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REVIEW ARTICLE

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The association between the weight of schoolbags and low back pain among schoolchildren: A systematic review, meta-analysis and individual patient data meta-analysis

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Abstract

Background: The objective of this study was to determine whether carrying a heavy schoolbag is associated to a higher prevalence of low back pain (LBP).

Methods: A systematic review and meta-analysis was conducted (PROSPERO, CRD42018077839). Observational studies analysing the relationship between schoolbag weight and LBP, were searched for in 20 electronic databases and 12 specialized journals until February 28th, 2019, without date or language restrictions. All studies which included ≥ 50 subjects aged 9 to 16, were reviewed. Methodological quality was assessed by two reviewers separately, using validated tools. A meta-analysis and an individual patient data (IPD) meta-analysis were conducted to examine the relationship between schoolbag weight and LBP. Certainty of evidence was assessed using an adapted GRADE methodology.

Results: 5,524 citations were screened, 21 studies (18,296 subjects) were reviewed and 11 studies (9,188 subjects) were included in the meta-analysis. The IPD meta-analysis included 9,188 subjects from seven studies. Among the 21 studies reviewed, the mean score for methodological quality was 78.3 of 100. Only one study suggested an association between heavier schoolbags and LBP. Neither the meta-analysis nor the IPD meta-analysis found an association between carrying schoolbags weighing > 10% of bodyweight, and LBP. No differences based on age, gender or sport activity were found.

Discussion: Available evidence does not support that schoolbags weighing > 10% of bodyweight are associated with a higher prevalence of LBP among schoolchildren aged 9–16. The certainty of evidence is low. Further research is required on the relationship between schoolbag weight and LBP.

Significance: This systematic review, with a meta-analysis and an IPD meta-analysis, failed to find a link between schoolbags weighing ≥ 10% of body weight and LBP among schoolchildren aged 9 to 16. Further longitudinal studies, with large samples, long follow-up periods, and rigorous methods taking into account duration of carry and the physical capacity of each subject, are required in this field.

Abbreviations: CI 95%, confidence interval 95%; HKSJ, Hartung-Knapp-Sidik-Jonkman method; IPD meta-analysis, individual patient data meta-analysis; LBP, low back pain; OR, odds ratio.

1 | BACKGROUND

Common low back pain (LBP) is defined as pain between the costal margins and the inferior gluteal folds, which is usually accompanied by painful limitation of movement, may be associated with pain referred down to the leg, and is not related to fracture, direct trauma or systemic diseases, such as neoplastic, infectious, vascular, metabolic or endocrine-related processes (Bardin, King, & Maher, 2017; Hoy et al., 2012; Maher, Underwood, & Buchbinder, 2017).

LBP represents a major health, social and economic burden. It is the main cause of years lived with disability worldwide (Hoy et al., 2014) and, only in the United States, the yearly costs associated with the condition have been estimated at 100 billion dollars (Dieleman et al., 2016).

LBP is more common among schoolchildren than previously believed (Calvo-Muñoz, Gómez-Conesa, & Sánchez-Meca, 2013; Kamper, Yamato, & Williams, 2016), with a lifetime prevalence of 47% at 14 years (Swain et al., 2014). Moreover, reporting LBP during adolescence is a risk factor for suffering it in adulthood (Hestbaek, Leboeuf-Yde, & Kyvik, 2006).

Many factors have been suggested to be associated with a higher risk of LBP among schoolchildren (Calvo-Muñoz, Kovacs, Roqué, Gago Fernández, & Seco Calvo, 2018), including biological (e.g., body weight, weight bearing, muscle strength or ergonomics) (Fairbank, Pynsent, Poortvliet, & Phillips, 1984; Sano et al., 2015; Yamato, Maher, Traeger, Wiliams, & Kamper, 2018), psychosocial (e.g., family and social relations or satisfaction with school) (Dianat, Alipour, & Asghari Jafarabadi, 2017; Mikkonen et al., 2016) and lifestyle related variables (e.g., physical activity, participation in sports or smoking) (Kovacs et al., 2003; Wedderkopp, Leboeuf-Yde, Bo Andersen, Froberg, & Hansen, 2003).

A recent systematic review has found that the evidence assessing the association between these factors and LBP in childhood and adolescence, is inconsistent (Calvo-Muñoz et al., 2018). It also suggested that the weight of the schoolbags schoolchildren carry to school is one of the factors which should be researched further. In fact, over 80% of schoolchildren reporting LBP blame the excessive weight of the schoolbag for their pain (Skaggs, Early, D'Ambra, Tolo, & Kay, 2006), the percentage of body weight that the schoolbag represents among schoolchildren exceeds the limit recommended for adults carrying weight in the work environment, which is usually established at 10% (Alghadir, Gabr, & Al-Eisa, 2017; Erne & Elfering, 2011; Grimmer & Williams, 2000; Negrini, Carabalona, & Sibilla, 1999; Spiteri et al., 2017), and several studies have suggested that excessively heavy schoolbags may be a risk factor for LBP (Dockrell, Simms, & Blake, 2013; Goodgold & Nielsen, 2003; Mackenzie, Sampath, Kruse, & Sheir-Neiss, 2003; Moore, White, & Moore, 2007; Rateau, 2004; Siambanes, Martinez, Butler, & Haider, 2004; Viry, Creveuil, & Marcelli, 1999).

However, most of the studies assessing the relationship between schoolbag weight and LBP among school students, are exploratory studies of low methodological quality (Huguet et al., 2013), and their heterogeneity makes it difficult to perform systematic reviews and meta-analysis (Dretzke et al., 2014; Riley et al., 2013). Individual Participant Data (IPD) meta-analysis offers advantages over meta-analysis of summary data, such as the opportunity to standardize the categorization of exposure variables and to explore heterogeneity through subgroup analysis (Stewart & Tierney, 2002).

Hence, IPD meta-analysis would be appropriate to analyse the existing data on the potential relationship between carrying schoolbags weighing more than 10% of bodyweight, and LBP among schoolchildren (Abo-Zaid, Sauerbrei, & Riley, 2012).

Therefore, the objective of this study was to perform a systematic review, coupled with a meta-analysis and IPD meta-analysis, to estimate whether carrying a heavier schoolbag, and specifically one weighing > 10% of bodyweight, is associated with a higher prevalence of LBP among schoolchildren aged 9–16.

2 | METHODS

The protocol of this meta-analysis was registered in an international register (PROSPERO, CRD42018077839).

2.1 | Search and study selection

An electronic search was conducted up to February 28th, 2019, in the following databases: CINAHL,Current Contents, EMBASE, Family health database, FSTA (Food Science and Technology Abstracts), ISI Web of Knowledge, LILACS, MEDLINE, NNNConsult, OvidMD, PEDro, ProQuest Central, PubMed, SciFinder Scholar, Science Direct, Scopus, SPORTDiscus, The Cochrane Library, Web of Science, Wiley Online Library. The search strategy used both MeSH and terms in "all fields", and was designed to ensure maximum sensitivity. It was conducted in seven successive phases, as shown in Appendix 1, adding references retrieved at each phase to those identified in the previous ones.

