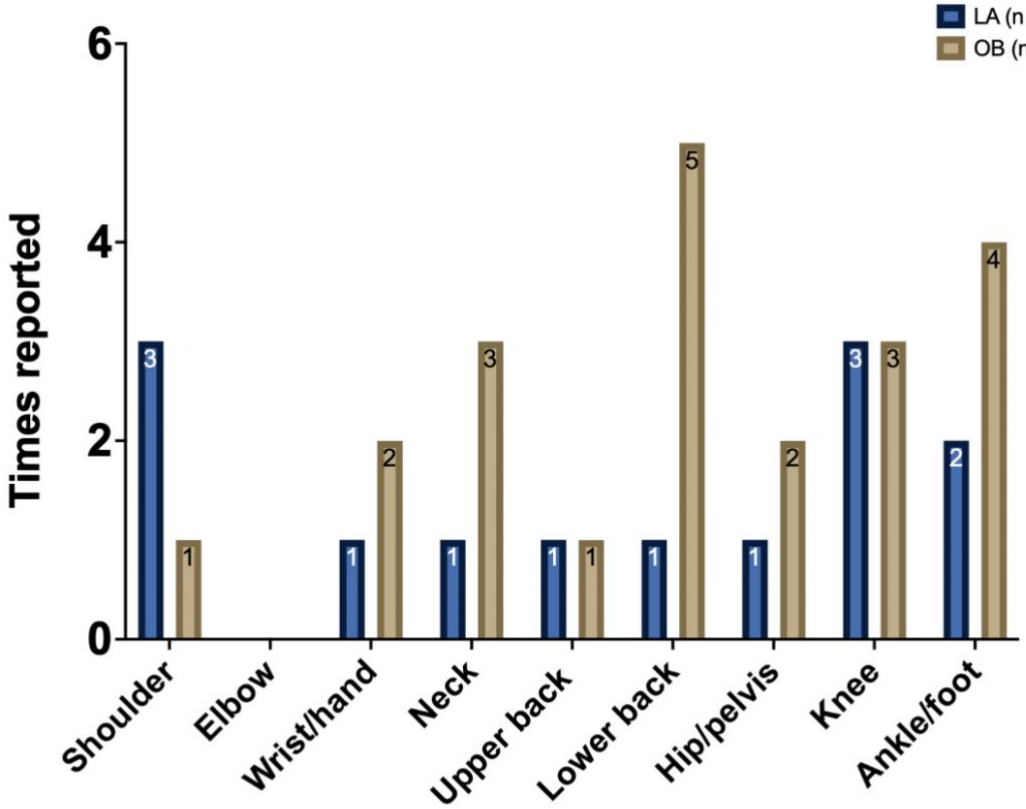


***Figure 4: Graphical representation of the painful locations within both groups***

*Note*. Bar height represents the number of times a specific location is reported as painful. All adolescents who reported pain are included in this visualization.

Chronic pain

Four OB (36.4%) reported experiencing chronic pain, defined as continuous or recurring pain in the last three months, compared to zero in LA ($p = 0.031$; Figure 5). Six OB (54.5%) reported having ever experienced an episode of chronic pain before, compared to two LA (15.4%). However, this difference was not statistically significant ($p = 0.083$; Figure 6).

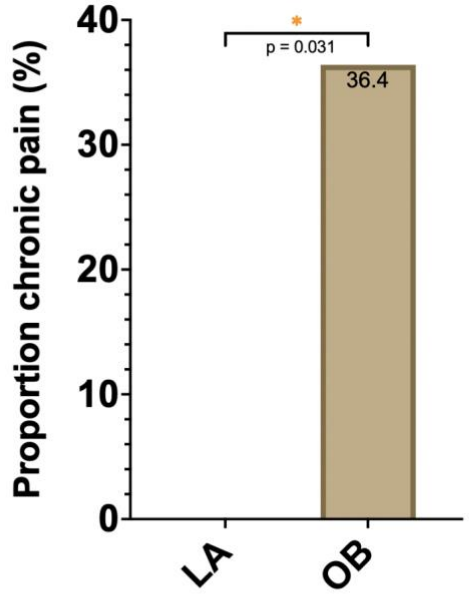


***Figure 5: Between-group differences in the proportion reporting chronic pain at the time of taking the questionnaire***

