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Systematic Review

The Impact of Schoolbags on Postural Health in School-Aged Children: An Updated Systematic Review

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Abstract

Schoolbags represent a common source of physical strain for school-aged children and may influence posture during critical years of growth. This systematic review synthesizes evidence published since the previous review (1995–2014), which mainly focused on load thresholds and did not consider postural health as a multidimensional outcome. The review protocol was prospectively registered in PROSPERO (CRD420251080328). PubMed, Web of Science, and Google Scholar were systematically searched up to 11 June 2024. Of 1013 screened articles, 12 studies met the inclusion criteria. Schoolbag weight was the most frequently investigated factor, followed by postural and spinal alterations, particularly scoliosis. Excessive loads were consistently associated with trunk inclination, postural asymmetry, lumbar strain, and musculoskeletal discomfort. Several studies reported demographic differences, with girls showing greater susceptibility to postural deviations and boys carrying heavier loads. Compared with earlier evidence, more recent studies employed improved postural assessment methods and broader outcome frameworks incorporating ergonomic and behavioral factors. Despite methodological heterogeneity, findings support limiting schoolbag weight to 10–15% of body weight. This review highlights the importance of integrating ergonomic design, carrying behaviors, and demographic modifiers into school health guidelines and provides practical recommendations for clinicians, educators, and policymakers.

Keywords: schoolbag parameters; postural changes; scoliosis; musculoskeletal health

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1. Introduction

The musculoskeletal health of schoolchildren is increasingly recognized as an important area for preventative intervention, particularly in educational settings where persistent physical demands, such as daily schoolbag carriage, are imposed. Transporting academic materials and personal items is one of the most common forms of repetitive weight-bearing activity during growth. While schoolbags are essential for daily school activities, growing

evidence suggests that excessive or improper use may negatively impact children's posture and spinal health.

From a biomechanical perspective, carrying excessive loads alters the body's center of gravity, increases muscle activation demands, and induces compensatory strategies such as forward trunk lean, asymmetrical shoulder elevation, and changes in spinal curvature [1]. Over time, these adaptations may lead to muscle fatigue, imbalance, and postural deviations, particularly in the developing musculoskeletal system [2]. Studies have shown that repetitive loading of heavy schoolbags is associated with a higher prevalence of back and shoulder pain, likely due to increased stress on immature spinal structures during critical developmental periods [3–5].

Research consistently recommends limiting schoolbag loads to no more than 10% of body weight to minimize the risk of musculoskeletal issues [6–12]. Exceeding this weight limit has been linked to changes in spinal curvature, including the hollowing of lumbar lordosis and postural instability [13]. Evidence from multiple regions worldwide indicates that many schoolchildren regularly carry bags weighing more than 15% of their body weight, placing them at greater risk of posture-related musculoskeletal issues [14–16].

In addition to load magnitude, schoolbag type and ergonomic design play a critical role in load distribution and postural response. Common schoolbag designs include double-strap schoolbags, single-strap shoulder bags, and rolling schoolbags, each associated with different biomechanical demands. Features such as strap symmetry, bag positioning, load placement, and adjustability influence spinal loading patterns and may contribute to asymmetrical stress and compensatory postural behaviors [17]. Accordingly, several health authorities have emphasized not only load limits but also ergonomic recommendations, such as the use of double-strap schoolbags with wide, padded shoulder straps and even weight distribution [18,19]. Despite these guidelines, improper schoolbag use remains common, with children frequently carrying heavy loads asymmetrically or for prolonged durations. Prolonged exposure to such conditions may lead to cervical and lumbar muscle fatigue, overloading of posterior spinal structures, and the development of maladaptive postural habits [20]. If left unaddressed, these stresses may contribute to long-term musculoskeletal alterations, including scoliosis, kyphosis, and other spinal deviations [21–23].

Currently, only one systematic review has specifically examined the influence of schoolbag load on postural deviations in schoolchildren, covering studies published from January 1995 to May 2014 [14]. The review primarily focused on schoolbag load threshold and carrying methods, with postural outcomes largely described in relation to load recommendations. However, postural health was not examined as a multidimensional construct, and the review did not systematically classify types of postural deviations, assess their prevalence, or explore demographic modifiers such as age and sex. In addition, methodological heterogeneity among included studies, reliance on older assessment tools, and the absence of newer objective postural and biomechanical measurement techniques limited the strength and applicability of its conclusions. Since the publication of that review, there has been considerable growth in scientific research on school ergonomics, including studies employing more detailed postural assessments, digital measurement tools, and broader outcome frameworks encompassing postural changes, musculoskeletal discomfort, and schoolbag usage behaviors. In parallel, school-based educational and ergonomic intervention programs have been introduced in some settings to reduce schoolbag load and promote healthy carrying habits [2,24]. These initiatives typically involve educating students, parents, and teachers about recommended load limits, proper schoolbag selection, and correct carrying techniques, as well as promoting behavioral changes such as regular bag organization and the use of double-strap schoolbags. Some programs have

also incorporated ergonomic modifications within schools, including locker availability, digital learning materials, and curriculum adjustments to reduce daily load demands and awareness of musculoskeletal health among students [25]. By emphasizing prevention through education and environmental modification, these programs highlight the potential for schools to play a central role in mitigating posture-related risks and underscore the relevance of schoolbag ergonomics as a public health and educational concern rather than solely an individual behavioral issue.