Additionally, an electronic search was conducted in the Websites of the Journals which were considered more likely to publish high quality studies on LBP in children. These Journals were: "Pain", "European Journal of Pain", "Clinical Journal of Pain", "Spine", "Spine Journal", "European Spine Journal", "Open Journal of Pediatrics", "European Journal of Pediatrics", "European Journal of Public Health", "Scandinavian J Public Health", "Ergonomics" and "Applied Ergonomics". This second electronic search combined the terms “adolescent”, “children”, “schoolchildren”, “young”,

"pediatric", "back pain", "low back pain", "lumbar pain", "prevalence", "epidemiology", "risk factors", "schoolbags", "school bag", "backpack", "carrying bag" and "bag".

Finally, references in the reviewed studies were manually tracked to identify additional studies.

All the references identified were listed and crosschecked to delete redundancies. The title and abstract of each study were screened by two authors separately (ICM and JSC). The full texts of those which were eligible were assessed for inclusion criteria by two authors separately (ICM and JSC). Disagreements at the screening and assessment stages were resolved through consensus with a third author (FMK).

Studies were included in this review if they: (a) were published, observational studies focusing on risk factors for LBP, either cross-sectional or longitudinal, including case–control studies and cohort studies; (b) included ≥ 50 subjects aged 9–16; (c) explored the relationship between the schoolbag weight (as a proportion of bodyweight) and LBP. No date or language restrictions were applied.

Among the studies included in the review, those which also provided estimates of the association between schoolbag weight (as a proportion of body weight) and LBP, with the corresponding 95% CI, were included in the meta-analysis.

The authors of the studies included in the meta-analysis were contacted and requested to provide the datasets of their original studies, with the names of the subjects deleted and substituted by codes. An individual patient data meta-analysis (IPD meta-analysis) was conducted including all data from all the studies whose authors had provided the data requested. In order to assess the completeness and consistency of these data, the analyses performed in each original study were reproduced, and consistency of results with those published was assessed.

2.2 | Variables

For the systematic review and the (non-IPD) meta-analysis, the weight of the schoolbag was categorized as "hot heavy" or "heavy" based on the definition implemented in the original studies. For the IPD meta-analysis, >10% of body weight was used as the cut-off value (Devroey, Jonkers, Becker, Lenaerts, & Spaepen, 2007; Mackie & Legg, 2008).

Covariates were; age, gender and sport activity outside the school (yes/no), since previous studies suggest that the prevalence of LBP increases with age, being female and practicing sports on a competitive level, and results from a previous systematic review on factors associated with a higher prevalence of LBP among children aged 9–16, supported this (Calvo-Muñoz et al., 2018).

2.3 | Quality assessment of the studies

The Ottawa-Newcastle Scale was selected to assess the methodological quality of longitudinal studies (Wells et al., 2009). This scale scores the quality of each study from 0 to 12 points (from worst to best). The score is composed of a maximum of 9 points assigned to studies meeting eight specific methodological criteria (one of these criteria is scored with up to 2 points), and 3 additional points attributed to studies complying with three criteria which are specific for LBP.

A tool used previously in systematic reviews and meta-analyses on the prevalence of LBP (Calvo-Muñoz et al., 2018; Loney & Stratford, 1999; Louw, Morris, & Grimmer-Somers, 2007; Walker, 2000), was selected to assess the methodological quality of the cross-sectional studies included in this review (Table S1). This tool includes 12 questions and assesses; how detailed the definition of LBP was (precision of anatomic description, gathering of data on frequency, duration, severity, etc.), validity of the sample (representativeness, description and management of missing data, etc.) and data quality (data gathered directly from subjects -without intermediaries-, methods for data gathering, etc.). The score ranges, from worst to best, from 0% to 100%.

Two independent authors conducted assessments separately (ICM and JSC), and disagreements were solved through consensus with a third author (FMK).

2.4 | Analyses

Odds Ratios and 95% CI were calculated to assess the association between reporting LBP and using a schoolbag weighing > 10% of body weight, versus a schoolbag weighing ≤ 10%.

A meta-analysis was conducted under the random effects model, in order to calculate a combined OR based on the individual OR for each study. An IPD meta-analysis was subsequently conducted. For both meta-analyses, the combined OR and corresponding 95% CI were converted post-hoc to the Hartung-Knapp-Sidik-Jonkman method (IntHout, Ioannidis, & Borm, 2014).

For all the studies for which adjusted ORs were available, the ORs adjusted in the most saturated models were included in the meta-analysis. When studies only presented unadjusted ORs, the latter were included. In the IPD meta-analysis, ORs were adjusted for age and gender.

In the meta-analysis, the same definition of "heavy" schoolbag which had been used in the original studies, was maintained. In the IPD meta-analysis, the cut-off value to define a bag as "heavy" was > 10% of bodyweight.

Heterogeneity was assessed through the I^2 (Higgins & Thompson, 2002; Higgins, Thompson, Deeks, & Altman, 2003). I^2 values between 30% and 60% were considered to be indicative of moderate heterogeneity, and values > 60% were considered to indicate considerable heterogeneity.

Two sub-group analyses were conducted in order to explore possible differences in the relationship between

schoolbag weight (≤10% vs.> 10% of bodyweight) and LBP, depending on age and sport activity. The first sub-group analysis categorized the schoolchildren in "children" (≤ 12 years of age) and "teenagers" (≥ 13 years), and combined risk estimates adjusted for gender. The second sub-group analysis categorized schoolchildren depending on whether they performed any sport activities outside the school, and combined estimates adjusted for age and gender.

2.5 | Assessment of certainty of evidence

Certainty of the evidence in the review was assessed using an adaptation of the GRADE system for studies on prognostic factors (Huguet et al., 2013).

Certainty of evidence was assessed based on the extent to which users can be confident that the estimated prognostic association reflects the item being evaluated (Guyatt et al., 2008), taking into account limitations in the methodology of the studies included, the inconsistency, indirectness and imprecision of results, and the potential for publication bias in the review (Huguet et al., 2013).

The certainty of evidence for prognosis was initially considered to be high, given that this review focuses on Phase 2 explanatory studies "aimed to confirm independent associations between potential prognostic factor and the outcome" (Huguet et al., 2013). This initial assessment was later downgraded due to limitations in five factors (study limitations, inconsistency, indirectness, imprecision and publication bias) and/or upgraded due to impact factors (moderate or large estimated effects and dose–response effects) (Huguet et al., 2013).

Assessment of certainty of evidence was conducted by two independent authors (ICM and JSC), and a consensus was reached through discussion with a third author (MR).

3 | RESULTS

The search strategies provided a total of to 5,524 records, which were reduced to 5,502 after duplicates were removed, and led to 84 full-text articles being assessed for eligibility.

