REVIEW ARTICLE

Pediatrics

Obesity and overweight as risk factors for low back pain in children and adolescents: a meta-analysis

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BACKGROUND: Childhood obesity and overweight are associated with musculoskeletal pain, but the association between low back pain (LBP) and overweight/obesity in this population needs clarification. The objective of this meta-analysis is to ascertain the relationship between LBP and obesity/overweight in children and adolescents.
METHODS: Various databases and specialized journals were queried from inception to October 2022. Encompassed were all studies examining the association between overweight or obesity and LBP among participants aged 6 to 18 years. The ROBINS-E tool was employed to assess bias. Random-effects models were used to pool results across studies, with location-scale models used to search for moderator variables where evidence of heterogeneity was found.
RESULTS: In total, 34 studies were incorporated. Four studies had a low risk of bias, while the remaining studies had some concerns. Nine studies evinced an association between overweight and LBP, in contrast to normal weight, yielding an OR of 1.13 (95% CI 1.10–1.16) and no heterogeneity. Eight studies demonstrated a similar association between obesity and LBP compared to normal weight, with an OR of 1.27 (95% CI 1.20–1.34) and no heterogeneity. Ten studies established an association between overweight/obesity and LBP compared to normal weight, yielding an OR of 1.18 (95% CI 1.14–1.23) and no heterogeneity. Finally, nineteen studies showcased an association between body mass index (BMI) and LBP, with an OR of 1.19 (95% CI 1.03–1.39) with evidence of heterogeneity. For this last analysis, we compared the mean BMI in groups and transformed results to log OR, and then retransformed to OR.
CONCLUSION: Overweight and obesity may be risk factors for LBP in children and adolescents. The association between LBP and obesity appears to be stronger than with overweight. However, the analysis revealed considerable heterogeneity and risk of bias across studies.

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INTRODUCTION

Low back pain (LBP) is a common condition among young population and the prevalence and severity are increasing [1, 2]. Among healthy children, the estimated point prevalence was 12%, week prevalence 17%, year prevalence reached 33%, and lifetime prevalence 39% [3], and the trajectory of back pain in this population was highly heterogeneous [4]. Young people with LBP often experience a negative impact on their activities of daily living, sport participation and school activities, even leading to school absenteeism [5, 6]. Preventing the development of this condition is essential for its management, and the approach to lifestyle habits plays a fundamental role [6]. In addition, identifying and managing LBP in childhood will minimize the impact in adulthood [2]. Modifiable factors should be the focus of attention to promote healthy habits that continue into adulthood [7]. Obesity is a crucial modifiable risk factor in developed countries, with particular importance in childhood, and its prevalence has been steadily improving in recent decades [8, 9]. The risk of obesity in childhood has been increased in recent years. In addition, the risks of weight gain can be intensified in the spine, which combined with a lack of muscle strength during growth, low physical activity level, increased sitting time, and psychosocial factors, among others, can lead to the appearance of back pain [10]. Besides, the World Health Organization (WHO) advocates that weight and adiposity control in children and adolescents is essential to improve overall health [11]. One of the most widely used methods for calculating a patient's level of overweight or obesity is the calculation of body mass index (BMI). Although this method does not directly calculate an individual's body fat, it is a commonly used indicator for assessing different health risks due to its ease of use and low cost [12].

The potential relationship between weight status and musculoskeletal pain in young people needs to be studied, as it may lead to a vicious circle in which being overweight or obese can lead to musculoskeletal pain, leading to a low level of physical activity that aggravates the pain [13].

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Although there are meta-analyses [13, 14], systematic reviews [10, 15], and studies on guidelines and recommendations [16, 17] relating obesity and overweight and musculoskeletal pain, the association between obesity and overweight and LBP in children and adolescents remains inconclusive.

As the prevalence of obesity, overweight, and LBP continues to rise, and their adverse effects on the health of young individuals become more apparent, it is imperative to conduct a meta-analysis to clarify the relationship between these public health concerns.

Therefore, this meta-analysis aimed to quantify the relationship between obesity and overweight and LBP in children and adolescents.

METHODS

Study design

This meta-analysis was carried out and reported following the Preferred Reporting Items for Systematic Reviews and Meta-analyses (PRISMA) recommendations [18], for more information, see supplementary information (Table 1), and registered with PROSPERO (CRD42022357033).

Eligibility criteria

We included observational studies that examined the association between LBP and obesity and overweight using BMI. Thus, we included studies that associated BMI category (normal weight, overweight and obese) and LBP; those that compared BMI between two groups (those with LBP and those without LBP); and those studies that examined the association between LBP and BMI quantitatively. In those studies where BMI categories were studied, the normal weight group should be the reference group. Studies had to be published or completed at the date of the search. No language restrictions were applied. Participants had to be aged between 6 and 18 years. Studies whose sample mostly had LBP due to pathology were excluded. Studies had to report results by analyzing the association between BMI and LBP using odds ratio (OR), relative risk (RR), or the difference of BMI between groups (participants with and without LBP).

Data sources

Different methods were used to search for articles: specialized health science and general databases, journals specialized in the topic, references from experts and citations of included studies. Published and unpublished studies were searched.

The different databases were PubMed, Web of Science, SCOPUS, PsycINFO, CENTRAL, PEDro, LILACS, IBECS, and ScienceDirect. The specialist journals reviewed were BMJ and Spine.

Search strategy

The search strategy was carried out from the inception of the databases and journals to October 2022, with a combination of the following keywords: “Low back pain”, “back pain”, “backache”, “LBP”, “body mass index”, “BMI”, overweight, obesity, “pediatric obesity”, “paediatric obesity”, “morbid obesity”, “prevalence”, “risk factor”, children, adolescent, teen, youth and school. For more details about the search terms and combinations, see supplementary information (Table 2).

The search was carried out by one author (JGM) and all authors reviewed and decided which studies were included.

Data extraction

Data extraction from the articles was carried out following a previously elaborated coding manual, so that the two authors who carried out the coding and the third author for the consensus had the same criteria for extracting the information. This manual was based on Lipsey’s recommendations [19], and variables were classified into 3 categories: substantive (context, and participant), methodological, and extrinsic variables. For more information, see supplementary information (Table 3).

Data from each study were collected separately by two authors (JGM, ICM). To resolve disagreements, a third author (AGC) intervened to decide on the extracted data. Additional data were requested directly from the authors of the collected studies when required.

In order to assess the reliability of the coding process, Cohen’s Kappa was calculated for qualitative variables and the intraclass correlation coefficient (ICC) [20] for quantitative variables. Kappa and ICC values were 1 and hence no intervention by a third author was necessary.

Risk of bias assessment

Risk of bias (RoB) was evaluated using the ROBINS-E tool version 2022 [21], which is specifically designed for observational studies that measure the impact of an exposure. Two authors independently performed the assessment of RoB (JGM and ICM). RoB was evaluated for each of the seven domains individually and then assigned a final rating based on the recommendations provided by the tool authors. The assessment classified RoB as “low”, “some concerns”, or “high”. Inter-rater agreement was measured using Cohen’s Kappa, which resulted in a score of 1.

Outcome measures

Studies should analyze the association between BMI and LBP – either with numerical variables or categorical ones – or provide sufficient data to analyze it. When BMI was reported by category (e.g., normal weight, overweight, obese), we used the cut-off points considered by the authors of the primary studies.

Effect size index

The studies that examined the relationship between BMI and LBP through various categories utilized the OR to calculate the effect size. In cases where d indices were provided, ORs were prioritized to ensure comparability across studies. The effect measure for the analyses was the log OR (LOR), which was then back-transformed to the ratio scale to facilitate interpretation.