Accordingly, this systematic review examines the effects of schoolbag weight, design, and usage on children's posture and spinal health. The primary aim is to synthesize recent evidence, identify research gaps, and translate findings into actionable recommendations for improving schoolbag safety. A secondary objective is to evaluate the methodological quality of included studies by assessing key parameters, reported outcomes, and practical implications.

2. Materials and Methods

This systematic review followed the Preferred Reporting Items for Systematic Reviews and Meta-analysis (PRISMA) 2020 guidelines [26] and was registered in PROSPERO (CRD420251080328). The PRISMA checklist for this review is provided in the Supplementary Table S1.

2.1. Search Strategy and Information Sources

The search was performed using three comprehensive databases: PubMed, Web of Science (all databases), and Google Scholar. The database search was completed on 11 June 2024. It includes all the studies from 1 January 2014 onwards that focus on schoolbag-related parameters and their impact on postural alterations. This date was chosen because of a prior review by Janakiraman, Ravichandran [14] covered studies up to May 2014.

2.2. Search Strategy

Two independent authors, Sadaf Ashraf (S.A.) and Cesar Bento (C.B.), screened three comprehensive databases. Primary source articles published until June 2024 were considered eligible. The following terms were defined and used to search in the title/abstract level: "Schoolbag *", "Backpack", "School bag", "Children *", "adolescent", "young people", "Spinal curve alterations*", "Scoliosis", "Kyphosis", "Lordosis", and "Kyphoscoliosis" combined with the Boolean operators "OR" and "AND". No controlled vocabulary terms (e.g., MeSH) were used, as the search strategy relied on free-text keywords to ensure consistency across databases. The details of the search strategy are presented in Table 1.

2.2.1. Inclusion Criteria

The inclusion criteria for the study were as follows: (a) participants aged between 7 and 18 years from both sexes; (b) studies that evaluated postural alterations concerning schoolbag measurements, including both the weight and type of schoolbags used; (c) research that reported associations between schoolbag use and the prevalence of postural alterations in the population studied; (d) studies that were published in full text in English, within the past 10 years, from 1 January 2014 to 11 June 2024; and (e) eligible study designs included cross-sectional, cohort, case–control, and experimental studies that quantitatively assessed the association between schoolbag use and postural alterations. These criteria ensured a focused examination of the impact of schoolbag use on posture among school-aged children and adolescents, using recent and relevant research in the field.

Table 1. Database-specific search strategies and results.

Database	Search Strategy	Filters Applied	Records Retrieved
PubMed	("Backpack" OR "school bag" OR "schoolbag") AND ("children" OR "adolescents" OR "young people") AND ("spinal curve alterations" OR scoliosis OR kyphosis OR lordosis OR kyphoscoliosis)	Publication date: 1 January 2014–11 June 2024; Language: English; Article type: peer-reviewed journal articles	14
Web of Science Core Collection	TI = (Backpack OR "school bag" OR schoolbag) OR AB = (Backpack OR "school bag" OR schoolbag) AND TI = (children OR adolescents OR "young people") OR AB = (children OR adolescents OR "young people") AND TI = ("spinal curve alterations" OR scoliosis OR kyphosis OR lordosis OR kyphoscoliosis) OR AB = ("spinal curve alterations" OR scoliosis OR kyphosis OR lordosis OR kyphoscoliosis)	Publication years: 2014–2024; Language: English; Indexes: SCI-EXPANDED, SSCI, ESCI	4
Google Scholar	("schoolbag" OR "backpack") AND (children OR adolescents) AND (posture OR scoliosis OR "spinal curvature")	Year range: 2014–2024; Language: English; Exclusion of patents and citations	995
Total records identified			1013

2.2.2. Exclusion Criteria

The exclusion criteria for the study were as follows: (a) studies involving participants with injuries, illnesses, disabilities, congenital deformities, or alterations not related to postural etiology were excluded; (b) studies that did not report both postural alterations and schoolbag measurements, such as weight and type, were not considered; (c) purely descriptive reports lacking quantitative assessment of schoolbag characteristics and postural outcomes, as well as systematic reviews, meta-analysis, opinion papers, book chapters, conference abstracts, letters to editors, and narrative commentaries were excluded; (d) dissertations and theses were excluded unless their findings had been published in a peer-reviewed journal; and (e) studies published before 2014 or written in languages other than English were excluded. Regarding study design, priority was given to original research that provided detailed methodologies for assessing the impact of schoolbag weight on postural alterations and reported corresponding quantitative results. This approach ensured a focus on high-quality primary evidence relevant to the relationship between schoolbag use and posture in school-aged children.

2.3. Study Selection and Data Collection

All the articles retrieved through the implemented search strategy were compiled using the EndNote reference manager version 20.5 (Clarivate, Philadelphia, PA, USA), developed by Clarivate Analytics. Initially, duplicate conference articles were screened out using the reference manager. Title, abstract, and full-text screenings were independently conducted by two authors (S.A. and C.B) to ensure that articles met the inclusion criteria. In cases of disagreement regarding the full-text reading for eligible studies, a final decision was made by a third, more experienced author (Ana Rodrigues—A.R).