Among these 84 studies, 21 representing a total sample of 18,296 complied with the criteria to be included in the systematic review (Akbar et al., 2019; Alghadir et al., 2017; Alghamdi, Nafee, El-Sayed, & Alsaadi, 2018; Angarita-Fonseca et al., 2019; Chiang, Jacobs, & Orsmond, 2006; de Oliveira, Chinaglia, & Lima, 2017; Dianat et al., 2017; Dianat, Sorkhi, Pourhossein, Alipour, & Asghari-Jafarabadi, 2014; Grimmer & Williams, 2000; Johnson, Adeniji, Mbada, Obembe, & Akosile, 2011; Korovessis, Koureas, & Papazisis, 2004; Martínez-Crespo et al., 2009; Minghelli, Oliveira, & Nunes, 2016; Mohseni-Bandpei, Bagheri-Nesami, & Shayesteh-Azar, 2007; Mwaka, Munabi, Buwembo, Kukkiriza, & Ochieng, 2014; Noormohammadpour et al., 2019; Oka, Ranade, & Kulkarni, 2019; Trevelyan & Legg, 2011; Vidal, Borràs, Ponseti, Gili, & Palou, 2010; Watson et al., 2003; Young, Haig, & Yamakawa, 2006), 11 with 9,188 subjects were included in the meta-analysis (Akbar et al., 2019; Alghadir et al., 2017; Angarita-Fonseca et al., 2019; de Oliveira et al., 2017; Dianat et al., 2017, 2014; Martínez-Crespo et al., 2009; Minghelli et al., 2016; Mohseni-Bandpei et al., 2007; Trevelyan & Legg, 2011; Vidal et al., 2010), and data from 8,218 subjects from 7 studies were included in the IPD meta-analysis (Akbar et al., 2019; de Oliveira et al., 2017; Martínez-Crespo et al., 2009; Minghelli et al., 2016; Mohseni-Bandpei et al., 2007; Trevelyan & Legg, 2011; Vidal et al., 2010). Figure 1 shows the PRISMA flow diagram.

3.1 | Systematic review

All of the 21 studies included in the review were cross-sectional, and in all of them the outcome was the prevalence of LBP. Six studies focused on the point prevalence (Alghamdi et al., 2018; de Oliveira et al., 2017; Johnson et al., 2011; Korovessis et al., 2004; Noormohammadpour et al., 2019; Young et al., 2006), 4 on the 1- or 2-week prevalence (Chiang et al., 2006; Grimmer & Williams, 2000; Mwaka et al., 2014; Vidal et al., 2010), 10 on the 1-month prevalence (Akbar et al., 2019; Angarita-Fonseca et al., 2019; Dianat et al., 2017, 2014; Martínez-Crespo et al., 2009; Mohseni-Bandpei et al., 2007; Noormohammadpour et al., 2019; Oka et al., 2019; Trevelyan & Legg, 2011; Watson et al., 2003), 2 on the 1-year prevalence (Alghadir et al., 2017; Minghelli et al., 2016) and 3 on the lifetime prevalence (Akbar et al., 2019; Noormohammadpour et al., 2019; Vidal et al., 2010). Table 1 shows the main characteristics of the studies included in the review.

Sample size of the studies ranged between 55 and 4,813. Three studies included only children (Angarita-Fonseca et al., 2019; de Oliveira et al., 2017; Vidal et al., 2010), and three studies included only teenagers (Akbar et al., 2019; Alghamdi et al., 2018; Noormohammadpour et al., 2019), while all the others included both children and teenagers. Two studies included only girls (Alghamdi et al., 2018; Noormohammadpour et al., 2019) while all the others included both boys and girls.

Among these 21 studies, 19 used standardized self-report questionnaires to determine the prevalence of LBP (Akbar et al., 2019; Alghadir et al., 2017; Alghamdi et al., 2018; Angarita-Fonseca et al., 2019; Chiang et al., 2006; de Oliveira et al., 2017; Dianat et al., 2017, 2014; Grimmer & Williams, 2000; Johnson et al., 2011; Martínez-Crespo et al., 2009; Minghelli et al., 2016; Mohseni-Bandpei et al., 2007; Mwaka et al., 2014; Noormohammadpour et al., 2019; Oka et al., 2019; Trevelyan & Legg, 2011; Vidal et al., 2010; Watson et al., 2003). One study used a non-standardized, ad hoc self-questionnaire (Young et al., 2006), and the last one verbally asked the subjects a non-standardized question (Korovessis et al., 2004).Twelve of these 21 studies (including the two studies which did not use standardized self-report

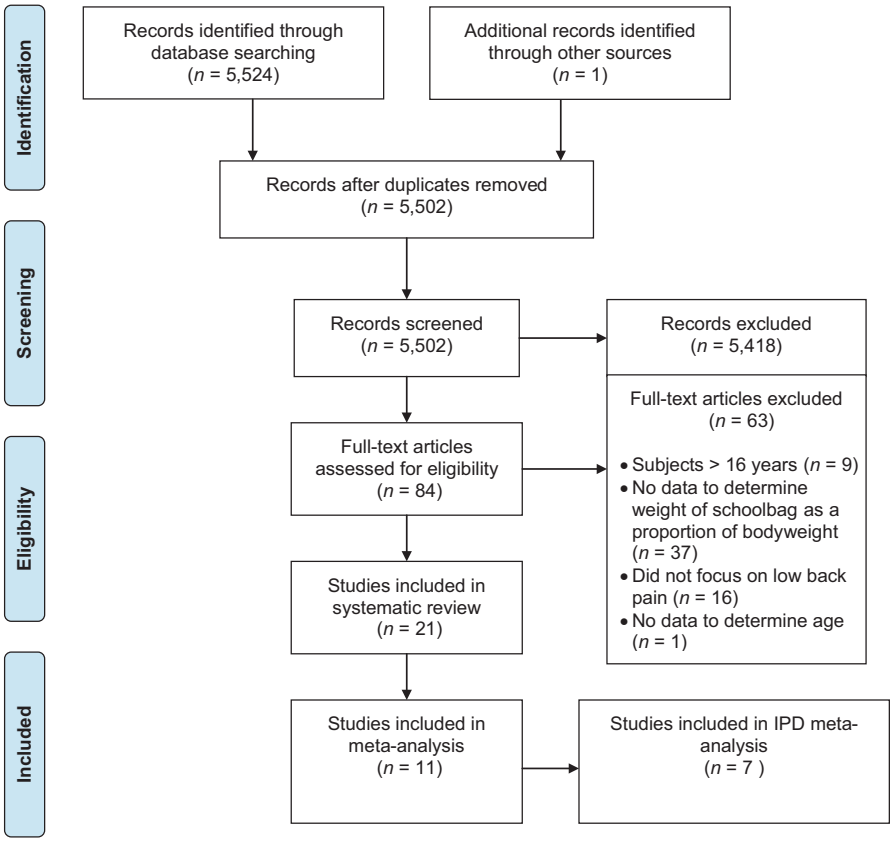

FIGURE 1 PRISMA flow diagram of the study

questionnaires), also used some form of physical examination (Akbar et al., 2019; Alghadir et al., 2017; Chiang et al., 2006; de Oliveira et al., 2017; Johnson et al., 2011; Minghelli et al., 2016; Mohseni-Bandpei et al., 2007; Mwaka et al., 2014; Noormohammadpour et al., 2019; Trevelyan & Legg, 2011).