The studies comparing the BMI of participants with LBP to those without LBP (for which d indices could be computed) were linked to studies that reported the logistic regression values. In order to facilitate a more comprehensive analysis and increase the reliability of the results, d indices were converted to OR using the formula $LOR = 1.65d$ [22]. This harmonization of indices allowed for the inclusion of a larger number of studies in the analysis, increasing the reliability of the results.

The calculation of the effect size was conducted by the first author (JGM) under the supervision of another researcher (JLL).

Data analysis

The calculations were performed using a random-effects model using the correction proposed by Hartung [23]. In order to visually and numerically represent the individual effects of each study and the overall effect, a forest plot with a 95% confidence interval was created. Heterogeneity was assessed using the I^2 index and prediction intervals [24]. When some evidence of heterogeneity was found and the number of studies allowed for it, moderator variable analyses were conducted using categorical variables (ANOVA) and numerical variables using location-scale models, which enable to identify moderators of the outcome size and/or amount of heterogeneity across outcomes [25]. The location-scale model was used to analyze whether study characteristics affect the magnitude of the observed effects (location) and whether the observed effects are more heterogeneous depending on specific features of the primary studies (scale). When studies provided both unadjusted and adjusted data, the adjusted data was used.

To assess publication bias, Egger’s test and funnel plot were utilized. The statistical analyses were conducted using the R

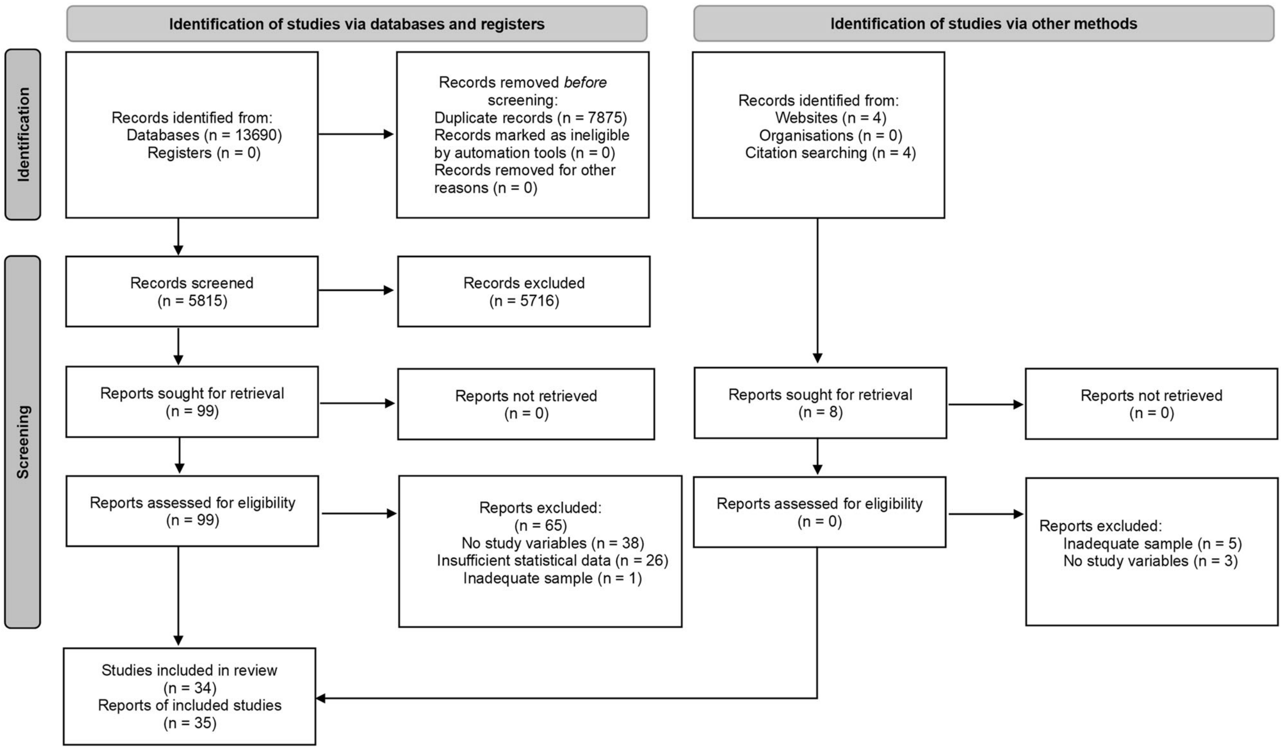

Fig. 1 PRISMA flow diagram. Summary of identified, screened, and included studies from databases and registers.

software [26] with the "metafor" package [27]. The PRISMA checklist [18] was utilized to verify the completeness and transparency of the meta-analysis process, for more information, see supplementary information (Table 1).

RESULTS

Out of the initial 13,694 results, 13,686 were found in databases and 8 were from other sources. After removing duplicate entries and carefully reviewing the remaining articles, 99 articles were selected for further examination. Most of the articles were subsequently eliminated due to various reasons, such as not including our variable of interest, insufficient information for statistical analysis, or the inclusion of adult samples. Finally, a total of 35 papers were included in the final analysis [7, 28–61]. One study was reported in two papers [44, 45], these two papers were counted as one in the analysis. Figure 1 shows the process of identification and selection of the studies. Three studies were finally excluded because they did not provide sufficient statistical information [62–64].

Study characteristics

The included studies were published between 1994 and 2021. Twenty-seven studies were cross-sectional studies [7, 28–39, 41, 44–49, 52–54, 56, 57, 59, 60], six were cohort studies [40, 42, 43, 50, 55, 61] and two were case-control studies [51, 58]. Studies were conducted in several countries, including Brazil [7, 33, 34, 47, 48, 52], Kuwait [28, 36], Iran [29, 35, 38, 56], Spain [30, 41], Japan [31, 32, 37], Colombia [39], Bosnia and Herzegovina [40], Australia [42], Finland [43, 61], Portugal [44, 45], Germany [46], Switzerland [49, 53, 55], Israel [50], China [51, 54], USA [57], England [58, 60] and Greece [59]. Based on the age of participants, six studies were conducted in children [7, 29, 34, 39, 41, 53], twelve in adolescents [30, 33, 36, 38, 43, 46, 48, 50, 57–59, 61], and seventeen included children and adolescents [28, 31, 32, 35, 37, 40, 42, 44, 45, 47, 49, 51, 52, 54–56, 60]. Most participants were recruited from educational institutions [7, 28, 29, 33–36, 38–41, 44, 45, 47, 48, 51–57, 59–61], others from sports teams [30–32, 37, 46], from community [42, 49, 50] and one unspecified [58]. The percentage of male varied from zero percent [38] to hundred percent [55]. Heterogeneity was found with respect to LBP prevalence, with studies reporting LBP lifetime prevalence [33, 34, 38, 41, 46, 47, 49, 55], LBP period prevalence [7, 28–30, 35, 36, 39, 42–45, 48, 51–54, 56, 57, 60, 61], and LBP point prevalence [31, 32, 37, 40, 58, 59]. The criteria used to categorize participants into groups according to BMI were heterogeneous, using WHO criteria [65] in three studies [28, 29, 36], International Obesity Task Force criteria [66, 67] in seven studies [33, 41, 43–45, 47, 48], and Centers for Disease Control and Prevention (CDC) criteria [68] in two studies [40, 50], and two unspecified [34, 52]. The total number of participants in all the studies were 859,248. For more information, see Table 1.

