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Reported influences of backpack loads on postural deviation among school children: A systematic review

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Abstract:

BACKGROUND: Nowadays, a large number of students experience spinal pain quite early in life due to heavy school bag loads. Moreover, external forces in the form of school bags may influence the normal growth, development of children and adolescents, and also maintenance of alignment of their bodies, which can pose a huge threat to postural integrity under external load. Awareness about the appropriate load and placement of backpack is thought to be important in reducing musculoskeletal complications among children's.

METHODS: A systematic review of randomized controlled trials (RCTs) was conducted to determine the influence of postural deviations due to backpack load among school children's. Electronic databases were searched, and a reference list of retrieved articles were relevant to postural changes among school children with the backpack were screened. Reviewers graded the papers according to Lloyd-Smith's hierarchy of evidence scale. Papers were quality appraised using a modified Crombie tool.

RESULTS: Twelve papers were identified for inclusion in this review. Methodological difference limited our ability to collate evidence.

CONCLUSION: Most of the articles recommended that backpack load limit for school children should be 10–15% of body weight. However, the appropriate load limit for school children is limited due to lack of articles, the low hierarchy of evidence, and small sample size. This review constrains the use of published literature to inform good load limit of school pack among the school children.

Keywords:

Musculoskeletal pain, postural angle, school bag loads, school children

Introduction

Recently, it is well-noted that a large number of children visit physicians to get treated for their musculoskeletal problems and spinal pain seems to be the most common reasons. Many studies reveal and recommend different school bag weight percentage and carrying methods to avoid bodily stress[1] School bag loads are reported to cause many problems in children such as body pain, cardio-respiratory changes, postural changes, and balance impairment. The ability to hold and align body segments specifically depends on the ability to fix and restore the center of mass in an optimal position.[2] School bag loads will blunt this ability and sometimes leads to fall and injuries in school children.

Overall lifetime prevalence of low back pain in children has been reported as high as 65%, and an alarming finding by an Iranian study reported an 86% prevalence of musculoskeletal symptoms among 307 primary school children at the younger ages between 7 and 12 years. Greater understanding of children posture and other underlying factors are needed to guide the decision-making process in child health.[3]

Heavy school bags are believed and reported to cause more than musculoskeletal symptoms. Pascoe *et al*. reported the association of school bag load and

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educational failure, lack of motivation, lack of learning, and absenteeism.[4] Studies have also shown that more than 50% of the students carry very heavy school loads and 55% of the student carried loads which weigh more than the recommended limit (10–15% of the body weight) to school which may damage the vertebral column and cause musculoskeletal pain.[5,6] Recent research in primary school children from an urban city in India revealed 60.6% male pupil and 65.7% female children reported musculoskeletal pain and the most affected area being low back and neck.[1]

A cross-sectional descriptive study done in Kampala, Uganda East Africa involving 532 children from six primary schools reported that about 30.8% of the children carried school bags which were more than 10% of their body weight, which was beyond American Public Transportation Association recommendation. About 88.2% of pupils reported having body pain, especially in the neck, shoulders, and upper back. About 35.4% of the children self-reported that carrying the schoolbag was the cause of their musculoskeletal pain. The prevalence of lower back pain was 37.8%.[7] A Brazilian study done in 2013 showed that the prevalence of musculoskeletal pain was 51% in primary school children, and the most affected areas were legs and spine.[8]

It has been shown that the school bag, of approximately more than 15% of the body weight can cause excessive loading on the spine, the upper part of the body (head and cervical spine), and upper limbs that load their weight into thoracic spine. Excessive loading of school bags has detrimental effects of posture. Excess and long-term loading cause's forward head posture, protracted shoulders, and kyphosis. To determine postural changes with school bag, measurement of cranio-horizontal angle, cranio-vertebral angle, and sagittal shoulder posture were taken while loaded in static (standing) and dynamic (walking) postures and it has to be compared when unloaded (without school bag).[9]

Research works to explore a critical school bag load to body ratio that if exceeded affects health is still evolving. The lack of reliable and valid posture measurement instruments which can be applied with confidence in any setting underpins the poor evidence base for the association between posture and pain. Current literature also provides evidence for the etiology of adolescent musculoskeletal pain to be multi-factorial in nature and could be attributed to psychological, social, and environmental factors, which adds to the complexity of determining the risk factors for adolescent musculoskeletal pain.[10]

To summarize, the available literature indicated that a large number of school children are carrying heavy school loads and suffer musculoskeletal issues. However, some authors have speculated on the associated impacts on the health and well-being of school children, to our knowledge there is no comprehensive review of the evidence. Efforts have been made to set a safe load limit for students, but universal safe limits remain elusive, due to inconsistent results from scientific articles. The impetus for this review came from lack of consensus regarding standardized data from different groups, evidence-based recommendation of critical backpack load limits for school children, recent increase in visit of school children with musculoskeletal pain to our department of Physiotherapy, University of Gondar Hospital. This systematic review, therefore, was undertaken to, identify, appraise, and collate the research evidence regarding postural changes due to backpack load carriage and critical school bag weight limits for school children's. In order to make recommendations based on the highest level of evidence; this review included only standardized trials.