Among the studies included in the systematic review, the relationship between the weight of the schoolbag and body weight was assessed quantitatively in six studies (Chiang et al., 2006; Korovessis et al., 2004; Noormohammadpour et al., 2019; Oka et al., 2019; Vidal et al., 2010; Young et al., 2006). The other 15 studies classified this relationship into categories. The cut-off values for establishing these categories varied across studies, as follows:">6.6% of bodyweight" in one study (Alghadir et al., 2017),">10% of bodyweight" in 10 studies (Akbar et al., 2019; de Oliveira et al., 2017; Dianat et al., 2017, 2014; Grimmer & Williams, 2000; Martínez-Crespo et al., 2009; Minghelli et al., 2016; Mohseni-Bandpei et al., 2007; Mwaka et al., 2014; Trevelyan & Legg, 2011),"≥12% of bodyweight" in one study (Angarita-Fonseca et al., 2019), two categories ("10% to 15%", ">15%") in one study (Alghamdi et al., 2018), five categories ("2.2% to 6.6%"; "6.7% to 8.8%"; "8.9% to 10.5%"; "10.6% to 13.5%" and "13.6% to 32.1%") in one study (Watson et al., 2003), and "normal and abnormal" (without defining the classification criteria in these categories) in one study (Johnson et al., 2011).

Ten studies gathered data on whether subjects participated in sports outside the school hours (Akbar et al., 2019; Alghadir et al., 2017; Angarita-Fonseca et al., 2019; Dianat et al., 2017; Johnson et al., 2011; Martínez-Crespo et al., 2009; Noormohammadpour et al., 2019; Oka et al., 2019; Vidal et al., 2010; Young et al., 2006).

Among the studies included in the review, the mean score for methodological quality was 78.3% of 100%, with all scores ranging between 55% and 100% (Table 2). Six studies scored ≤ 70%, five scored between 71% and 80%, five scored between 81% and 90% and three over 90%. Table 2 shows the methodological strengths and weaknesses of each study.

Among the 10 studies which were not included in the meta-analyses, only one suggested that LBP was more prevalent among the children who carried schoolbags representing a higher percentage of their bodyweight, especially among boys (vs. girls), with the percentage of the bodyweight associated with a higher risk for LBP being smaller when the children were younger (Grimmer & Williams, 2000). None of the other nine studies which were not included in the meta-analysis, found such an association (Alghamdi et al., 2018; Chiang et al., 2006; Johnson et al., 2011; Korovessis et al., 2004; Mwaka et al., 2014; Noormohammadpour et al., 2019; Oka et al., 2019; Watson et al., 2003; Young et al., 2006).

3.2 | Meta-analysis

Seven studies were included in the IPD meta-analysis (Akbar et al., 2019; de Oliveira et al., 2017; Martínez-Crespo et al.,

TABLE 1 Main characteristics of the studies included in the systematic review

Study	*N*	Age (years)	Prevalence of LBP (D: Days, M: Month, Y: Years, P: Point prevalence)	Method for assessing LBP	Weight of schoolbag	OR (95% CI) for LBP among subjects with heavier schoolbags	Adjusted analysis	Included in meta-analysis	Included in the IPD Meta-analysis
Alghadir et al., 2017	250	12–16	1 y: 130/250 (52.0%)	STD + PE	>6.6% of body weight: 136/250 (54.4%)	1.1 (0.86–1.32)	Logistic regression adjusted for age and gender	Yes	No
Alghamdi et al., 2018	300	13–15	P: 75/300 (25%)	STD	>15% of body weight: 289/300 (96.3%)	NA	NA	No	No
Akbar et al., 2019	950	14–19 (16.7)	L: 668/950 (70.3%) 6 m: 466/950 (49.1%) 1 m: 293/950 (30.8%)	STD + PE	>10% of body weight: 150/299 (50.17%)	1.21 (0.92–1.59	Unconditional logistic regression.	Yes	Yes
Angarit-Fonseca et al., 2019	73	10–12	1 m: 15/73 39.7%	STD	Among subjects with LBP; 12%−20% of body weight (16/55, *SD* 3.75) Among those without LBP; 12%−20% of body weight (19/55, *SD* 3.75)	PR (prevalence ratio) Bivariate analysis 1.33 (0.76–2.36) Bivariate analysis 1.33 (0.76–2.36) Multivariate analysis 1.88 (1.04–3.39)	Bivariate analysis and Multivariate analysis	Yes	No
Chiang et al., 2006	55	13–14	14 d: 19/55 (34.5%)	STD + PE	Among subjects with LBP; 10% of body weight (*SD* 3.75) Among those without LBP: 8% (*SD* 3.86)	NA	NA	No	No
de Oliveira et al., 2017	217	6–10	PC: 11/217 (5.07%)	STD + PE	>10% of body weight: 49/74 (66.22%)	0.72 (0.11–4.70)	Logistic regression	Yes	Yes
Dianat et al., 2014	586	12–14	1 m: 193/586 (32.9%)	STD	Not reported	1.50 (0.59–3.81)	Univariate logistic regression	Yes	No
Dianat et al., 2017	1611	11–14	1 m: 553/1611 (34.3%)	STD	>10% of body weight: 33/64 (51.6%)	1.14 (0.69–1.87)	Univariate logistic regression	Yes	No
Grimmer & Williams, 2000	1,193	12–17	14 d: 293/1193 (24.6%)	STD	>10% of body weight 387/1,193 (32.4%)	NA	NA	No	No
Johnson et al., 2011	381	10–16	P: 70/381 (18.3%)	STD + PE	"Abnormal" (not defined): 163/381 (42.8%)	NA	Univariate logistic regression	No	No
Korovessis et al., 2004	3,441	9–15	P: 671/3441 (19.5%)	NSTD + PE	Average 4,6% of body weight (*SD* 12)	NA	NA	No	No
Martínez-Crespo et al., 2009	849	12–16	1 m: 560/849 (66.0%)	STD	>10% of body weight: 580/848 (68.4%)	0.898 (0.65–1.24)	Logistic regression adjusted for age and gender	Yes	Yes

(Continues)

TABLE 1 (Continued)