Regarding the prevalence of LBP, there was significant heterogeneity. For example, in lifetime prevalence, it ranged from 34.74% [55] to 76.97% [33]. Additionally, there was heterogeneity among different BMI subgroups, with a higher prevalence in studies involving adolescents compared to those including only children. Concerning the period prevalence, there was substantial temporal heterogeneity. In one-month prevalence, it varied from 13.1% [52] to 39.72% [39], and this prevalence seemed to be higher in studies that exclusively involved children. The one-year prevalence ranged from 18% [35] to 57.36% [48], with a higher prevalence in studies exclusively involving adolescents. Lastly, regarding point prevalence, it ranged from 4.8% in athletes [31] to 22.74% in non-athlete populations [40], up to 50% in non-athlete populations [58]. This prevalence appeared to be higher in studies that solely included adolescents.

Concerning the incidence of overweight and obesity in the studies included, it was noted that in all studies except one [28] more than half of the participants had a normal weight. The prevalence of participants with normal weight varied from 43.55% [28] to 90.41% [39]. Regarding overweight, the prevalence ranged

Table 1. Characteristics of the studies.

Study	Design	Country	Number of participants	Age category	% Male	BMI category diagnostic method	Source	Type of prevalence	Period prevalence (months)
Santos [7]	Cross-sectional	Brazil	377	Children	49	NA	Educational institution	Period	1
Al-Taiar [28]	Cross-sectional	Kuwait	760	Mixed	50.66	WHO	Educational institution	Period	6
Rezapur-Shahkolai [29]	Cross-sectional	Iran	693	Children	45.89	WHO	Educational institution	Period	1
Cejudo [30]	Cross-sectional	Spain	19	Adolescent	42.1	NA	Sport team	Period	12
Yabe [31]	Cross-sectional	Japan	896	Mixed	67.7	NA	Sport team	Point	NI
Yabe [32]	Cross-sectional	Japan	566	Mixed	25.62	NA	Sport team	Point	NI
Schwertner [33]	Cross-sectional	Brazil	330	Adolescent	26	International Obesity Task Force	Educational institution	Lifetime	NI
dos Santos [34]	Cross-sectional	Brazil	150	Children	49.3	No specific	Educational institution	Lifetime	NI
Aghilinejad [35]	Cross-sectional	Iran	472	Mixed	57.2	NA	Educational institution	Period	12
Akbar [36]	Cross-sectional	Kuwait	NI	Adolescent	56.4	WHO	Educational institution	Period	6
Yabe [37]	Cross-sectional	Japan	NI	Mixed	95.52	NA	Sport team	Point	NI
Noormohammadpour [38]	Cross-sectional	Iran	372	Adolescent	0	NA	Educational institution	Lifetime	NI
Angarita-Fonseca [39]	Cross-sectional	Colombia	73	Children	80.8	NA	Educational institution	Period	1
Azabagic [40]	Cohort	Bosnia and Hezergovina	1,315	Mixed	49.6	CDC	Educational institution	Point	NI
Muntaner-Mas [41]	Cross-sectional	Spain	2,032	Children	53.6	International Obesity Task Force	Educational institution	Lifetime	NI
Smith [42]	Cohort	Australia	1,088	Mixed	47.9	NA	Community	Period	1
Mikkonen [43]	Cohort	Finland	4,525	Adolescent	43.81	International Obesity Task Force	Community	Period	6
Minghelli [44]	Cross-sectional	Portugal	966	Mixed	45.2	International Obesity Task Force	Educational institution	Period	12
Minghelli [45]	Cross-sectional	Portugal	966	Mixed	45.2	International Obesity Task Force	Educational institution	Period	12
Schmidt [46]	Cross-sectional	Germany	272	Adolescent	58.5	NA	Sport team	Lifetime	NI

Table 1. continued

Study	Design	Country	Number of participants	Age category	% Male	BMI category diagnostic method	Source	Type of prevalence	Period prevalence (months)
Graup [47]	Cross-sectional	Brazil	1,290	Mixed	49.1	International Obesity Task Force	Educational institution	Lifetime	NI
Silva [48]	Cross-sectional	Brazil	326	Adolescent	39	International Obesity Task Force	Educational institution	Period	12
Wirth [49]	Cross-sectional	Switzerland	279	Mixed	45.69	NA	Community	Lifetime	NI
Hershkovich [50]	Cohort	Israel	805,925	Adolescent	56.65	CDC	Community		NI
Yao [51]	Control-cases	China	1,214	Mixed	39.7	NA	Educational institution	Period	3
Onofrio [52]	Cross-sectional	Brazil	1,191	Mixed	36.1	No specific	Educational institution	Period	1
Erne and Elfering [53]	Cross-sectional	Switzerland	189	Children	45	NA	Educational institution	Period	1
Yao [54]	Control-cases	China	2,083	Mixed	46.9	NA	Educational institution	Period	3
Balagué [55]	Cohort	Switzerland	95	Mixed	100	NA	Educational institution and sport team	Lifetime	NI
Mohseni-Bandpei [56]	Cross-sectional	Iran	4,813	Mixed	47.7	NA	Educational institution	Period	1
Chiang [57]	Cross-sectional	USA	55	Adolescent	40	NA	Educational institution	Period	0.5
Jones [58]	Control-cases	England	56	Adolescent	53.57	NA	Educational institution	Point	NI
Korovessis [59]	Cross-sectional	Greece	1,252	Adolescent	47	NA	Educational institution	Point	NI
Watson [60]	Cross-sectional	England	849	Mixed	46.1	NA	Educational institution	Period	1
Nissinen [61]	Cohort	Finland	859	Adolescent	52.5	NA	Educational institution	Period	12

CDC Centers for Disease Control and Prevention, *NA* not applicable, *NI* no information, *USA* United States of America, *WHO* World Health Organization.

Table 2. Prevalence of body mass index categories, prevalence of low back pain, and effect size.