*Note*. P-value represents the difference in the proportion reporting chronic pain at the time of taking the questionnaire between adolescents with and without obesity. Data are reported as percentages. Asterisk represents significant ($p < 0.05$) between-group differences. Chronic pain defined as continuous or recurring pain in the last three months. LA = adolescents without obesity (n = 13); OB = adolescents with obesity (n = 11).

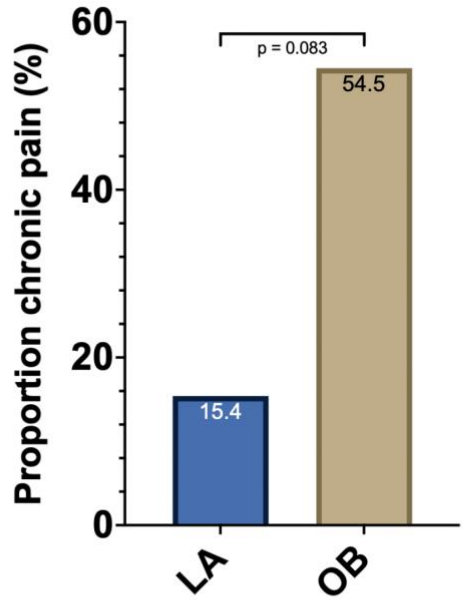


***Figure 6: Between-group differences in the proportion who ever experienced an episode of chronic pain***

*Note*. P-value represents the difference in the proportion who ever experienced chronic pain between adolescents with and without obesity. Data are reported as percentages. Asterisk represents significant ($p < 0.05$) between-group differences. Chronic pain defined as continuous or recurring pain in the last three months. LA = adolescents without obesity (n = 13); OB = adolescents with obesity (n = 11).

Multisite pain

Six OB (54.5%) experienced multisite pain, defined as pain in two or more locations, during the past week versus three LA (23.1%) ($p = 0.206$; Figure 7). OB reported an average of 1.9 ± 0.4 painful locations during the last week versus 1.1 ± 0.4 in the LA group ($p = 0.207$; Figure 8).

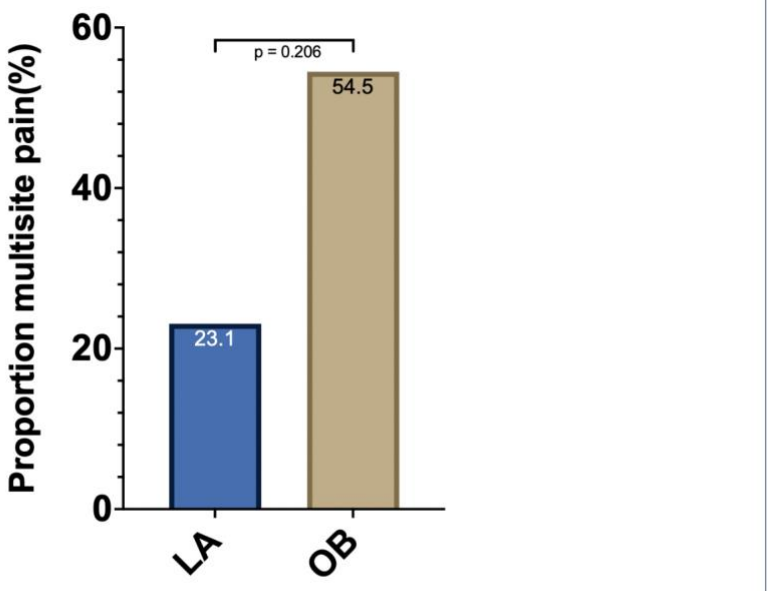


***Figure 7: Between-group differences in the proportion reporting multisite pain in the last week***

*Note*. P-value represents the difference in the proportion reporting multisite pain in the last week between adolescents with and without obesity. Data are reported as percentages. Asterisk represents significant ($p < 0.05$) between-group differences. Multisite pain defined as pain in two or more sites. LA = adolescents without obesity (n = 13); OB = adolescents with obesity (n = 11).