Study	*N*	Age (years)	Prevalence of LBP (D: Days, M: Month, Y: Years, P: Point prevalence)	Method for assessing LBP	Weight of schoolbag	OR (95% CI) for LBP among subjects with heavier schoolbags	Adjusted analysis	Included in meta-analysis	Included in the IPD Meta-analysis
Minghelli et al., 2016	966	10–16	1 y: 456/966 (47.2%)	STD + PE	>10% of body weight: 397/966 (41.1%)	0.97 (0.74–1,27)	Logistic regression adjusted for age and gender	Yes	Yes
Mohseni-Bandpei et al., 2007	4,813	11–14	1 m: 695/4813 (14.4%)	STD + PE	>10% of body weight: 13/4813 (0,3%)	1.29 (0.28–5.92)	Logistic regression adjusted for age and gender	Yes	Yes
Mwaka et al., 2014	532	10–21	14 d (pain for ≥ 1 d):[a] 201/532 (37.8%)	STD + PE	>10% of body weight: 164/532 (30.8%)	Not reported	Univariate logistic regression	No	No
Oka et al., 2019	163	12–16	1 m 22/163 (13.50%)	STD	>10% of body weight: 124/163 (76.1%)	NA	NA	No	No
Noormohammadpour et al., 2019	372	13–18	L: 172/372 (46.2%) 3 m: 43/372 (11.6%) 1 m: 116/372 (31.2%) P: 84/372 (22.6%)	STD + PE	Not reported	NA	NA	No	No
Trevelyan & Legg, 2011	245	7–14	1 m (pain for > 1 d):[a] 75/245 (30.6%)[b]	STD + PE	>10% of body weight: 8/233 (3.4%)	0.77 (0.15–0.94)	Logistic regression adjusted for age and gender	Yes	Yes
Vidal et al., 2010	178	10–12	L: 38/178 (21.2%) 7 d: 16/178 (9.0%)	STD	>10% of body weight 108/178 (60.7%)	1.18 (0.40–3.49)	Logistic regression adjusted for age and gender	Yes	Yes
Watson et al., 2003	1,446	11–14	1 m: 330/1446 (23.9%)	STD	>10% of body weight 419/1048	NA	Logistic regression adjusted for age and gender	No	No
Young et al., 2006	125	11–14	P: 57/125 (45.6%)	NSTD + PE	Subjects with LBP: mean 10.9% of body weight (*SD* 4.8) Subjects without LBP: mean: 11.8% (*SD* 4.9)	NA	NA	No	No

Abbreviations: D, days; IPD, individual patient data; LBP, low back pain; M, months; NSTD, non-standardized self-report; P: point prevalence; PC, point prevalence: pain when carrying the schoolbag; PE, physical examination; *SD*, Standard Deviation; STD, standardized self-reported questionnaire; Y, years.

[a]In Mwaka 2014 and Trevelyan 2011, data on prevalence relates to pain lasting longer than the specified duration (e.g., in Trevelyan 2011, 30.6% of the sample reported having suffered from low back pain lasting for over 1 day, during the month before data gathering).

[b]Figures based on IPD data. They compute all the subjects included in the original study, 75 of which reported LBP (the published paper only reports 67 subjects with LBP).

(Continues)

2009; Minghelli et al., 2016; Mohseni-Bandpei et al., 2007; Trevelyan & Legg, 2011; Vidal et al., 2010).

Four additional studies were included in the meta-analysis, but could not be included in the IPD meta-analysis because their authors did not provide IPD data (Alghadir et al., 2017; Angarita-Fonseca et al., 2019; Dianat et al., 2017, 2014). Among these four studies, three defined "heavy" schoolbag using the > 10% bodyweight threshold (Angarita-Fonseca et al., 2019; Dianat et al., 2017, 2014), while the last one had used > 6.6% (Alghadir et al., 2017).

The methodological scores of studies included in the meta-analysis ranged between 55 and 91, and those included in the IPD meta-analysis ranged between 70 and 91 (Tables 1 and 2).

The meta-analysis failed to identify a significant association between carrying schoolbags representing > 10% of bodyweight, and the prevalence of LBP (OR = 1.06 [95% HKSJ CI]: 0.94; 1.20; $I^2 = 0\%$; 11 studies, 10,087 participants; "low" certainty of evidence) (Figure 2; Table 3).

The forest plots (Figures 2–4) do not distinguish between adjusted and non-adjusted ORs, because there was no heterogeneity between them.

Results were homogeneous ($I^2 = 0\%$) and no significant differences were found among studies, both in the meta-analysis of unadjusted results (OR = 1,13 [95% HKSJ CI]; 0.91; 1.40) and in the meta-analysis of adjusted results (OR = 0.95 [95% HKSJ CI]: 0.86 to 1.05).

The reanalysis of data from studies included in the IPD meta-analysis, led to results which were consistent with those from the original studies except in one case (Trevelyan & Legg, 2011), in which the database provided by the authors identified 75 of the included 245 subjects as reporting LBP, whereas the publication only mentioned 67. In the IPD meta-analysis, the 75 subjects identified in the database as reporting LBP, were treated as such.

The sub-group meta-analyses were conducted with individual participant data (IPD meta-analysis). In the first one, on age, there were non-significant differences between children (i.e., ≤ 12 years) and teenagers (i.e., ≥ 13 years) with regards to the value of the weight of the schoolbag (as a proportion of bodyweight) to predict LBP (test for differences between subgroups: $Chi^2 = 2.88$, $df = 1$ [$p = .09$], $I^2 = 65.2\%$). Moderate heterogeneity was found in the group of teenagers (four studies; 4,982 participants; $I^2 = 26\%$; "very low" certainty of evidence), while no heterogeneity was found in the group of children (six studies; 2,421 participants; $I^2 = 0\%$; "very low" certainty of evidence).

In the second subgroup analysis, on sport activity, schoolbag weight (as a proportion of bodyweight) was not found to predict LBP regardless of whether the subjects did and did not do sports (test for differences between subgroups: $Chi^2 = 0.52$, $df = 1$ [$p = .47$], $I^2 = 0\%$). No heterogeneity was found in the group practicing sports (three studies; 2,889 participants; $I^2 = 0\%$; "very low" certainty of evidence), while moderate heterogeneity was found in the group not practicing sports (two studies; 3,005 participants; $I^2 = 35\%$; "very low" certainty of evidence).

4 | DISCUSSION

The notion that the excessive weight of schoolbags carried by school students can trigger LBP, makes clinical sense. Moreover, the cut-off point of > 10% of bodyweight defining an "excessive" weight to be carried, is indirectly supported by some evidence and has elicited consensus among clinicians, researchers and some professional associations (Alghadir et al., 2017; American Chiropractic Association, 2018; American Occupational Therapy Association, 2017; American Physical Therapy Association, 2017; Devroey et al., 2007; Erne & Elfering, 2011; Grimmer & Williams, 2000; Mackie & Legg, 2008; Negrini et al., 1999; Sahli et al., 2013; Spiteri et al., 2017).

However, results from this meta-analysis reflect that the available evidence does not support this notion. In fact, the prevalence of LBP was the same among subjects carrying schoolbags weighing > 10% of their body weight, and those carrying lighter ones, even after adjusting for age, gender or sport activity. These results are consistent with data from most of the previous studies which have analysed the relationship between the weight of the schoolbag and the prevalence of LBP (Table 2) (Calvo-Muñoz et al., 2018).

Therefore, the "take home" message from this study is that the available evidence does not show a relationship between schoolbag weight and LBP among children and teenagers aged 9–16, despite having been assumed for years and sounding plausible. Nevertheless, only cross-sectional, observational studies could be included in this systematic review and meta-analysis, and the certainty of evidence is low. An IPD meta-analysis was designed to allow reanalysis of the data gathered by the previous original studies, but only seven studies could be included and some of their limitations, such as their cross-sectional design, could not be overcome. Therefore, the available evidence does not completely rule out the possibility that excessive weight of the schoolbags may indeed influence the presence, recurrence or persistence of LBP among school students, or that this may be the case among some school students facing specific circumstances (e.g., those needing to carry their schoolbags for long distances or periods). In fact, the level of certainty of the conclusion on the irrelevance of schoolbag weight to predict LBP is very low, implying that further research may modify it.