Study	BMI categories prevalence	Prevalence of LBP by BMI category group	OR (95% CI)
Santos [7]	No categories data	Total: 27.32%	BMI and LBP: 1.07 (0.98–1.17)
Al-Taiar [28]	Underweight: 1.57% Normal weight: 43.55% Overweight: 21.71% Obesity: 33.16%	Underweight: 25% Normal weight: 19.94% Overweight: 21.21% Obesity: 22.62% Total: 21.18%	Overweight and LBP: 1.08 (0.43–2.72) Obesity and LBP: 1.17 (0.53–2.59)
Rezapur-Shahkolai [29]	Underweight: 6.78% Normal weight: 67.39% Overweight-obesity: 25.82	Underweight: 27.66% Normal weight: 26.98% Overweight-obesity: 25.14% Total: 26.55%	Overweight-obesity and LBP: 0.88 (0.40–1.94)
Cejudo [30]	No categories data	Total: 42.1%	BMI and LBP: 2.19 (0.52–9.22)
Yabe [31]	No categories data	Judo: 6.9% Kendo: 4.7% Karate: 2.9% Total: 4.8%	BMI and LBP: 1.12 (0.85–1.47) judo 1.07 (0.79–1.47) kendo 0.89 (0.40–1.97) karate
Yabe [32]	No categories data	Total: 9.54%	BMI and LBP: 0.96 (0.70–1.32)
Schwertner [33]	Underweight: 52.67% Normal weight: 43.33% Overweight: 4%	Underweight: 17.72% Normal weight: 20% Overweight: 50% Total: 37.97%	Overweight and LBP: 4 (0.13–122.74)
dos Santos [34]	No categories data	Total: 18%	BMI and LBP: 1.18 (1.10–1.26)
Aghilinejad [35]	Underweight: 5.76% Normal weight: 71.21% Overweight: 17.58% Obese: 5.45%	Underweight: 73.68% Normal weight: 77.02% Overweight: 79.31% Obesity: 72.22% Total: 76.97%	Overweight and LBP: 1.14 (0.28–4.68) Obesity and LBP: 0.78 (0.09–6.78) Overweight-obesity and LBP: 1.03 (0.30–3.57)
Akbar [36]	No categories data	No prevalence data, effect size contributed directly	Overweight and LBP: 1.20 (0.60–2.40) Obesity and LBP: 0.94 (0.52–1.71)
Yabe [37]	No categories data	No prevalence data, effect size contributed directly	BMI and LBP: 1.05 (0.94–1.18)
Noormohammadpour [38]	No categories data	Total: 46.24%	BMI and LBP: 1.18 (1.10–1.26)
Angarita-Fonseca [39]	Normal weight: 90.41% Overweight: 9.59%	Normal weight: 36.36% Overweight: 71.4% Total: 39.72%	Overweight and LBP: 1.59 (0.43–5.91)
Azabagic [40]	Underweight: 4.87% Normal weight: 64.03% Overweight: 18.48% Obesity: 12.62%	Underweight: 32.81% Normal weight: 21.38% Overweight: 22.63% Obesity: 25.9% Total: 22.74%	Overweight and LBP: 1.07 (0.54–2.13) Obesity and LBP: 1.28 (0.59–2.79) Overweight-obesity and LBP: 1.16 (0.66–2.03)
Muntaner-Mas [41]	Underweight: 8.96% Normal weight: 67.57% Overweight-obesity: 23.47%	No prevalence data, effect size contributed directly	Overweight-obesity and LBP: 1.37 (0.87–2.16)
Smith [42]	No categories data	Total: 32.44%	BMI and LBP: 1.23 (1.20–1.27)
Mikkonen [43]	Normal weight: 89.26% Obesity: 10.74%	Normal weight: 35.23% Obesity: 37.86% Total: 35.51%	Obesity and LBP: 1.12 (0.76–1.65)
Minghelli [44]	Underweight: 2.9% Normal weight: 73.29% Overweight: 18.43% Obesity: 5.38%	Underweight:66.67% Normal weight: 46.89% Overweight: 47.19% Obesity: 53.85% Total: 47.2%	Overweight and LBP: 1.01 (0.52–1.21) Obesity and LBP: 1.32 (0.43–4.09) Overweight-obesity and LBP: 1.07 (0.59-–1.95)
Minghelli [45]	Underweight: 2.9% Normal weight: 73.29% Overweight: 18.43% Obesity: 5.38%	Underweight:66.67% Normal weight: 46.89% Overweight: 47.19% Obesity: 53.85% Total: 47.2%	Overweight and LBP: 1.01 (0.52–1.21) Obesity and LBP: 1.32 (0.43–4.09) Overweight-obesity and LBP: 1.07 (0.59–1.95)
Schmidt [46]	No categories data	Total: 65.81%	BMI and LBP: 1.62 (1.45–1.80)
Graup [47]	Normal weight: 73.26% Overweight-obesity: 26.74	No prevalence data, effect size contributed directly	Overweight-obesity and LBP: 1.50 (0.79–2.83)

Table 2. continued

Study	BMI categories prevalence	Prevalence of LBP by BMI category group	OR (95% CI)
Silva [48]	Underweight: 11.96% Normal weight: 72.39% Overweight-obesity: 15.64%	Underweight: 38.46% Normal weight: 58.47% Overweight-obesity: 66.67% Total: 57.36%	Overweight-obesity and LBP: 1.42 (0.40–5.08)
Wirth [49]	No categories data	No prevalence data, effect size contributed directly	BMI and LBP: 0.98 (0.75–1.29)
Hershkovich [50]	Underweight: 5.72% Normal weight: 78.08% Overweight: 10.39% Obesity: 5.81%	Underweight: 4.19% Normal weight: 4.21% Overweight: 4.72% Obesity: 5.29% Total: 4.32%	Overweight and LBP: 1.13 (1.06–1.21) Obesity and LBP: 1.29 (1.19–1.40) Overweight-obesity and LBP: 1.19 (1.12–1.25)
Yao [51]	No categories data	Total: 50%	BMI and LBP: 1.13 (1.11–1.16)
Onofrio [52]	Normal weight: 74.64% Overweight: 19.73% Obesity: 5.62	Normal weight: 13.72% Overweight: 11.49% Obesity: 10.45% Total: 13.1%	Overweight and LBP: 1.00 (0.50–2.00) Obesity and LBP: 0.80 (0.20–3.20) Overweight-obesity and LBP: 0.77 (0.34–1.75)
Erne and Elfering [53]	No categories data	No prevalence data, effect size contributed directly	BMI and LBP: 1.19 (0.82–1.72)
Yao [54]	No categories data	Total: 29.14%	BMI and LBP: 1.22 (1.20–1.24)
Balagué [55]	No categories data	Total: 34.74%	BMI and LBP: 2.30 (1.69–3.13)
Mohseni-Bandpei [56]	No categories data	No prevalence data, effect size contributed directly	BMI and LBP: 0.89 (0.38–2.10)
Chiang [57]	No categories data	Total: 34.54%	BMI and LBP: 0.72 (0.43–1.21)
Jones [58]	No categories data	Total: 50%	BMI and LBP: 4.25 (2.56–7.05)
Korovessis [59]	No categories data	No prevalence data, effect size contributed directly	BMI and LBP: 1.11 (0.93–1.33)
Watson [60]	Normal weight: 69.14% Overweight-obesity: 30.86%	Normal weight: 24.02% Overweight-obesity: 24.43% Total: 24.15%	Overweight-obesity and LBP: 1.02 (0.52–2.01)
Nissinen [61]	No categories data	No prevalence data, effect size contributed directly	BMI and LBP: 1.00 (0.67–1.49)

BMI Body Mass Index, *LBP* Low Back Pain, *CI* Confidence Interval, *OR* Odds Ratio

from 4% [34] to 21.71% [28]. Lastly, the prevalence of obesity ranged from 10.74% [43] to 33.16% [28]. In all studies that reported separate prevalence figures for overweight and obesity, overweight was consistently more prevalent than obesity. Overall, 5.65% with underweight, 77.75% with normal weight, 10.3% with overweight, and 5.82% with obesity. See Table 2 for more information.

Risk of bias

Only four studies [7, 30, 37, 61] were considered to have low risk of bias, while the rest raised some concerns. The articles with low risk of bias in their final assessment obtained this score across all domains. The studies with some concerns obtained a high risk of bias score in domains 1 A or 1B, and low risk of bias in the remaining domains, following the author's recommendations. Domains 1A and 1B were responsible for evaluating confounding variables, and studies penalized with a high risk of bias failed to adequately control for these variables, and the results from the risk of bias assessments directly affect the results reported, as they should be interpreted with caution. For more information, see Table 3.

Mean effect size and heterogeneity analysis

Comparison of normal weight and overweight in association with LBP. Regarding the effect size in the association between overweight and LBP, an overall OR of 1.13 (95% CI 1.10–1.16) based on 9 studies was obtained, with no evidence of heterogeneity ($\tau^2 = 0$), suggesting slightly higher odds of LBP among overweight children and adolescents. To calculate the effect size, the Minghelli 2015 [44] and 2014 [45] papers were combined. Figure 2a displays the forest plot, presenting all the included studies and the average effect size. All nine studies [28, 33, 34, 36, 39, 40, 44, 45, 50, 52] included in this analysis reported an individual OR of 1 or higher, with the study by dos Santos et al. [34] standing out with an OR of 4 (95% CI 0.13–122.74). The effect size was driven by Hershkovich et al. [50], which was the only one to reach a significant individual OR. Importantly, this study covered a substantial sample size of 712296 participants, with a weight of 95.28% of the total effect size. Consequently, a sensitivity analysis was conducted, excluding this study from the calculation. The removal of this study resulted in a reduction of the effect size, yielding an OR of 1.11 (95% CI 0.96–1.27, τ^2=0). In order to assess the robustness of the findings, a second sensitivity analysis was conducted by excluding the study conducted by dos Santos et al. [34] due to its substantial effect size. The effect size remained unchanged in this re-analysis, consistent with the first analysis, yielding a value of OR = 1.13 (95% CI 1.10–1.15, τ^2=0).