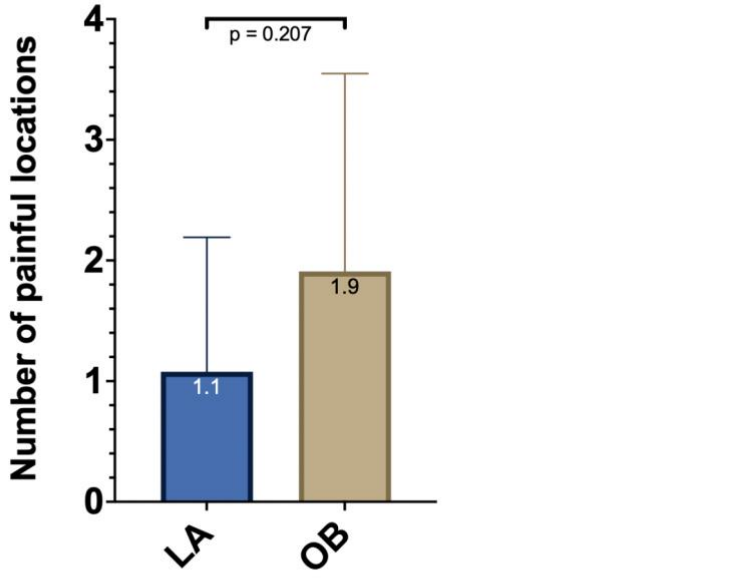


***Figure 8: Between-group differences in the mean number of painful locations during the past week***

*Note*. P-value represents the difference in number of painful locations between adolescents with and without obesity. Data are reported as mean ± SD. A higher score indicates a greater number of painful locations.

Next, the combinations of pain locations reported by adolescents with obesity and multisite pain (OB-P) were examined (Figure 9). The upper limb, spine, and lower limb were reported three, five, and five times respectively. Three adolescents exhibit a combination of the spine and lower limbs. The combination of the upper limb, spine, and lower limb is reported once. A combination of the upper limb and spine and the upper and lower limbs are reported once. Finally, all painful sites that the OB-P reported were checked for the presence of pain in adjacent regions (Table 2). Two individuals showed pain in adjacent regions; one adolescent reported pain in the ankle and knee region, and a second adolescent reported pain in the following adjacent regions: hip/pelvis, lower back, upper back, and neck.