Establishing 10% of the bodyweight as the cut-off point to consider the weight of the schoolbag as "excessive" may appear reasonable; it has some data supporting it and is equivalent to the threshold most commonly used for adults

TABLE 2 Methodological quality of the studies included in the systematic review

	Methodological criteria[a]												
	1	2	3	4	5	6	7	8	9	10	11	12	Score[a]
Alghadir et al., 2017	YES	YES	NO	YES	YES	YES	YES	NA	YES	NO	YES	YES	82
Alghamdi et al., 2018	YES	NO	NO	YES	YES	YES	YES	NA	NA	NO	YES	YES	70
Akbar et al., 2019	YES	YES	NO	YES	YES	YES	YES	NA	YES	YES	YES	YES	91
Angarita-Fonseca et al., 2019	YES	YES	YES	YES	YES	YES	YES	NA	NA	YES	YES	YES	100
Chiang et al., 2006	YES	YES	YES	YES	YES	YES	YES	NA	YES	NO	NO	YES	82
de Oliveira et al., 2017	YES	YES	NO	YES	YES	YES	YES	NA	YES	NO	NO	YES	73
Dianat et al., 2014	YES	NO	NO	YES	YES	YES	YES	NA	NA	NO	NO	YES	60
Dianat et al., 2017	YES	YES	YES	YES	YES	YES	YES	NA	NA	NO	YES	YES	90
Grimmer & Williams, 2000	YES	NO	YES	YES	YES	YES	YES	NA	NA	NO	NO	YES	70
Johnson et al., 2011	YES	NO	NO	YES	YES	YES	YES	NA	YES	NO	NO	YES	64
Korovessis et al., 2004	YES	YES	YES	YES	YES	YES	NA	NO	YES	YES	NO	YES	82
Martínez-Crespo et al., 2009	YES	YES	NO	YES	YES	YES	YES	NA	NA	NO	YES	YES	80
Minghelli et al., 2016	YES	YES	NO	YES	YES	YES	YES	NA	YES	YES	YES	YES	91
Mohseni-Bandpei et al., 2007	YES	NO	YES	YES	YES	YES	YES	NA	YES	YES	NO	YES	82
Mwaka et al., 2014	YES	YES	YES	YES	YES	YES	YES	NA	YES	YES	NO	YES	91
Oka et al., 2019	YES	YES	NO	YES	YES	YES	YES	NA	NA	YES	YES	YES	90
Noormohammadpour et al., 2019	YES	NO	NO	YES	YES	YES	YES	NA	YES	YES	NO	YES	73
Trevelyan & Legg, 2011	YES	NO	NO	YES	YES	YES	YES	NA	YES	NO	YES	YES	73
Vidal et al., 2010	YES	YES	YES	YES	NO	YES	YES	NA	NA	YES	YES	YES	70
Watson et al., 2003	YES	YES	YES	YES	YES	YES	YES	NA	NA	NO	YES	NO	80
Young et al., 2006	YES	NO	YES	YES	NO	YES	NO	NA	YES	NO	YES	NO	55

Note: Score range (from worst to best): 0–100.

Abbreviation: NA, not applicable.

[a]The methodological criteria and the scoring procedure are described in Table S1.

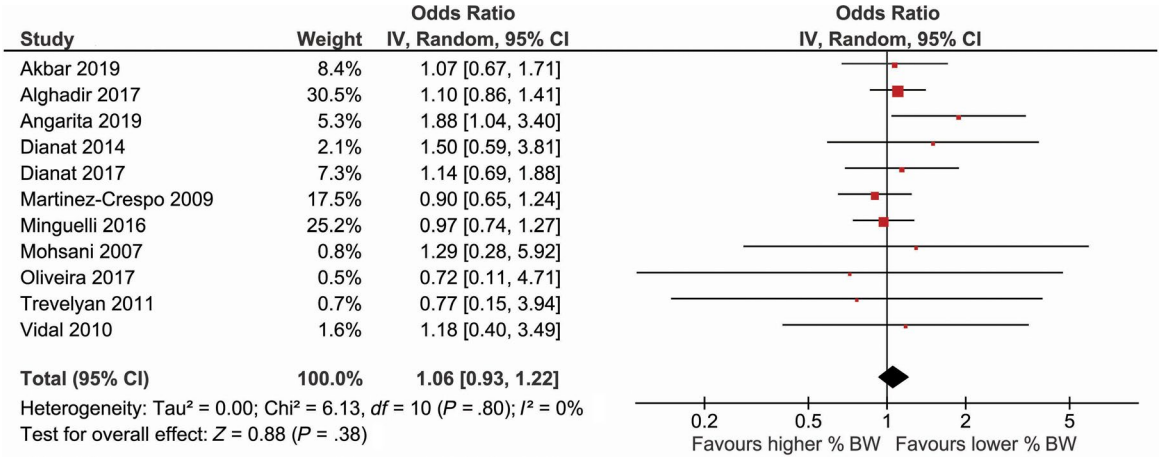

FIGURE 2 Meta-analysis of the relationship between carrying schoolbags representing >10% of bodyweight, and low back pain

TABLE 3 Summary of findings and certainty of evidence

Prognostic factors	Number of participants	Number of studies	Number of cohorts	Estimated effect size (95% confidence interval)	Phase	Factors to downgrade certainty					Factors to upgrade certainty		Overall certainty
						Study limitations	Inconsistency	Indirectness	Imprecision	Publication bias	Moderate/large effect size	Dose effect	
LBP (children and adolescents) [*1]	9,188	11	11	1.06 [0.94–1.20]	++	x[a]	✓	X[b]	✓	✓	X[d]	X[e]	++ LOW
LBP children [*2]	1,475	6	6	1.41 [1.8– 1.84]	++	x[a]	✓	X[b]	X[c]	✓	X[d]	X[e]	+ VERY LOW
LBP adolescents [*3]	6,816	4	4	0.98 [0.60–1.60]	++	x[aOTNOTES:	✓	X[b]	X[c]	✓	X[d]	X[e]	+ VERY LOW
LBP sport practice [*4]	2,889	3	3	1,06 [0,74, 1,52]	++	x[a]	✓	X[b]	X[c]	✓	X[d]	X[e]	+ VERY LOW
LBP no sport practice [*4]	3,005	2	2	0,66 [0,19, 2,29]	++	x[a]	✓	X[b]	X[c]	✓	X[d]	X[e]	+ VERY LOW

Note: For GRADE factors: ✓, no serious limitations; ×, serious limitations (or not present for moderate/large effect size, dose effect); unclear, unable to rate item based on available information. For overall quality of evidence: +, very low; ++, low; +++, moderate; ++++, high.