2.4. Data Collection and Outcomes

Data extraction was conducted independently by two reviewers (S.A. and C.B.) using a predefined data extraction framework developed for this review. Extracted information included study characteristics, schoolbag-related parameters, postural outcomes, and key findings. Discrepancies were resolved through discussion, with consultation of a third reviewer (A.R.) when consensus could not be reached. Formal inter-rater reliability

statistics (e.g., kappa coefficients) were not calculated when interpreting the consistency of data extraction.

2.5. Study Quality Assessment

Study quality was assessed independently by two reviewers (S.A. and C.B.) under the supervision of a third author (A.R.), using a structured scoring scheme (Supplementary Table S5). The assessment tool was specifically developed to reflect the objectives of this review and to allow systematic comparison across heterogeneous study designs.

Each included study was evaluated across six criteria: (1) clarity of study purpose, (2) sample characteristics, (3) methodological approach and measurement instruments, (4) schoolbag-related parameters, (5) postural alterations assessed, and (6) clarity of reported findings. These domains were selected to capture both methodological soundness and the completeness and relevance of reporting for variables central to schoolbag-related postural research.

Scores were assigned based on the adequacy, clarity, and appropriateness of reporting within each domain. All criteria were equally weighted to minimize subjective bias and because no empirical evidence supports differential weighting of these parameters in this research field. Total scores were used to classify studies into four quality tiers: weak ($\leq$5), reasonable (6–8), good (9–10), and strong ($\geq$11). Disagreements between reviewers were resolved through discussion and consensus.

2.6. Heterogeneity, Missing Data, and Subgroup Analysis

Given the anticipated heterogeneity in study designs, outcome measures, and assessment tools, a narrative synthesis approach was planned a priori. The included studies examined diverse schoolbag-related parameters (e.g., absolute weight, weight relative to body weight, bag type, strap symmetry, carrying method, and duration of carriage) and reported a wide range of postural outcomes using heterogeneous measurement techniques, including scoliometry, photogrammetry, digital inclinometers, posture scoring systems, and self-reported measures. Due to the variability in exposure definitions, outcome metrics, and reporting formats, a quantitative meta-analysis was deemed infeasible. Although the standardization of effect sizes was explored during data extraction, insufficient consistency in outcome reporting and a lack of comparable statistical data prevented the meaningful pooling of results. Consequently, findings were synthesized qualitatively by comparing reported associations across studies.

Subgroup and sensitivity analyses were not conducted due to missing data, inconsistent reporting of demographic variables, and the limited number of studies providing comparable subgroup-specific outcomes. Instead, reported schoolbag parameters and postural outcomes were systematically grouped and summarized to identify recurring patterns, sex- and age-related trends, and gaps in the existing literature.

3. Results

3.1. Study Screening Results

Out of 1013 articles retrieved from the search strategy presented in Table 1 using multiple databases, 12 articles were included, followed by data collection and analysis. Figure 1 illustrates the PRISMA flow diagram, which outlines the article's screening process. It is essential to note that no explicit search was conducted for other parameters, except for schoolbags and posture. A summary of the study's description, the variables included, and the main findings is shown in Supplementary Table S2. The articles excluded after eligibility assessment, along with the specific reasons for exclusion, are presented in Supplementary Table S3.

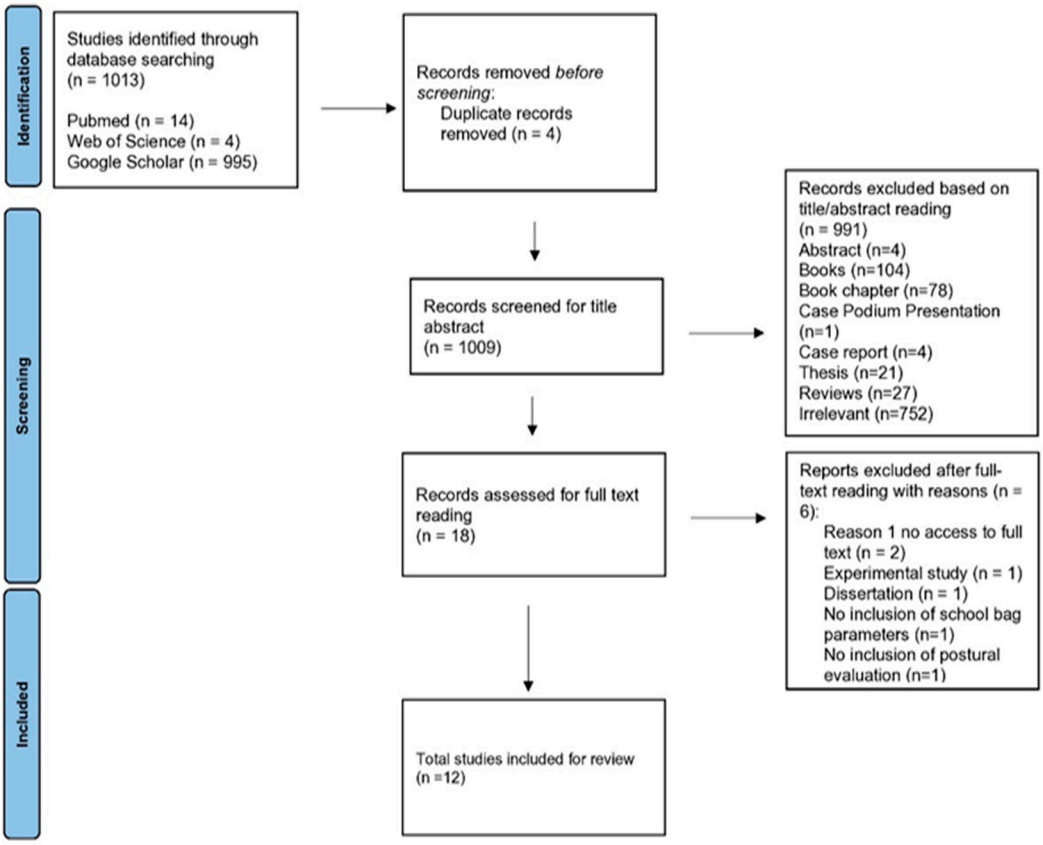

Figure 1. PRISMA flow diagram.