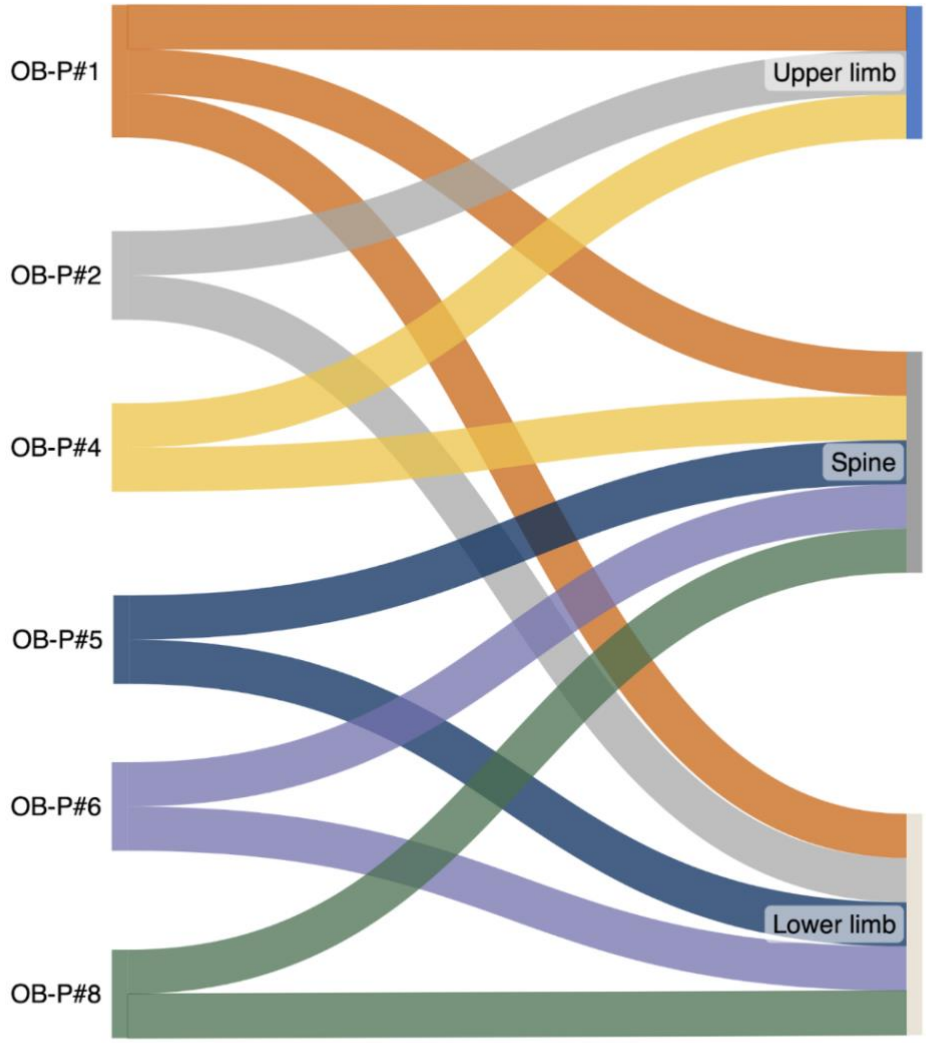


***Figure 9: Combinations of painful locations within the group of adolescents with obesity who experienced multisite pain in the past week (n = 6).***

*Note.* Each line represents a painful location of an individual. OB-P = adolescents with obesity and multisite pain.

***Table 2***

*Painful locations within the group of adolescents with obesity and multi-site pain (n=6)*

| | Ankle/foot | Knee | Hip/pelvis | Lower back | Upper back | Neck | Shoulder | Elbow | Wrist/hand |
|---|---|---|---|---|---|---|---|---|---|
| OB-P #1 | x | | | x | | | | | x |
| OB-P #2 | x | x | | | | | x | | |
| OB-P #4 | | | | x | | | | | x |
| OB-P #5 | x | | x | x | x | x | | | |
| OB-P #6 | | x | | x | | x | | | |
| OB-P #8 | | x | | x | | x | | | |

*Note.* Painful locations per adolescent with obesity and multisite pain are reported as 'x', colors indicate pain in two or more adjacent regions. OB-P = adolescents with obesity and multisite pain.

**Functional Disability Inventory (FDI), Pain Catastrophizing Scale (PCS), and Fear of Pain Questionnaire - Youth edition (FOPQ-Y)**

For the between-group comparison of these questionnaires, the participants were divided into three groups: lean adolescents (LA), obese adolescents (OB), and obese adolescents with multisite pain (OB-P).

Functional Disability Inventory (FDI)

There was a significant difference in the mean scores of the FDI between the LA, OB, and OB-P (2.0 ± 1.7; 5.6 ± 2.7; and 9.2 ± 2.5, respectively; p = 0.037; Figure 10). Post-hoc tests revealed that OB-P experienced more functional disability when compared to LA (p = 0.025).