Methods

Literature search

This systematic review was performed during February 2014 and June 2014. We made a comprehensive search to locate papers in following database: CINAHL, PubMed, and Cochrane Library. Only articles with the English language were considered, time restraints were set as papers with a year of publication from January 1995 to May 2014 and no limits on the geographical region were set on the search. The search was made using specific keywords; backpack or bag or load, and youth or school children, and postural angle changes or postural deviations. Full paper copies of relevant studies were retrieved, and hand searching of reference lists was carried out to identify further relevant studies [Table 6].

Table 1: Modified Crombie tool

Clearly stated aims
Appropriateness of design to meet the aims
Adequate specifications of subject group given
Justification of sample size
Likelihood of reliable and valid measurement
Sensitivity of outcome tool
Adequate description of statistical methods
Adequate description of data
Consistency in the number of subjects reported throughout the paper
Assessment of statistical significance
Attention to potential biases
Meaningful main findings
Interpretation of null findings
Interpretation of important effects
Comparison of results with previous reports
Implications in real life

Inclusion criteria

The level of evidence of each paper was determined according to the hierarchical system of Lloyd-Smith. The level reflects the degree to which bias has been considered within study design, with a lower rating on the hierarchy indicating less bias. Only papers that scored between 1a and 2b on Lloyd-Smith's scale[11] were included in this review.

Outcome measures

Musculoskeletal pain and postural deviation aggravated by school backpack load.

Hierarchy of evidence

Four experienced research physiotherapist worked independently to assess all source papers. Articles were filtered based on the appropriate title and keywords.

Quality appraisal

The quality of each paper was appraised using a modified Crombie tool [Table 1].[12] The quality of each paper was scored according to the factors shown in modified Crombie scale. In that appraisal tool "sensitivity of outcome tool" was added. All reviewers were ensured that they are consistent in their approach. One point was allocated for the fulfillment of each quality appraisal item. The lowest score was 0, and the maximum possible score was 16. The methodological quality of each study was graded as low (0–5), moderate (6–11), or high (12–16). Disagreements among the reviewers were solved by consensus building.

Study outcomes

The following outcomes were of interest: School bag weight, bag carrying method (one-sided or both sided), the position of load on the spine, duration of bag carriage, and distance carried.

Results

Literature search, hierarchy of evidence and quality appraisal

Two hundred and ninety-three papers were identified from our initial search of the database. Two hundred and forty-six papers were excluded from our review, as they did not meet our inclusion criteria. Remaining 47 papers were assessed for level of evidence [Figure 1].