3.2. Population Characteristics

Participants' Demographics

Age was consistently reported across all studies, with participants ranging in age from 7 to 18. The smallest sample comprised six children [27], while the largest involved 3018 children [28]. Of the 12 studies, 10 (83.3%) provided specific age ranges with varying distributions, while two studies (16.6%) did not mention age ranges [8,27]. Only five studies (41.6%) reported the average age of the participants [20,29,30]. Two studies included small-scale samples (fewer than 100 participants) [19,27], while ten studies had large-scale samples (over 1000 participants) [6,8,13,20,28–33]. Overall, reporting participants' numbers was clear and consistent across most included studies.

Gender was recorded in most studies. In 10 out of 12 studies (83.3%), the gender distribution was specified; one study did not provide this information [8], and another study featured a female-dominant sample [31]. Overall, the gender distribution was not evenly balanced across studies.

3.3. Purpose of Study

The reviewed studies examined the relationship between schoolbag weight, body posture, and spinal health in children and adolescents, with a focus on adolescent idiopathic scoliosis (AIS) and other postural disorders. Several studies [13,19,27,29] investigate the impact of varying schoolbag loads on posture and spinal movement, assessing how these loads compare to carrying no schoolbag. Studies, including [20,28,30,32,33], also examine the prevalence of AIS and its associated risk factors, such as body mass index (BMI), physical activity, gender, age at menarche, and transportation methods, including schoolbag characteristics like weight and carrying style. Additionally, the prevalence of postural disorders was explored in [8,20,30,31], including scoliosis within specific populations, with

studies targeting schoolchildren and adolescents in various regions. These investigations aim to determine how demographic factors such as body weight, gender, and region contribute to postural issues. Furthermore, several studies [6,29,33] assess how schoolbag design features, including straps and how schoolbags are carried, affect back health and posture over time. Overall, insights are provided into how school-related factors, especially schoolbag usage, influence posture and contribute to spinal disorders in young populations.

3.4. Parameters of Schoolbags

The most frequently reported parameter mentioned in 10 studies was school bag weight, highlighting its significance related to posture. The type of bag used by students was considered in four studies [6,28,29,31], while more specific details like the specific schoolbag weight [19,27] and the schoolbag carrying method [31,32] were each reported in two studies. Similarly, studies [6,19] reported the time spent carrying the bag. Less commonly addressed factors included the symmetry of both straps, the length of straps, schoolbag positioning, and bag handling technique, each mentioned in just one study [29]. This indicates that while weight is a primary concern, other ergonomic factors related to bag usage should be more consistently explored across the studies. The parameters of schoolbags are mentioned in Figure 2.

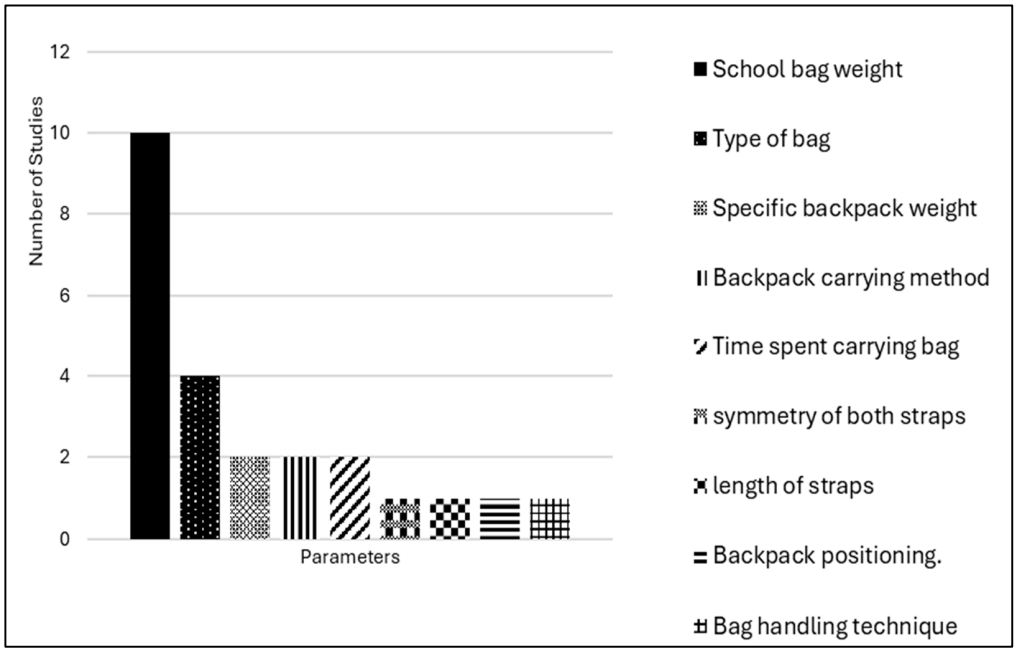

Figure 2. Distribution of schoolbag-related parameters assessed across included studies. Note: Parameters include backpack weight, bag type, carrying method, duration of carriage, and ergonomic features such as strap symmetry and backpack positioning.