Four studies [28, 36, 39, 52] presented their ORs, while the ORs for the remaining studies were manually calculated from the 2×2 table frequencies. The studies that provided the OR designated the normal weight group as the reference category. To calculate the OR using this method, it was necessary for the normal weight and overweight groups to be well-defined. The total sample size

Table 3. Risk of bias assessment.

Study	R-E1A	R-E1B	R-E2A	R-E3	R-E4	R-E5	R-E6	R-E7	R-Overall
Santos [7]	Low	Low	Low	Low	Low	Low	Low	Low	Low
Al-Taiar [28]	High	High	Low	Low	Low	Low	Low	Low	Some concerns
Rezapur-Shahkolai [29]	High	High	Low	Low	Low	Low	Low	Low	Some concerns
Cejudo [30]	Low	Low	Low	Low	Low	Low	Low	Low	Low
Yabe [31]	High	High	Low	Low	Low	Low	Low	Low	Some concerns
Yabe [32]	High	High	Low	Low	Low	Low	Low	Low	Some concerns
Schwertner [33]	High	High	Low	Low	Low	Low	Low	Low	Some concerns
dos Santos [34]	High	High	Low	Low	Low	Low	Low	Low	Some concerns
Aghilinejad [35]	High	High	Low	Low	Low	Low	Low	Low	Some concerns
Akbar [36]	High	High	Low	Low	Low	Low	Low	Low	Some concerns
Yabe [37]	Low	Low	Low	Low	Low	Low	Low	Low	Low
Noormohammadpour [38]	High	High	Low	Low	Low	Low	Low	Low	Some concerns
Angarita-Fonseca [39]	High	High	Low	Low	Low	Low	Low	Low	Some concerns
Azabagic [40]	High	High	Low	Low	Low	Low	Low	Low	Some concerns
Muntaner-Mas [41]	High	High	Low	Low	Low	Low	Low	Low	Some concerns
Smith [42]	High	High	Low	Low	Low	Low	Low	Low	Some concerns
Mikkonen [43]	High	High	Low	Low	Low	Low	Low	Low	Some concerns
Minghelli [44]	High	High	Low	Low	Low	Low	Low	Low	Some concerns
Minghelli [45]	High	High	Low	Low	Low	Low	Low	Low	Some concerns
Schmidt [46]	Some concerns	Low	Low	Low	Low	Low	Low	Low	Some concerns
Graup [47]	High	High	Low	Low	Low	Low	Low	Low	Some concerns
Silva [48]	High	High	Low	Low	Low	Low	Low	Low	Some concerns
Wirth [49]	High	High	Low	Low	Low	Low	Low	Low	Some concerns
Hershkovich [50]	High	High	Low	Low	Low	Low	Low	Low	Some concerns
Yao [51]	High	High	Low	Low	Low	Low	Low	Low	Some concerns
Onofrio [52]	High	High	Low	Low	Low	Low	Low	Low	Some concerns
Erne and Elfering [53]	High	High	Low	Low	Low	Low	Low	Low	Some concerns
Yao [54]	High	High	Low	Low	Low	Low	Low	Low	Some concerns
Balagué [55]	High	High	Low	Low	Low	Low	Low	Low	Some concerns
Mohseni-Bandpei [56]	High	High	Low	Low	Low	Low	Low	Low	Some concerns
Chiang [57]	High	High	Low	Low	Low	Low	Low	Low	Some concerns
Jones [58]	Some concerns	Some concerns	Low	Low	Low	Low	Low	Low	Some concerns
Korovessis [59]	High	High	Low	Low	Low	Low	Low	Low	Some concerns
Watson [60]	Low	Low	Low	Low	Low	Low	Low	Low	Low
Nissinen [61]	Low	Low	Low	Low	Low	Low	Low	Low	Low

across all studies included in this analysis amounted to 716297 participants.

To evaluate publication bias, the Egger's test and funnel plot were utilized. The results revealed a non-significant finding with a p-value of 0.58, indicating the absence of publication bias. Figure 2b visually depicts the funnel plot, providing further support for the absence of publication bias.

Comparison of normal weight and obesity in association with LBP. Eight studies [28, 33, 36, 40, 43–45, 50, 52] were included in this analysis to evaluate the effect size in the association between obesity and LBP. The overall effect estimate was OR = 1.27 (95% CI 1.20-1.34), with no evidence of heterogeneity ($\tau^2 = 0$), suggesting higher odds of LBP among children and adolescents with obesity. Three studies [33, 36, 52] reported an OR lower than 1. As well as to the previous analysis, the two papers by Minghelli et al. [44, 45] were considered as a single study. The forest plot in Fig. 3a presents the comprehensive analysis of all the included studies and the final effect size. Among the included studies, only the study conducted by Hershkovich et al. [50], which boasted the largest sample size of 675089 participants, achieved statistical significance in its individual analysis. This study, as the previous comparison, carried significant weight in determining the final effect size, contributing to 90.94% of the total. Consequently, a sensitivity analysis was conducted, involving the exclusion of this study, resulting in a reduction of the effect size to OR = 1.10 (95%CI 0.97–1.24).

Only three studies [28, 36, 52] provided the OR with normal weight as the reference group, while the remaining studies reported the raw counts in 2×2 tables. The combined sample size of all studies included in this analysis amounted to 682512 participants.

Moreover, the presence of publication bias was assessed using the Egger's test and funnel plot. The results indicated a statistically significant finding with a p-value of 0.037, highlighting the need to consider publication bias, as depicted in Fig. 3b.