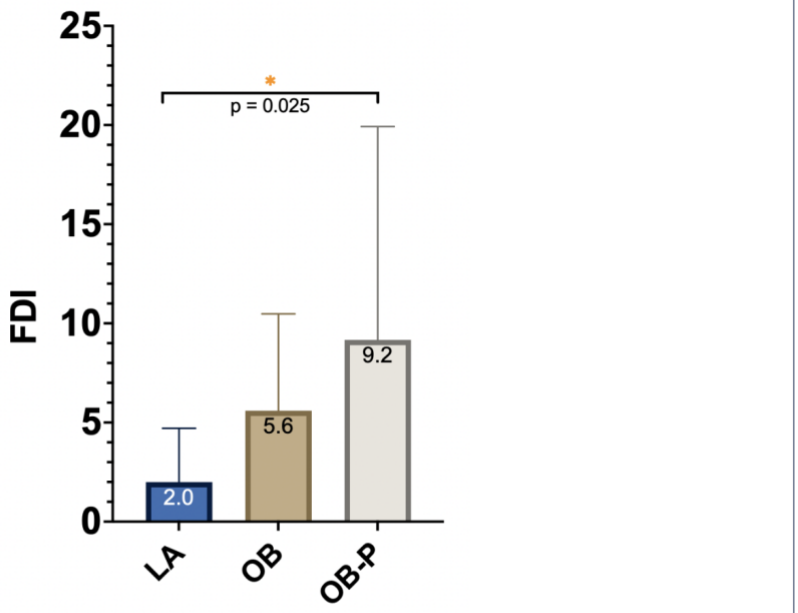


***Figure 10: Between-group differences in Functional Disability Inventory (FDI) scores***

*Note*. P-value represents the difference in mean Functional Disability Inventory (FDI) scores between adolescents without obesity, adolescents with obesity, and adolescents with obesity and multisite pain. Data are reported as mean ± SD. Asterisk represents significant ($p < 0.05$) between-group differences. A higher score represents a greater degree of functional disability. FDI = Functional Disability Inventory; LA = adolescents without obesity (n = 13), OB = adolescents with obesity (n = 5); OB-P = adolescents with obesity and multisite pain (n = 6).

Pain Catastrophizing Scale (PCS)

There was a significant difference in the mean scores of the PCS between the LA, OB, and OB-P (7.5 ± 1.2; 10.0 ± 2.0; and 17.5 ± 1.8, respectively; p = 0.008; Figure 11). Post-hoc tests revealed that OB-P experienced more catastrophizing thoughts when compared to LA (p = 0.001) and OB (p = 0.012), potentially including a greater sense of helplessness, rumination, or magnification.

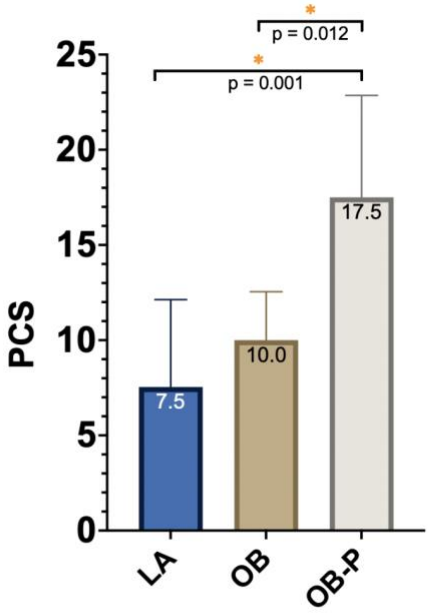


***Figure 11: Between-group differences in Pain Catastrophizing Scale (PCS) scores***

*Note.* P-value represents the difference in mean Pain Catastrophizing Scale (PCS) scores between adolescents without obesity, adolescents with obesity, and adolescents with obesity and multisite pain. Data are reported as mean ± SD. Asterisk represents significant ($p < 0.05$) between-group differences. A higher score represents a greater degree of pain catastrophizing. PCS = Pain Catastrophizing Scale; LA = adolescents without obesity (n = 13), OB = adolescents with obesity (n = 5); OB-P = adolescents with obesity and multisite pain (n = 6).