3.5. Postural Changes Evaluated

As shown in Figure 3, the posture assessment varied across the studies. Out of 12 studies, scoliosis was the most frequently assessed condition, examined in six studies, either as a primary focus [28,30,32] or in conjunction with other postural parameters [20,27,31]. A complete postural assessment was conducted in five studies, providing a comprehensive overview of participants' postural health. Specific measurements, such as kyphosis, lordosis, and pelvic/scapulothoracic positions, were evaluated in two studies [29,31], while head, neck, and spine deviations were examined in two studies [6,18]. Additionally, the symmetry of various body parts, such as the shoulders, scapulae, hips, arms, and trunk, was assessed in one study [20].

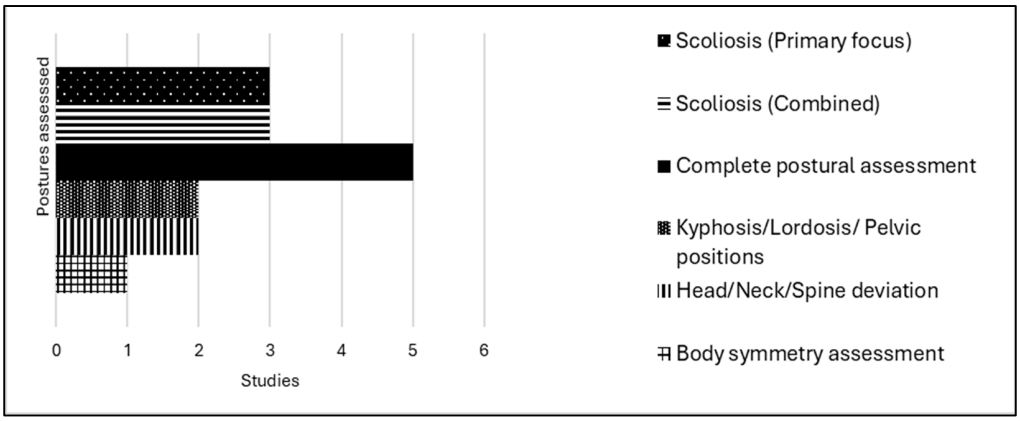

Figure 3. Distribution of postural changes evaluated across included studies. Note. Postural outcomes include scoliosis, spinal curvature measures, segmental alignment, and symmetry-related parameters assessed in the reviewed studies.

3.6. Instruments Used

The results present various instruments and methods to assess posture, spinal health, and schoolbag ergonomics. One of the studies [27] utilized specialized schoolbags of varying weights (3 kg and 6 kg) along with motion-capture tools such as digital cameras, Kinovea software, and MATLAB for analyzing gait cycles and postural movement. Another study [32] used commonly employed questionnaire-based approaches, with instruments like the 21-item questionnaire that incorporated the International Physical Activity Questionnaire (IPAQ) and the Adam Forward Bend Test (AFBT) to assess idiopathic scoliosis. Other studies [28,33] gathered similar demographic and ergonomic data. Several studies [8,19,31,32] recorded schoolbag weight using medical or portable electronic scales. At the same time, posture assessments utilized tools such as the Adams test with a PediScoliometer, digital inclinometers, and the New York scoring protocol to evaluate spinal deviations.

Moreover, one study [13] employed more advanced postural analysis tools, such as the Zebris Ultrasonic System with WinSpine 2.3 software, while another [31] used traditional tools like a flexible ruler for lumbar lordosis and the Debrunner kyphometer for thoracic kyphosis for more detailed postural evaluations. Several other studies [6,19,20,30] also incorporated photogrammetry, scoliometers, and posture scales, such as the Reedco scale, Grimmer's Questionnaire, and the Wroclaw Physical Fitness Test, to complement the physical assessments of scoliosis, posture, and related risk factors.

3.7. Main Findings

The main findings of the included studies are summarized in Supplementary Table S4, highlighting the reported effects of schoolbag load on posture, the prevalence of postural alterations, and factors such as incorrect schoolbag use, musculoskeletal pain, and gender differences.

3.7.1. Impact of Schoolbag Load on Posture

Refs. [13,19,27] consistently highlighted the adverse effects of heavy schoolbag loads on spinal alignment, posture asymmetry, and balance. Certain studies [27] emphasized increased trunk tilt and spinal stress, while others [19] highlighted asymmetry in the torso, shoulder, and waist. Additionally, another study [13] indicated a statistical correlation between load weight and changes in spinal parameters, such as lumbar lordosis and sacrum inclination, which has also been reported. However, another study [8] also reported that factors such as body weight and height may influence postural deviations more than the schoolbag load.

3.7.2. Prevalence of Postural Changes

Tassawur et al. identified postural alterations, reporting that 48.66% of students had scoliosis, while 73% exhibited shoulder and scapular asymmetry [20]. Likewise, another study reported that 65% of students had scoliosis, lordosis (56.6%), and kyphosis (20%) [33]. However, another study found no significant association between schoolbag weight and adolescent idiopathic scoliosis, suggesting that other factors, such as BMI and physical activity, might play a role in scoliosis development.