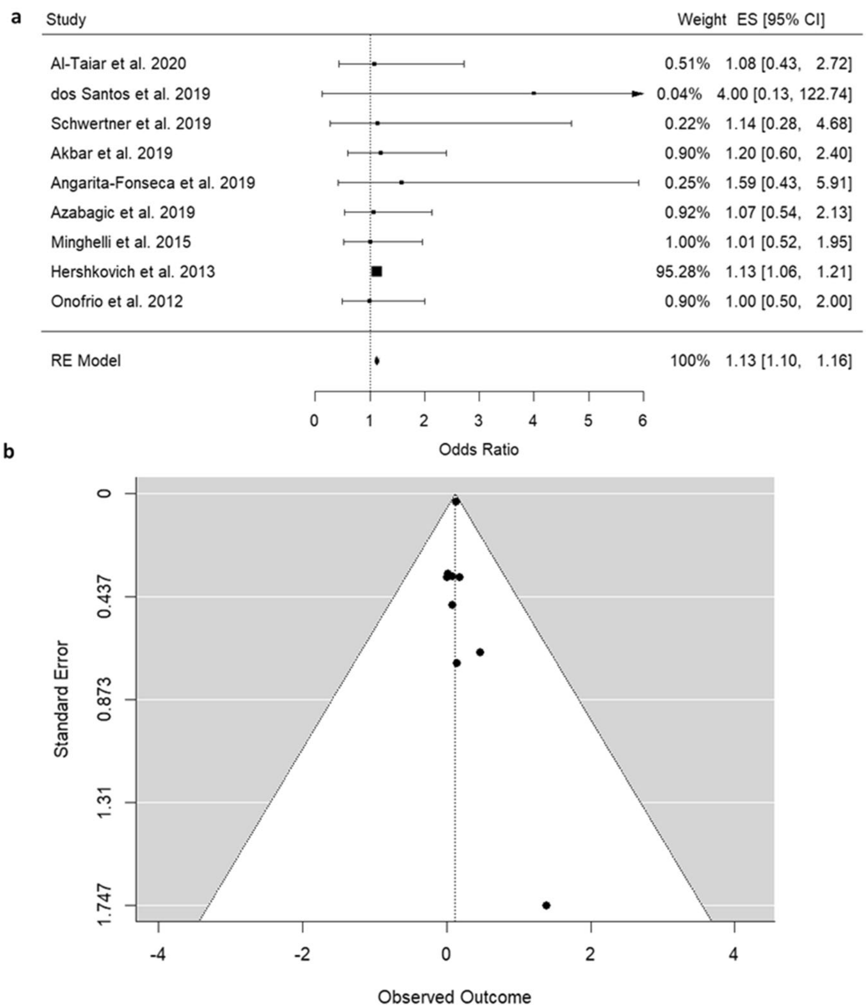

Fig. 2 Overweight and LBP association forest plot and funnel plot. Forest plot (**a**); and funnel plot (**b**).

Comparison of normal weight and overweight-obesity in association with LBP. The association between combined overweight/obesity and LBP was also calculated, including ten studies [29, 33, 40, 41, 44, 45, 47, 48, 50, 52, 60] that provided such comparison. The overall effect size was OR = 1.18 (95% CI 1.14–1.23), with no evidence of heterogeneity ($\tau^2 = 0$), suggesting slightly higher odds of LBP among children and adolescents with overweight and obesity, compared to their counterparts with body weight considered as normal. Consistent with previous analyses, the two papers by Minghelli et al. [44, 45] were considered as a single study. The forest plot in Fig. 4a displays the overall effect size and contributions of each study. Among the included studies, only two studies [29, 52] reported an OR below 1, and only the study by Hershkovich et al. [50] achieved statistical significance in its individual analysis, which had the largest sample size of 758487 participants and contributed to 94.39% of the overall effect size. To assess the robustness of the findings, a sensitivity analysis was conducted, excluding this study from the analysis. As a result, the effect size was reduced to OR = 1.16 (95% CI 0.99-1.36).

For this analysis, only three studies [41, 47, 60] provided the ORs with normal weight as the reference group, while the remaining studies reported 2×2 tables with the information to calculate them. The total sample size across all studies was 766,257 participants. One study [60] categorized weight groups based on BMI thresholds of ≤25 and >25. Despite this unconventional categorization, it was included in the analysis since the lower limit did not extend below normal weight and the upper limit reached into the range of obesity categories. In addition, only one study provided adjusted OR data (adjusted for unspecified socio-economics variables) [47].

The result of the Egger's test and funnel plot showed no statistically significant findings with a p-value of 0.50. This suggests an absence of publication bias (Fig. 4b).

BMI and LBP association. The association between BMI and LBP was examined in 19 studies [7, 30–32, 35, 37, 38, 42, 46, 49, 51, 53–59, 61], which ultimately resulted in 21 analyses as one study provided three independent group comparisons [31]. Eight studies reported the OR from logistic regression in their articles [31, 32, 37, 49, 53, 56, 59, 61], and eleven studies provided the BMI values of participants with and without LBP [7, 30, 35, 38, 42, 46, 51, 54, 55, 57, 58]. By combining all these studies, we obtained the 21 analyses. The adaptation of these 21 results to a common index (log OR) allows us to analyze them as a whole and obtain more robust results.

The overall effect size was 1.19 (95%CI 1.03–1.39), with strong evidence of heterogeneity ($I^2 = 98.51$, $\tau^2 = 0.06$, 95% PI 0.70 to 2.04). The forest plot in Fig. 5a visually represents the combined effect size as well as the individual contributions of each study towards the overall analysis. Seven studies obtained significant values supporting the association between the two variables [38, 42, 46, 51, 54, 55, 58], while the rest did not. One study yielded a highly negative value without statistical significance [57]. It was

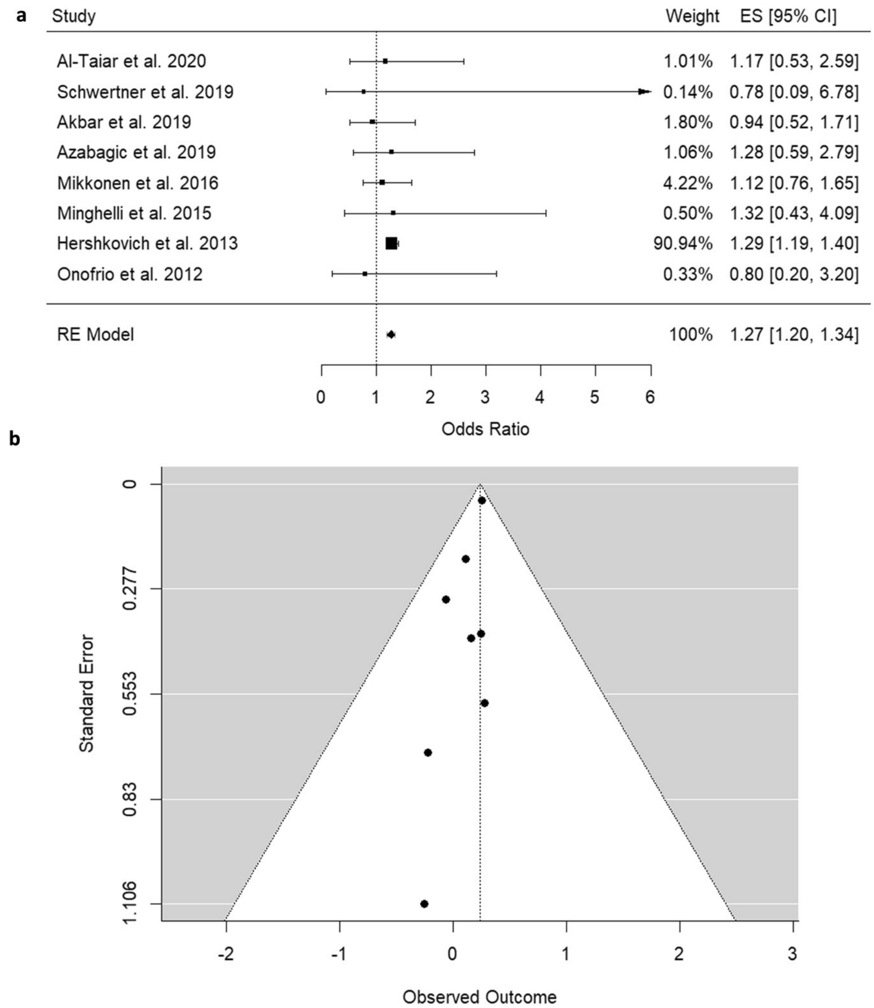

Fig. 3 Obese and LBP association forest plot and funnel plot. Forest plot (**a**); and funnel plot (**b**).

observed that most articles providing their data through OR and logistic regression did not find an association. On the other hand, articles that compared the BMI of participants with and without LBP showed a tendency towards association. Due to the heterogeneity of including studies that provided the OR with studies that provided the mean difference, a sensitivity analysis was performed including only the eight studies (ten analysis) that provided the OR with a reduction of the effect size to OR 1.06 (95% CI 1.01–1.10).