Fear of Pain Questionnaire - Youth edition (FOPQ-Y)

Statistical analyses are performed on the total score as well as the pain and avoidance subscales. There was a significant difference in the mean total scores of the FOPQ between LA, OB, and OB-P (15.2 ± 3.4; 22.8 ± 5.5; and 31.5 ± 5.0, respectively; p = 0.042; Figure 12, A). Post-hoc tests revealed that OB-P experienced more pain-related anxiety when compared to LA (p = 0.014). When looking at the avoidance subscale, the mean scores for LA, OB, and OB-P were 5.9 ± 1.7; 9.4 ± 2.7; and 12.8 ± 2.5, respectively (p = 0.091; Figure 12, B). Finally, looking at the pain subscale, the mean scores for LA, OB, and OB-P were 9.3 ± 2.1; 13.4 ± 3.3; and 18.7 ± 3.0, respectively (p = 0.058; Figure 12, C).

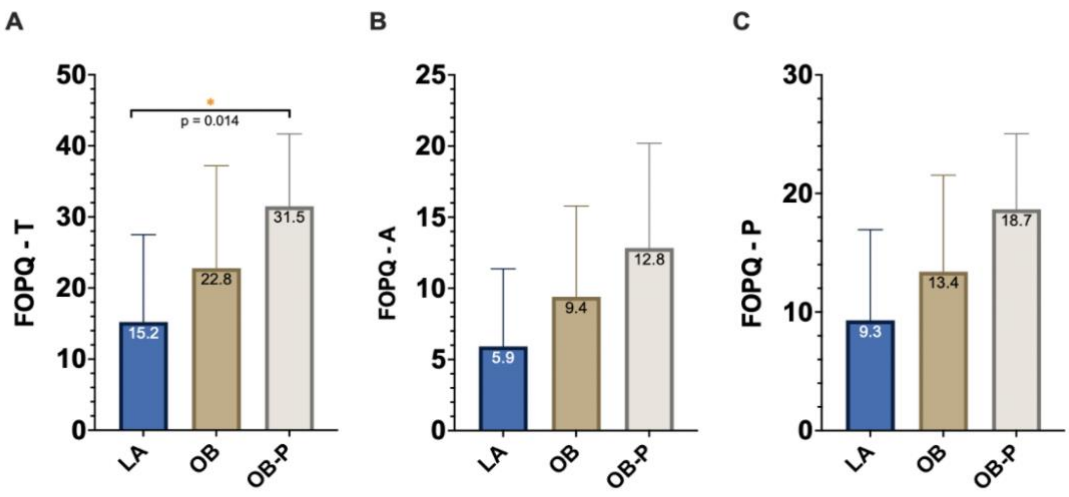


***Figure 12: Between-group differences in Fear of Pain Questionnaire (FOPQ) total scores (A), 'avoidance' subscale (B), and 'pain' subscale (C)***

*Note*. P-value represents the difference in mean Fear of Pain Questionnaire (FOPQ) scores between adolescents without obesity, adolescents with obesity, and adolescents with obesity and multisite pain. Data are reported as mean ± SD. Asterisk represents significant ($p < 0.05$) between-group differences. Higher scores indicate a greater degree of pain-related fear and avoidance. FOPQ = Fear Of Pain Questionnaire; LA = adolescents without obesity (n = 13), OB = adolescents with obesity (n = 5); OB-P = adolescents with obesity and multisite pain (n = 6).

## Discussion

Understanding how adolescents with obesity experience musculoskeletal pain, with specific attention to multisite pain and pain-related maladaptive cognitions, is critical to develop effective and tailored interventions. To the authors' knowledge, this is the first study to investigate pain-related cognitions and multisite pain in adolescents with obesity. The preliminary data from the current study revealed that over 50% of the adolescents with obesity reported experiencing multisite musculoskeletal pain within the past seven days. These adolescents demonstrated higher levels of functional disability compared to their lean counterparts. Furthermore, adolescents with obesity and multisite pain exhibited greater pain catastrophizing tendencies than those without, regardless of obesity status. Additionally, adolescents with obesity and multisite pain reported higher levels of fear of pain than their lean counterparts.