3.7.3. Incorrect Use of Schoolbags

The improper use of schoolbags was another parameter that contributed to malalignments. A study reported that asymmetric straps used by 79.3% of students contributed to spinal misalignment and increased trunk rotation [28]. Another study illustrated that 97.2% of students carried schoolbags, but only 1.9% did so correctly, contributing to postural deviations [33]. Furthermore, ref. [6] reported that 55% of students did not use waist belts, and many carried additional items in their schoolbags, which further increased the load and strain on their posture.

3.7.4. Back Pain and Musculoskeletal Discomfort

Carrying schoolbags for extended periods and exceeding limits contributes to musculoskeletal discomfort, as mentioned in various studies. One study reported that 42% of students described back pain with an average schoolbag weight of 7.61 kg [32], while another study stated that 22.8% of students experienced moderate to severe pain [33]. Moreover, a study illustrated that 64% of students had neck pain, 53% had upper back pain, and 19% had shoulder pain [6].

3.7.5. Gender and Age Differences

Studies exhibited that boys carried heavier loads than girls, with the weight of schoolbags increasing as students aged [29]. Boys also exhibited greater thoracic and thoracolumbar spine rotation, while girls were more affected by vertical deviations and trunk rotation due to poorly adjusted straps. Additionally, another study found that females had a higher rate of pathological trunk rotation than males, suggesting that girls may be more susceptible to postural changes from schoolbag use [30].

3.7.6. Recommendations and Threshold for Safe Load

Across the included studies that quantitatively evaluated schoolbag weight, most expressed load as a percentage of body weight rather than as an absolute value. Several studies reported that a substantial proportion of schoolchildren carried schoolbags exceeding recommended limits, most commonly above 10% of body weight [6,13]. For instance, Walicka-Cupryś et al. (2015) reported that only 40.37% of children carried schoolbags weighing less than 10% of their body weight, indicating frequent exceedance of recommended thresholds [13].

Among studies examining the association between schoolbag load and postural parameters, statistically significant relationships were reported for at least one outcome in most studies, although not all postural measures were consistently affected. Walicka-Cupryś et al. (2015) identified statistically significant associations between schoolbag load and total spine length, lumbar lordosis length, lumbar lordosis angle, and sacral inclination angle [13]. However, no significant differences were observed for thoracic kyphosis or trunk inclination. The authors also found a significant relationship between schoolbag load and spinal parameters such as lumbar lordosis angle and sacrum inclination, recommending that schoolbags should weigh no more than 10–15% of body weight [13].

Other studies reported that heavier schoolbag loads and longer carriage durations were associated with a higher prevalence of poor neck, shoulder, and upper back posture, as well as musculoskeletal discomfort. In Zaheer et al. (2022), students carrying schoolbags for longer durations and exceeding recommended load limits demonstrated higher rates of neck and upper back postural deviations and pain [6].

Due to heterogeneity in study design, exposure categorization, and outcome measures, a pooled average schoolbag weight could not be calculated across studies.

3.8. Study Quality Assessment Results

This review identified six key parameters for assessing the quality of studies on the impact of schoolbags on postural alterations: purpose clarity, sample characteristics, methodology and instrumentation, schoolbag parameters, postural alteration assessment, and reporting of main findings. Studies were evaluated on each parameter with an emphasis on the completeness, clarity, and relevance of reporting, as well as the appropriateness and validation of the methodology and assessment tools.

The quality assessment focused primarily on reporting completeness and the inclusion of predefined key parameters rather than on a strict hierarchy of study design. Consequently, studies employing cross-sectional designs or small sample sizes could still be classified as good and strong if they comprehensively reported the specified criteria and provided detailed, relevant methodological and outcome information. While this approach allowed for a structured comparison across heterogeneous study designs, it may have favored reporting quality over methodological rigor in some cases.

Some parameters were commonly included, such as sample demographics and methodological validation, while further information on schoolbag parameters, bias control, and statistical analysis was less consistently reported, limiting comparability in some cases.

The details of each study, along with its quality assessment based on these parameters, are presented in Supplementary Table S5. Studies were subsequently classified into four quality tiers: strong, good, reasonable, and weak. According to this categorization, six studies were classified as strong quality, and four studies were rated as good quality, reflecting comprehensive methodological rigor and thorough assessment across multiple domains. In contrast, two studies were categorized as reasonable quality, primarily due to limited reporting or insufficient coverage of critical assessment domains.

4. Discussion

This systematic review aims to identify and synthesize current schoolbag parameters and their impact on postural alterations in children. By examining existing studies, this review provides a consolidated view of the parameters most relevant to assessing the influence of schoolbags on posture, helping researchers refine their study designs and identify key variables. Additionally, this analysis highlights gaps in the literature, offering guidance on parameters that could be further explored to improve the understanding of the postural impacts of schoolbags on children.

4.1. Context of Evidence and Limitations

Our review of 12 studies reinforces several key findings regarding how schoolbag parameters such as weight, type, design, and carrying methods contribute to postural misalignment and musculoskeletal discomfort. Factors such as gender, age, and ergonomic practices are crucial in affecting how young individuals experience and respond to the physical strain of the schoolbags. Accordingly, this discussion is structured around four key themes: the effects of schoolbag weight on postural alignment, the role of ergonomic

design and carrying practices, gender-related differences in postural responses, and the potential long-term health implications associated with schoolbag use.