Abbreviation: LBP, low back pain.

[a]Due to risk of bias of included studies.

[b]Outcome of interest was measured at different time points.

[c]Confidence intervals for measure of association include both clinically relevant and non-relevant values.

[d]No moderate or large effect was estimated.

[e]Studies did not allow assessment of potential dose–response.

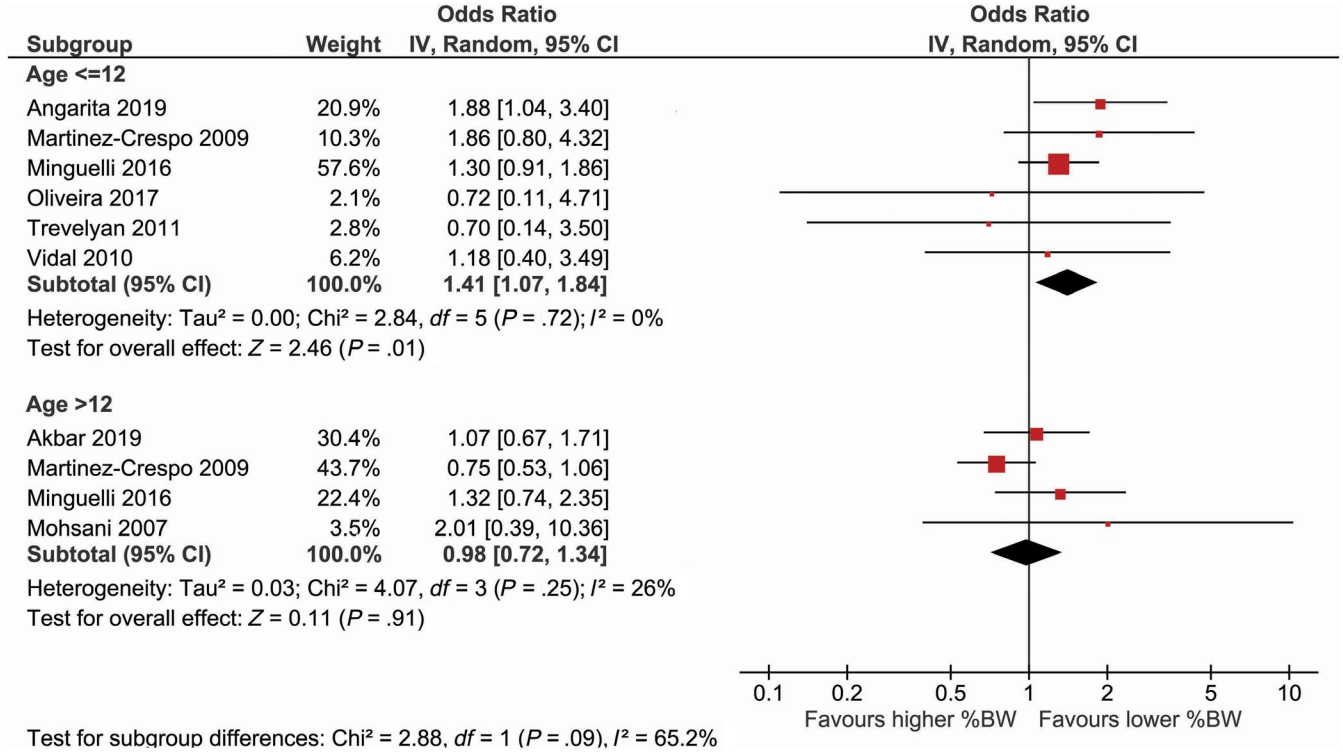

FIGURE 3 Subgroup meta-analysis on age, adjusting by gender

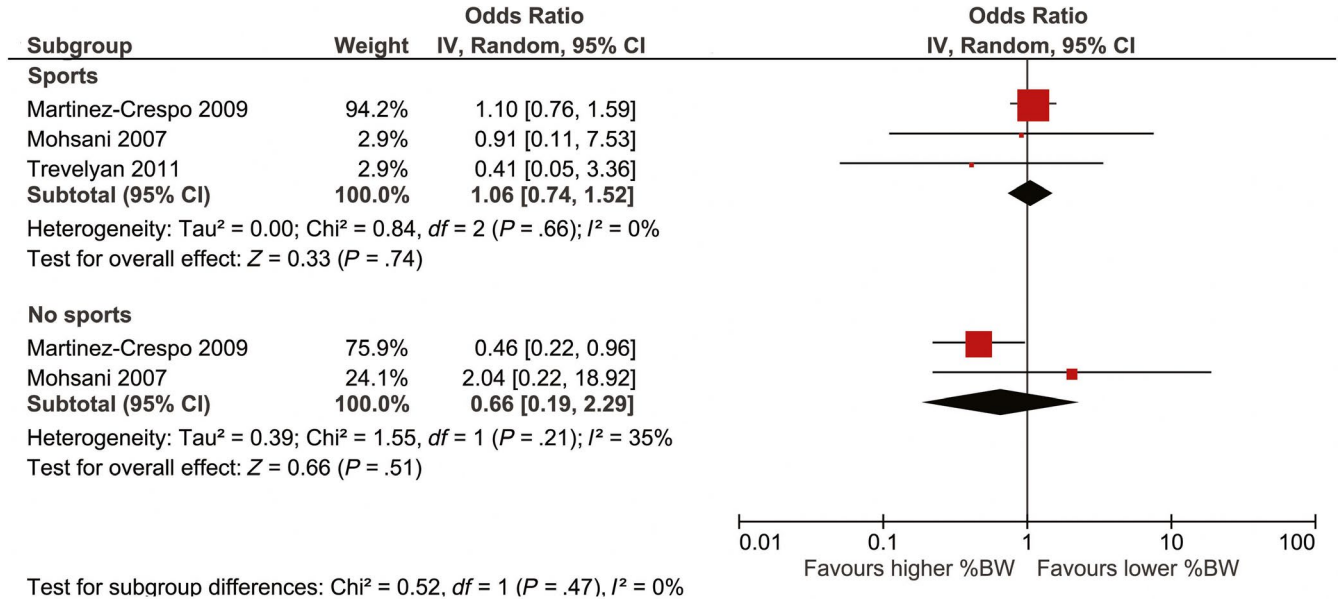

FIGURE 4 Subgroup meta-analysis on sport activity, adjusting by age and gender

in the work-related environment. This has led to most recommendations establishing that the "acceptable" weight for the schoolbag should be below this threshold (Alghadir et al., 2017; American Chiropractic Association, 2018; American Occupational Therapy Association, 2017; American Physical Therapy Association, 2017; Devroey et al., 2007; Erne & Elfering, 2011; Grimmer & Williams, 2000; Mackie & Legg, 2008; Negrini et al., 1999; Sahli et al., 2013; Spiteri et al., 2017). However, other cut-off points have been proposed, as low as 5% or as high as 20% (Dockrell et al., 2013; Rateau, 2004). A different cut-off limit for schoolbag weight might alter the conclusions from this study but this could not be analysed in the IPD meta-analysis because, due to the data available, it was impossible to explore other thresholds.