In the past seven days, adolescents with obesity reported experiencing pain more frequently than lean adolescents. Furthermore, adolescents with obesity had a higher average number of pain locations and reported higher average pain intensity than their lean counterparts. They also reported experiencing chronic pain more often at the time of completing the questionnaire compared to controls, and adolescents with obesity had already experienced an episode of chronic pain more often than controls. However, not all these differences were statistically significant, presumably due to the small sample size, considering the p-values approached 0.05 in each case. These findings reinforce the current literature in which it is clear that adolescents with obesity are more likely to report (chronic) pain with higher pain scores (Deere et al., 2012; Smith et al., 2014).

In the group with obesity, the mean number of painful locations during the last week was slightly higher compared with their lean counterparts. Again, this difference was not statistically significant. The adolescents with obesity mainly reported pain in the spine and lower limb and, to a lesser extent, in the upper limb during the past seven days. These painful

locations are consistent with the findings of previous studies (Azabagic & Pranjic, 2019; Stovitz et al., 2008) and could be explained by increased biomechanical loading on these weight-bearing regions. For example, a quasi-linear relationship exists between body weight and joint loading at the ankle, knee, and hip level during walking (Sanford et al., 2014). This again highlights the benefits of weight loss in the obese population, given that per kilogram of weight loss, the pressure at the knee joint level during walking decreases by 2.2 kg (Aaboe et al., 2011).

Over 50% of the adolescents with obesity reported experiencing multisite musculoskeletal pain within the past seven days. Still, musculoskeletal pain is usually diagnosed and treated as localized pain in clinical practice. This is troublesome since there is a strong inverse relationship between the number of pain sites and functional ability (Kamaleri et al., 2008). Further examining the pattern of multisite pain in adolescents with obesity yielded interesting results. These showed that pain did not remain purely in the same body segment (lower limb, spine, upper limb) in any participant. Each participant showed a combination of at least two painful body segments, and one even showed a combination of the three segments. Even more interesting was that only two out of six had pain in adjacent joints. Park et al. showed that a painful joint inhibits the surrounding musculature (Park & Hopkins, 2013), potentially increasing the risk of developing pain in adjacent joints. Also, a painful joint (e.g., the knee joint) in the lower limbs can lead to altered gait biomechanics in the kinetic chain (e.g., the ankle and hip joint) (Ro et al., 2019), potentially further increasing the risk of developing pain in adjacent joints. These findings suggest an important role for factors other than biomechanics in explaining the pattern of multisite pain. Considering the biopsychosocial model of pain and the findings on pain-related cognitions presented in this study indicate that psychosocial factors also play an important role in adolescents with obesity and multisite pain. Therefore, this study's results indicate that factors beyond biomechanics may significantly influence the manifestation of multisite pain. In light of the biopsychosocial model of pain and the findings regarding pain-related cognitions presented in this study, it is evident that psychosocial factors are pivotal in adolescents with obesity experiencing multisite pain. Of

interest, multisite pain in adolescents has been associated with mental health problems, possibly resulting in an increased risk of mental health disorders in young adulthood (Eckhoff et al., 2017). Furthermore, obesity has been consistently associated with chronic low-grade inflammation (Khanna et al., 2022), which, in turn, has been associated with musculoskeletal pain (Zhou et al., 2021). It is hypothesized that multisite pain in adolescents with obesity may be attributed to the complex interplay between biomechanical, inflammatory, and psychosocial factors (S. H. Chin et al., 2020).