Adjusted and unadjusted results were included in this analysis. Adjustment of results was only found in 3 studies, with low consensus on the variables that should be adjusted for in the analysis of this variable, including gender, age, BMI, level of sports equipment and number of training days per week [37], carrying the school bag on one shoulder only [59] and adjusted for all variables included in the study (sitting height, BMI, growth of BMI, kyphosis, increase of kyphosis, and hump size) [61]. The three studies that included adjusted data joined the other studies that did not provide adjusted data for the overall analysis and their effect sizes were non-significant in all cases. However, there were no notable differences in effect size compared to other studies that provided unadjusted data.

Five studies provided data from participants engaged in competitive sports, specifically equestrianism [30], judo, karate and kendo [31], volleyball [32], baseball [37], and athletics [46]. Among these, only athletics showed a significant association. The study by Yabe et al. [31] divided its participants based on the sport they engaged in and provided separate ORs for each group, which were analyzed separately.

The Egger's test yielded a result of $p = 0.67$, indicating that there is no risk of publication bias. Additionally, the funnel plot was generated and no asymmetry was observed (Fig. 5b).

Analyzing moderator variables

Given the evidence of heterogeneity found in the last meta-analysis, moderator analyses were carried out with the aim to better understand the heterogeneity among the 21 effect sizes included. To analyze the age group variable and considering the distribution of participants, the most suitable comparison was between children and adolescents versus adolescents alone. The location-scale model revealed no association between the age group and the magnitude of the effect estimates ($\hat{\beta} = 0.21$, 95% CI: -0.461 to 0.892, without statistical significance. Conversely, the scale coefficient yielded a marginally significant effect, ($\hat{\alpha} = -1.347$, 95% CI: -2.813 to 0.117, $p = 0.07$, suggesting that the heterogeneity was lower in the group of adolescents compared to the group that included adolescents and children.

Regarding percentage of males, the location part of the model showed no evidence of an association with the magnitude of the effect estimates ($\hat{\beta} = 0.004$, 95% CI: -0.003 to 0.012), whereas the scale part provided evidence of more heterogeneous results among studies with more females ($\hat{\alpha} = -0.033$, 95% CI: -0.047 to -0.018).

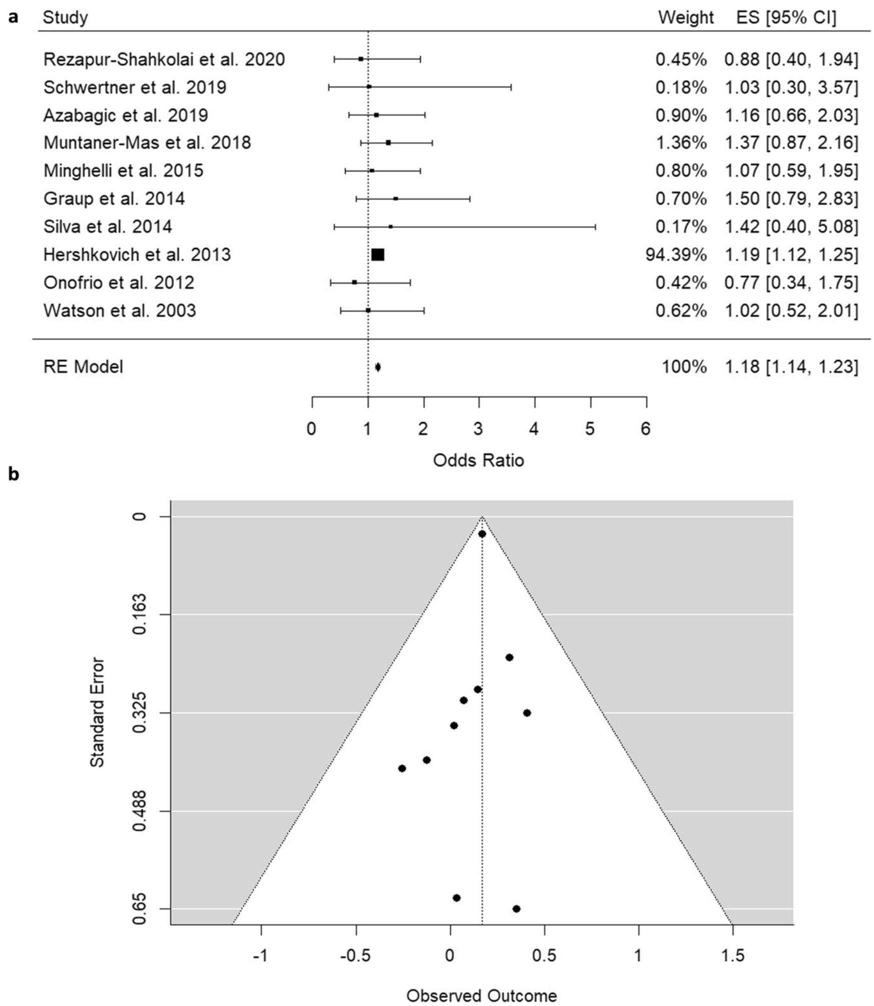

Fig. 4 Overweight-obesity and LBP association forest plot and funnel plot. Forest plot (**a**); and funnel plot (**b**).

DISCUSSION

A systematic review with meta-analysis was conducted to determine the association between obesity, overweight, and LBP. The physiological relationship between BMI and LBP is undeniable, as the lumbar region supports the entire weight of the back, which, combined with the growth changes that occur during childhood and adolescence, makes it a susceptible area for pain [10]. In fact, systematic reviews attempting to establish a relationship between weight and LBP have been conducted, but the conclusions have been inconclusive [10, 15]. Regarding meta-analyses, one demonstrated that overweight and obesity are associated with comorbidities [14], and only one specifically focused on overweight and LBP. This meta-analysis yielded an effect size of RR = 1.42 (95% CI 1.03–1.97). However, due to the low number of studies, potential publication bias, and high heterogeneity among the studies, the authors concluded that there is low-quality evidence and the results should be interpreted as such. Additionally, this meta-analysis included a study with an effect size of RR = 14.39 (95%CI 1.98-104.66) [69], and no sensitivity analysis was performed to assess whether the effects remained consistent without this study. This study was not included in our meta-analysis because it did not specify that the pathology under study was LBP, but rather BP. Since the present study exclusively focuses on LBP, this study was excluded. As for the variable of overweight, our meta-analysis obtained an OR = 1.13 (95% CI 1.10-1.16), which is very similar to the findings of this study. However, when excluding the study by Hershkovich et al. [50], the effect size decreased to OR = 1.11 (95% CI 0.96-1.27) eliminating statistical significance. No previous meta-analysis has examined the association between obesity and LBP or between overweight/obesity and LBP.

As mentioned before, in our analyses of overweight, obesity, and overweight/obesity with LBP, the study by Hershkovich et al. [50] carries the most weight in the final effect size due to its large sample size. Sensitivity analyses determined a lack of association between the variables analyzed once this influential study was removed, and the minimal or absent heterogeneity in the analyses demonstrates a tendency towards a small association. While it is true that such large studies can distort the results for other studies, the risk of bias in this study is considered to be "some concerns", similar to the majority of the other studies. Our findings highlight a need for more robust studies to be conducted in this field, so that future evidence synthesis efforts can draw more solid conclusions.