Excessive bag weight has a strong association with spinal misalignments, including lumbar lordosis, sacral inclination, and torso asymmetries [13,19,27], trunk tilt, and spinal stress [27], and imbalances in shoulder and waist alignment [19]. From a biomechanical perspective, heavier schoolbag loads shift the body's center of gravity backwards, requiring compensatory forward lean of the trunk to maintain balance [34]. This adaptation increases compressive and shear forces along the spinal column, altering load distribution across the shoulders, waist, and lower back, and thereby contributing to postural imbalance and musculoskeletal strain [35].

Relatively few studies have examined the ergonomic characteristics of schoolbags in detail; however, available evidence suggests that schoolbag design and carrying methods play a crucial role in modulating postural responses. Two-strap schoolbags promote more symmetrical load distribution across the shoulders and trunk, whereas single-strap shoulder bags are associated with compensatory lateral trunk lean and asymmetric spinal loading [2,36]. Such asymmetry has been linked to reductions in expiratory muscle strength [37], altered electromyographic activity in both upper and lower limb muscles [36,38], and an increased risk of gait disturbances and spinal deviations, including scoliosis [39,40].

Rolling schoolbags have been proposed as an alternative to reduce spinal loading; however, they introduce different biomechanical demands related to sustained pulling forces and increased upper-limb involvement. These pulling forces may exceed the actual load weight, in some cases approaching nearly twice the mass of the carried load [41]. Furthermore, despite a common perception that rolling schoolbags are safer, their use may encourage the transport of heavier loads compared with conventional schoolbags, with reported weights averaging approximately 2.4 kg [42].

Schoolbag position on the trunk is another important ergonomic factor influencing postural alignment. Loads positioned lower on the back increase forward trunk inclination and postural displacement relative to higher placement near the waist or hip level [43]. Accordingly, recommendations emphasize positioning the schoolbag higher on the back and properly adjusting shoulder straps to maintain stability and reduce postural strain [44]. When schoolbags are worn lower due to longer shoulder straps, forward inclination of the upper trunk becomes more pronounced, shifting body weight toward the forefoot and increasing postural demands during standing and walking [45,46].

Strap length and fit further modulate these effects. Excessively long shoulder straps allow for the schoolbag to hang farther from the body, increasing the moment arm of the load and altering the direction of applied forces. Biomechanically, this configuration increases torque acting on the trunk and shoulders, thereby amplifying rotational and compressive demands on the musculoskeletal system compared with properly tightened straps [47]. In contrast, shorter, well-adjusted straps enable partial load sharing across the back, reducing localized shoulder strain.

Beyond design features, improper schoolbag use, such as asymmetrical strap carriage or the absence of waist belts, further compounds the risk of spinal misalignment [6,29,33]. These behaviors are widespread, with evidence suggesting that many students do not consistently wear schoolbags as recommended [33]. Importantly, schoolbag choice and usage in real-world settings are often influenced by aesthetic preferences, convenience, and peer behaviors, which may undermine ergonomic recommendations. Addressing these behavioral and psychosocial factors, alongside design improvements, is essential for developing effective ergonomic guidelines, educational interventions, and school-level policies aimed at reducing musculoskeletal risk.

Across the studies included in this review, gender-related differences were observed in both schoolbag-carrying behaviors and postural responses. Several studies reported that female students exhibited a greater tendency toward trunk rotation and spinal asymmetry, whereas male students were more likely to carry heavier loads, resulting in increased mechanical stress on spinal structures [29,30]. Rather than reflecting a single causal factor, these differences likely arise from an interaction of biological and behavioral influences.

From a biological perspective, differences in anthropometry, muscle strength, and skeletal maturation between boys and girls may contribute to distinct postural adaptations when carrying external loads. Behaviorally, variations in schoolbag use, such as strap adjustment practices, carrying style, and consistency of use, may further modulate these responses. For example, some studies suggest that improper strap adjustment is more frequently observed among female students, which may increase asymmetrical loading patterns and contribute to postural deviations [29,30]. However, the available evidence remains limited and heterogeneous, and such observations should be interpreted cautiously.

Overall, the findings suggest that gender is a significant moderating factor in the relationship between schoolbag use and postural alignment. This underscores the need for ergonomics education and preventive strategies that are sensitive to gender-specific behaviors and physical characteristics, rather than relying on uniform assumptions about schoolbag use across all students.

Musculoskeletal discomfort associated with schoolbag use is commonly reported among school-aged children, particularly in the neck, upper back, and shoulder regions [6,32,33]. While these symptoms are often transient, repeated exposure to excessive loads or improper carrying practices may increase the risk of persistent musculoskeletal strain during critical periods of growth and development. Importantly, the available evidence suggests associations rather than direct causation, and the long-term consequences of sustained schoolbag-related stress remain insufficiently understood.

From a developmental perspective, prolonged exposure to unfavorable loading conditions may contribute to maladaptive postural behaviors, altered movement patterns, and increased susceptibility to musculoskeletal discomfort later in life. However, most studies included in this review employed cross-sectional designs, limiting the ability to determine whether observed postural deviations or pain symptoms persist, worsen, or resolve over time. As such, the extent to which childhood schoolbag use influences long-term spinal health or chronic musculoskeletal conditions cannot be conclusively established.