The weight of the schoolbag has been shown to vary significantly from one day to another (Negrini & Carabalona,

2002).Therefore, the data on weight gathered in a cross-sectional study, may not accurately reflect the load the school student carries most of the days. The reporting of LBP on one day (i.e., point prevalence) may be more influenced by the load carried previously than on the weight of the schoolbag on that very day. Moreover, most data on prevalence of LBP for longer periods (e.g., 14 days, 1 month or 1 year), were based on children's memory, as opposed to data included in a registry. All of the above may have diluted the potential relation between "weight of the schoolbag" and "LBP". Ideally, future studies should use previously validated methods, register data on LBP and on the weight of the schoolbag for a period long enough to capture daily variations in the weight of the schoolbag, and determine whether there is a minimum exposure to the presumed risk factor for it to increase the risk of LBP.

The method used to carry the schoolbag (e.g., cross-body bag vs. backpack vs. hung on one vs. two straps, etc.), has not shown to be significantly associated with the prevalence of LBP among schoolchildren, probably because the vast majority use backpacks strapped on both shoulders (Calvo-Muñoz et al., 2018). Nevertheless, this and other mechanical factors, such as the consistence between the size of class furniture and the students' size, could be further explored in future studies.

Some studies suggest that non-mechanical factors can also increase the risk of schoolchildren reporting LBP. These factors include students' perception that the weight of the schoolbag is excessive for them, irrespective of its actual weight (Dockrell, Blake, & Simms, 2015; Dockrell, Simms, & Blake, 2015), and psycho-social factors, such as a conflictive relationship with parents and schoolmates, behavioural or emotional problems, hyperactivity, and lack of attention (Dianat et al., 2017; Mikkonen et al., 2016; Sjolie, 2002; Watson et al., 2003). Therefore, future studies should also gather valid data on these factors.

Furthermore, it is likely that the key mechanical factor triggering LBP when carrying a schoolbag is not its weight per se, but whether it exceeds the physical capacity of the subject, how often and severely this occurs, and for how many years the overexertion persists or recurs. This would explain results from studies showing that LBP and other musculoskeletal complaints are higher among children who have to carry their schoolbags for longer periods, (Delele, Janakiraman, Bekele Abebe, Tafese, & Water, 2018; Dockrell, Blake, et al., 2015; Dockrell, Simms, et al., 2015) and may suggest that the weight of schoolbags is less relevant in environments where the children have to walk carrying their schoolbag short distances, than in those where they have to carry them for miles every day to attend class (Delele et al., 2018).

Therefore, further studies should gather valid and reliable data on the usual duration of carry and on the physical capacity of the children, such as muscle balance, strength and resistance. In this study, "sport activity" was included in the meta-analysis as a surrogate for "physical capacity", assuming that LBP could be more prevalent among children who, carrying schoolbags of equal weight to those of their peers, had a lower level of physical fitness, and factoring in previous studies which suggest that LBP is more prevalent among schoolchildren involved in competitive sports (Kovacs et al., 2003; Wedderkopp et al., 2003). Results did not confirm this assumption, although this may be due to the fact that gathering valid and reliable quantitative data on sport activity is difficult, and that the methods used to this end in the original studies included in the meta-analysis were inconsistent.

Future studies on this topic should be longitudinal, include large samples, implement follow-up periods long enough for the potential effects of a heavy schoolbag to appear, and use reliable and valid methods to gather data on presence, recurrence and duration of LBP, psychosocial factors, daily variations in the weight of the schoolbag, duration of carry, bodyweight, as well as variables reflecting the balance, strength and resistance of muscles involved in spine function.

In conclusion, data analysed in this study do not support the notion that carrying schoolbags weighing > 10% of bodyweight, is associated with a higher prevalence of LBP among schoolchildren aged 9–16. However, this conclusion is based only on cross-sectional studies, and future research may modify it.

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CONFLICTS OF INTEREST

This study does not discuss off-label or investigational use of any drugs or devices. No benefits in any form have been or will be received from a commercial party related directly or indirectly to the subject of this article. The authors do not have any financial or personal relationships with third parties that could influence this work inappropriately. The authors have no conflicts of interest to report.

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SUPPORTING INFORMATION

Additional supporting information may be found online in the Supporting Information section at the end of the article.

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APPENDIX 1

Search strategy

PHASE 1

"adolescent"[MeSH Terms] OR "adolescent"[All Fields]
"child"[MeSH Terms] OR "child"[All Fields]
"young"[All Fields]
"schools"[MeSH Terms] OR "schools"[All Fields] OR "school"[All Fields]
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PHASE 2

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PHASE 3

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PHASE 4

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PHASE 5

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PHASE 6

("adolescent"[MeSH Terms] OR "adolescent"[All Fields]) OR ("child"[MeSH Terms] OR "child"[All Fields]) OR ("Young"[Journal] OR "young"[All Fields]) OR ("schools"[MeSH Terms] OR "schools"[All Fields] OR "school"[All Fields]) OR ("pediatrics"[MeSH Terms] OR "pediatrics"[All Fields] OR "pediatric"[All Fields]) AND ("back pain"[MeSH Terms] OR ("back"[All Fields] AND "pain"[All Fields]) OR "back pain"[All Fields]) OR ("low back pain"[MeSH Terms] OR ("low"[All Fields] AND "back"[All

Fields] AND "pain"[All Fields]) OR "low back pain"[All Fields]) OR ("low back pain"[MeSH Terms] OR ("low"[All Fields] AND "back"[All Fields] AND "pain"[All Fields]) OR "low back pain"[All Fields] OR ("lumbar"[All Fields] AND "pain"[All Fields]) OR "lumbar pain"[All Fields]) AND ("epidemiology"[Subheading] OR "epidemiology"[All Fields] OR "prevalence"[All Fields] OR "prevalence"[MeSH Terms]) OR ("epidemiology"[Subheading] OR "epidemiology"[All Fields] OR "epidemiology"[MeSH Terms]) OR ("risk factors"[MeSH Terms] OR ("risk"[All Fields] AND "factors"[All Fields]) OR "risk factors"[All Fields] OR ("risk"[All Fields] AND "factor"[All Fields]) OR "risk factor"[All Fields]) OR Bag[All Fields] OR (("schools"[MeSH Terms] OR "schools"[All Fields] OR "school"[All Fields]) AND bag[All Fields]) AND (("lifting"[MeSH Terms] OR "lifting"[All Fields] OR "carrying"[All Fields]) AND bag[All Fields]) OR (("schools"[MeSH Terms] OR "schools"[All Fields] OR "school"[All Fields]) AND bag[All Fields])

PHASE 7

["adolescent" OR "child" OR "young"] AND "schools" AND "pediatrics" AND ["back pain" OR "low back pain" OR “lumbar pain” OR "musculoskeletal pain" OR “waist pain” OR "musculoskeletal diseases" OR "musculoskeletal disorder" OR "low back ache"] AND "epidemiology" AND "prevalence" AND "risk factors" AND ["lifting" OR "lifting"OR "carrying" OR bag]