We found heterogeneity in the types of studies included (cross-sectional, case-controls and cohorts) to investigate the association between variables. Due to the limited number of studies, we had to mix the different types of studies by converting the effect size of each study into a common metric in order to group them together, although methodologically correct, it would have been more accurate to find as many cohorts and case-control studies as possible with low risk of bias and with a large analysis of the moderator variables. Furthermore, the transformation formula

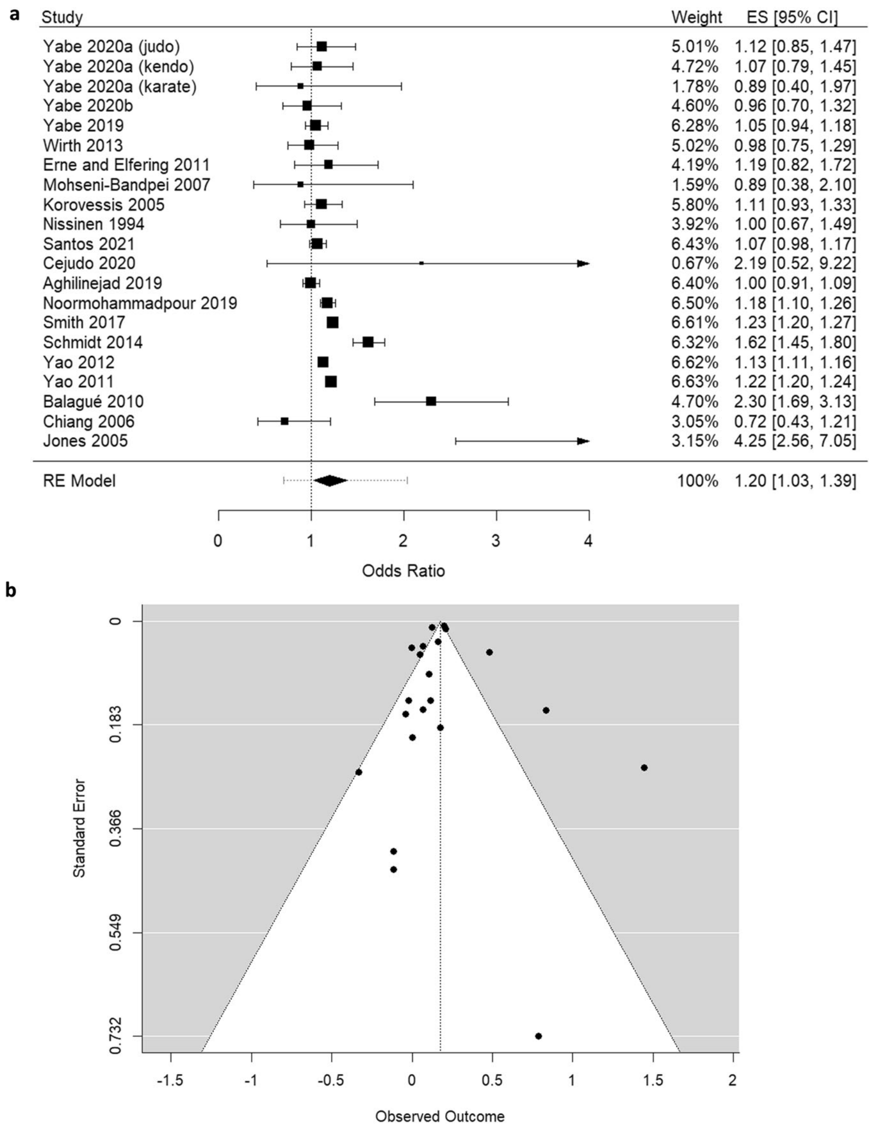

Fig. 5 **BMI and LBP association forest plot and funnel plot.** Forest plot (**a**); and funnel plot (**b**).

used to convert d values into LOR values is based on some assumptions that might not always be met in practice, leading to potential bias in the resulting estimates.

Furthermore, there is considerable heterogeneity in classifying individuals as having normal weight, overweight, and obesity. In this meta-analysis, studies were included that categorized their participants based on BMI using criteria from the WHO [65], International Obesity Task Force [66, 67], or CDC [68]. Although these criteria are very similar, and it is unlikely that there would be significant differences in the composition of participants in each group, greater homogeneity among the research community would be desirable. By conducting separate analyses for overweight and obesity, this study enables us to explore whether the transition from normal weight to overweight or from overweight to obesity results in a notable increase in the association. Specifically, the association between LBP and obesity appears to be stronger than that with overweight.

The heterogeneity observed in the included articles was also reflected in the study population itself, given the inclusion of children and adolescents. Due to information limitations, age was analyzed, when feasible, as a moderating variable to account for the association degree across different age groups. Studies conducted on participants involved in sports were included, contributing to increased heterogeneity among them. However, due to limited information, analyses comparing participants engaged in sports with those who were not were not feasible. It would have been particularly insightful to examine the level of sports engagement (competitive or high level); however, studies did not furnish this information.

Children were predominantly sourced from school environments and through schools or entire classes. Generally, information regarding LBP assessment relied on self-report, and BMI was determined by the respective authors of each study. Regarding the prevalence in the studies, there was also heterogeneity, with some studies providing lifetime prevalence of LBP, while others focused on the last few months or point prevalence. This diversity further complicated the analysis of associations, as pinpointing the association amidst such heterogeneity proved challenging. It would also have been interesting if data on previous injuries or previous episodes of LBP had been reported, but this information was not provided in the studies.

The heterogeneity found in the prevalence range deserves to be taken into account. We found from lifetime prevalence to point prevalence, thus, longer periods may capture chronic or recurring cases, while shorter durations may highlight acute or transient occurrences; however, a longer period may help to better analyze and understand certain confounding variables.

Moreover, it would have been interesting to explore other moderating variables that could potentially influence the effect size, such as sitting time or engagement in physical activities. Although these variables were included in the analysis, the limited number of studies available did not allow for conclusive results. Therefore, it is recommended that future scientific articles incorporate this information to further enhance our understanding of this pathology.

The study has numerous strengths. Firstly, it conducted a comprehensive search of both published and unpublished articles, ensuring that all available information on the topic was considered. This thorough search yielded a total of 35 articles and involved a substantial number of participants, enhancing the study's robustness. Secondly, to ensure accuracy and reliability, two authors independently extracted data from the selected studies and applied a risk of bias-tool. Furthermore, this study is particularly noteworthy as it was the first meta-analysis exclusively focusing on LBP in children and adolescents, and provided substantial knowledge on this topic. However, it is important to acknowledge the limitations of the study. Firstly, many of the articles included in the analysis exhibited some concerns regarding the risk of bias.

Additionally, significant heterogeneity was observed in relation to the tool used to categorize the BMI category of participants, in the population studied (children, adolescents, athletes), in the types of study (cohorts, case-controls, and cross-sectional, with very different prevalence studied (lifetime, period and point prevalence), and it is noteworthy to consider the possibility that the effect size reported in the study may have been driven by the results of a particular study.

CONCLUSION

Overweight and obesity may be risk factors for LBP in children and adolescents. The association between LBP and obesity appears to be stronger than the association with overweight. However, the analysis revealed considerable heterogeneity between the various studies, which were mostly assessed to have moderate risk of bias. In particular, these studies often did not take into account confounding factors that could influence the effect size. Consequently, it is imperative to approach the observed results with caution, emphasizing the need for careful interpretation due to these inherent limitations.

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AUTHOR CONTRIBUTIONS

All authors contributed to the conception and design, acquisition, analysis and interpretation of data and drafting of the manuscript. JGM, ICM and AGC carried out the systematic review. JGM and JLL performed the statistical analyses. JGM wrote a first full draft of the manuscript. All authors participated in the critical revision of the manuscript for important intellectual content. All authors read and approved the final manuscript.

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COMPETING INTERESTS

The authors declare no competing interests.

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