These findings underscore the need for longitudinal research that tracks postural development, pain progression, and functional outcomes across childhood and adolescence. Such evidence would be critical for clarifying long-term risk trajectories and informing preventive strategies aimed at reducing the potential cumulative impact of schoolbag-related musculoskeletal loading.

The interpretation of the findings from this systematic review must consider the methodological variability across the included studies. Substantial differences were observed in sample size, study design, and postural assessment approaches, all of which may have contributed to heterogeneity in reported outcomes. Smaller experimental studies often provided detailed biomechanical insights but were limited by reduced statistical power, whereas larger observational studies offered broader population-level perspectives, albeit with less precise assessment methods.

4.2. Practical Implications

This systematic review provides practical insights into the impact of schoolbag characteristics and carrying practices on postural health in children. By consolidating evidence on schoolbag weight, type, and ergonomics, the review informs the design of postural

evaluation strategies and supports the development of preventive health interventions within school settings. In line with internationally recognized ergonomic and public health guidance, several health and pediatric organizations recommend that schoolbag loads should generally not exceed approximately 10–15% of a child's body weight and emphasize the importance of proper backpack fit and symmetrical load distribution to minimize biomechanical strain. These principles underpin school health policies and ergonomic recommendations adopted across multiple countries and educational systems [48].

The findings provide guidance for parents, teachers, and policymakers on optimal schoolbag use, including effective load management and ergonomic carrying practices. Increased awareness of schoolbag-related postural risks may facilitate earlier identification of postural deviations and encourage the implementation of school-based strategies aimed at promoting healthy habits. Educational initiatives and routine monitoring within schools may help reduce postural alterations, musculoskeletal discomfort, and the potential progression of posture-related problems later in life.

4.3. Limitations of the Review Process

Several limitations should be considered when interpreting the findings of this review. First, only peer-reviewed studies published in English were included, which may have introduced language bias and excluded relevant evidence from non-English sources. In addition, unpublished studies and conference proceedings were not considered, which raises the possibility of publication bias favoring studies that report statistically significant findings.

The reliance on the published literature and database-driven search strategies also introduces the potential for reporting and lead-time bias. Furthermore, the diversity of study metrics and outcome measures complicated cross-study comparisons and limited the robustness of risk-of-bias assessments. In some cases, postural outcomes were presented visually rather than numerically, restricting the extraction of precise data for synthesis.

Several included studies relied on self-reported measures of schoolbag use and musculoskeletal discomfort, which may be subject to recall bias and reporting inaccuracies. Moreover, although most studies were rated as methodologically strong and good, many employed cross-sectional designs and relatively small sample sizes. As a result, these quality ratings primarily reflect reporting standards rather than the ability to establish causal relationships. A key limitation of the existing literature is the lack of longitudinal studies examining the long-term effects of schoolbag use on postural development and musculoskeletal health. This gap restricts the ability to draw conclusions regarding causality and the persistence of observed postural deviations over time. Future research incorporating longitudinal follow-up and objective assessment methods would be essential to clarify risk trajectories and inform evidence-based interventions.

Despite these limitations, the findings of this review provide a valuable foundation for informing school-based preventive strategies, such as routine posture screening, teacher education on ergonomic monitoring, and student-focused training on proper schoolbag use. Continued refinement of research methods and intervention studies will be critical for translating ergonomic evidence into effective public health and educational policies.

4.4. Future Research and Recommendations

Although only 12 studies met the inclusion criteria of this review, this number reflects the limited availability of research that simultaneously examines schoolbag-related parameters and objectively evaluates postural outcomes in children. The included studies, therefore, represent the entirety of the available evidence meeting predefined methodological and outcome criteria, rather than a selective subset. Nevertheless, the limited number

of eligible studies and their methodological heterogeneity restrict the generalizability of current findings and underscore a clear need for further high-quality research in this field.

Future research should extend beyond schoolbag weight to more comprehensively examine ergonomic factors that influence postural health. These include strap characteristics (length, width, and bilateral symmetry), schoolbag positioning on the trunk, and carrying techniques (e.g., one-shoulder, two-shoulder, cross-body, or handheld use). The inclusion of these variables is essential for fully characterizing the biomechanical and postural effects of schoolbag use in children and adolescents.

There is also a critical need for longitudinal study designs to better understand the long-term impact of schoolbag use on postural development. While cross-sectional studies provide valuable snapshots, they are insufficient for capturing cumulative effects or progressive postural changes over time. Longitudinal investigations would enable researchers to track posture-related outcomes across key developmental stages, thereby helping to clarify potential associations between schoolbag ergonomics and conditions such as scoliosis, kyphosis, and chronic musculoskeletal discomfort.

Finally, future studies should aim to integrate standardized postural assessment protocols that are both reliable and feasible in school environments. The use of harmonized measurement frameworks would enhance comparability across studies, strengthen evidence synthesis, and support the development of robust, evidence-informed ergonomic recommendations for children and adolescents.

Supplementary Materials: The following supporting information can be downloaded at: https://www.mdpi.com/article/10.3390/future4010007/s1, Table S1: PRISMA 2020 checklist; Table S2: Summary of studies description, variables included, and main findings; Table S3: Reasons for exclusion of full-text articles; Table S4: Summary of main findings; Table S5: Quality assessment. Table S5a: Scoring for study quality assessment.

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