Adolescents with obesity and multisite pain demonstrated higher levels of functional disability than their lean counterparts, suggesting that the presence of both obesity and pain in multiple body sites contributes to greater impairment in daily functioning for these individuals. Furthermore, adolescents with obesity and multisite pain exhibited greater pain catastrophizing tendencies than those with or without obesity who did not report multisite pain. Pain catastrophizing refers to the tendency to magnify pain's significance and feel helpless in coping with it. The higher levels of pain catastrophizing in adolescents with obesity and multisite pain suggest that they may have more negative cognitive and emotional responses to their pain experiences. Additionally, adolescents with obesity and multisite pain reported higher fear of pain than their lean counterparts. This fear of pain may contribute to avoidance behaviors and further impairments in their daily lives. It is worth noting that fear of pain and pain catastrophizing are associated with higher levels of disability (Brosbe et al., 2022; Martin et al., 2007) in previous research studies, potentially explaining the higher levels of functional disability found in this study in adolescents with obesity and multisite pain. To the authors' knowledge, this is the first study to examine pain-related cognitions in this population. This has potentially far-reaching clinical implications. Catastrophizing pain is predictive of pain intensity, impairment, and psychological distress independent of the degree of physical impairment in chronic pain patients (Severeijns et al., 2001). Interpreting pain as threatening leads to developing pain-related anxiety, leading to avoidance and hypervigilance. This is followed by restriction, sedentarism, and depression (Simons et al., 2011). In this way, the adolescent with obesity might end up in a vicious cycle.

A distinct strength of this study is the novelty, as this is the first study, to the authors' knowledge, to examine pain-related cognitions and multisite pain in adolescents with obesity. Often, pain research examines only one specific site, whereas, in this study, as many as nine sites were surveyed simultaneously. Since multisite pain is more frequent than single-site pain (Kamaleri et al., 2008), this is an interesting, innovative way to research pain. To avoid recall bias, multisite pain was surveyed within seven days. Furthermore, the cross-sectional design is ideally suited to assess the prevalence of multisite pain in the obese adolescent population. However, the current study also had some limitations. The small sample size is a significant limitation, resulting in limited statistical power. This study is also prone to some forms of bias. There is a high risk of recall bias when surveying chronic pain due to the extended period surveyed. Moreover, the adolescents completed the questionnaires independently without supervision, significantly increasing the risk of information bias. Furthermore, this is a cross-sectional study, so that no firm conclusions can be made about causality. Still, this study does constitute a nice setup for new hypotheses and future research.

In light of the findings from this study, recommendations for both the clinical field and future scientific research can be made. For the clinical field, it is crucial to recognize the frequent occurrence of multisite pain in adolescents with obesity and acknowledge that it is likely the result of a complex interaction between various factors, such as biomechanics, physiology, and psychology. Clinicians should therefore be mindful not to focus solely on individual pain sites but consider the entirety of painful locations. A comprehensive approach that addresses the underlying factors contributing to multisite pain is essential for effective management and treatment. Regarding future research directions, further investigation with larger sample sizes is warranted to delve deeper into multisite pain in adolescents with obesity. A more comprehensive understanding of the underlying mechanisms can be achieved by including a range of relevant factors, such as biomechanical, inflammatory, and psychosocial aspects. Longitudinal studies that examine the temporal relationship between these factors and the development of multisite pain would also provide valuable insights. Additionally, exploring

potential interventions targeting these complex interactions could pave the way for more tailored and effective approaches to managing multisite pain in this population.

## Conclusion

In conclusion, this study is the first to examine pain-related cognitions and multisite pain in adolescents with obesity. The preliminary data revealed that a significant proportion of adolescents with obesity reported experiencing multisite musculoskeletal pain in the past week. These individuals also exhibited higher levels of functional disability compared to their lean counterparts. Moreover, adolescents with obesity and multisite pain displayed greater tendencies for pain catastrophizing, which suggests that they may have more negative cognitive and emotional responses to their pain. Additionally, these adolescents reported higher fear of pain than their lean counterparts. These findings emphasize the need to address and manage pain-related cognitions, fear of pain, and multisite pain in adolescents with obesity to improve their quality of life. Future research should further explore (interventions targeting) these factors to develop effective strategies for this population.

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