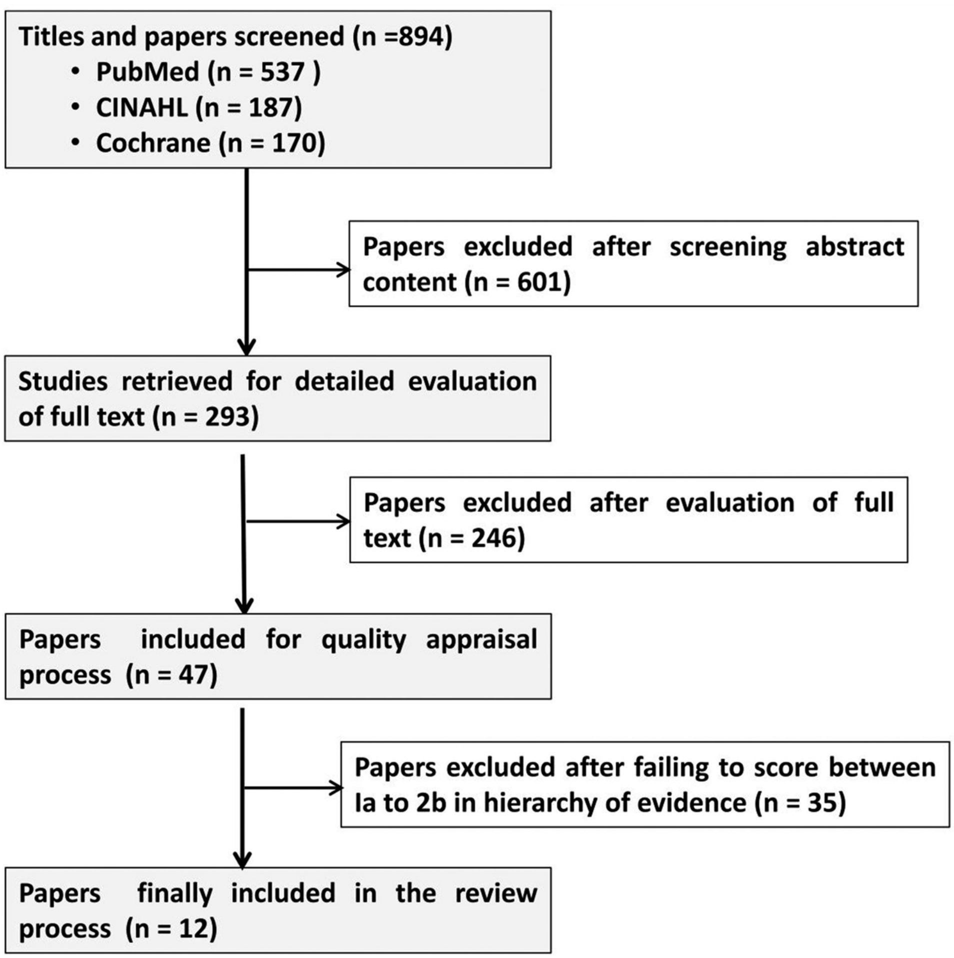

Figure 1: Flow of studies through the review

Only 12 papers scored between Ia and IIb. According to Lloyd-Smith, none of the papers were Ia (meta-analysis of randomized controlled trials [RCT]), four of the papers were I-b (RCT) and eight papers were IIa (well-designed, nonrandomized studies) [Table 2].

Table 3 provides a description of papers that fulfilled the criteria for appraisal items. Table 4 provides the information relating to the publications included in this systematic review. Based on the results of the quality appraisal process, paper by Grimmer *et al*. was ranked high among all other 11 papers included in this review, with the remainder being moderate in quality.

Effect of backpack on postural deviation

Most articles recommend that backpack load should be 10-15% of body weight. The increase in backpack load (beyond 15% of body weight) leads to the postural deviation. Table 5 summarizes the purpose, intervention, and outcome of the 12 article reviewed.

Effect of backpack on postural deviation

The purpose of investigating the effect of the backpack was to propose the optimal load for school children in order to reduce the postural deviation and musculoskeletal pain. Despite various outcome measures were used in articles related to backpack load among school children, all were still related to postural measurement. In Table 5 our reviewers have reviewed 12 papers and reported the results. Among the 12 papers reviewed, papers by Hong and Brueggemann, Chansirinukor *et al*., Grimmer *et al*., Hong and Cheung, Talbott, Devroey *et al*., Brackley *et al*., Singh and Koh particularly recommend that backpack load should not exceed 10–15% of body weight for school children. Also, it is reported that the increase in backpack load may lead to postural deviation compared to posture without the backpack.

Effect of backpack placement on posture

This review also found the appropriate limit of backpack load recommended in various studies for school children was between 10% and 15% of their body weight. Apart from the load limit, there were certain reports on load placement too; Brackley *et al*. concluded that placing backpack at a lower position in the back reduced trunk forward lean and cranio-vertebral angle when compared to higher and middle positions. Review articles[17,19,21-23] states that positioning backpack in the lower back reduced postural deviations when compared to higher and middle placements.

Table 2: Lloyd-Smith hierarchy of evidence

Level of evidence	Study design	Selected studies
Ia	Meta-analysis of RCT	0
Ib	One individual randomized controlled study	4
IIa	One well-designed, nonrandomized studies	8
IIb	Well-designed quasi-experimental study	0

RCT = Randomized controlled trial

Table 3: Quality appraisal scoring

Quality appraisal item	Papers which fulfilled the criteria
Clearly stated aims	Pascoe *et al*. (1997)[4]
	Wong and Hong (1997)[13]
	Kennedy *et al*. (1999)[14]
	Hong and Brueggemann (2000)[15]
	Chansirinukor *et al*. (2001)[16]
	Grimmer *et al*. (2002)[17]
	Hong and Cheung (2003)[18]
	Talbott (2005)[19]
	Devroey *et al*. (2007)[20]
	Brackley *et al*. (2009)[21]
	Singh and Koh (2009)[22]
	Chow *et al*. (2010)[23]
Appropriateness of design to meet the aims	Kennedy *et al*. (1999)
	Hong and Brueggemann (2000)
	Grimmer *et al*. (2002)
	Hong and Cheung (2003)
	Talbott (2005)
	Devroey *et al*. (2007)
	Brackley *et al*. (2009)
	Chow *et al*. (2010)
Adequate specifications of subject group given	Grimmer *et al*. (2002)
	Brackley *et al*. (2009)
Justification of sample size	Grimmer *et al*. (2002)
Likelihood of reliable and valid measurement	Grimmer *et al*. (2002)
	Brackley *et al*. (2009)
	Singh and Koh (2009)
Sensitivity of outcome tool	Chansirinukor *et al*. (2001)
	Grimmer *et al*. (2002)
	Singh and Koh (2009)
Adequate description of statistical methods	Pascoe *et al*. (1997)
	Chansirinukor *et al*. (2001)
	Grimmer *et al*. (2002)
	Hong and Cheung (2003)
	Devroey *et al*. (2007)
	Chow *et al*. (2010)
Adequate description of data	Pascoe *et al*. (1997)
	Wong and Hong (1997)
	Kennedy *et al*. (1999)
	Hong and Brueggemann (2000)
	Chansirinukor *et al*. (2001)
	Grimmer *et al*. (2002)
	Hong and Cheung (2003)
	Talbott (2005)
	Devroey *et al*. (2007)
	Brackley *et al*. (2009)
	Singh and Koh (2009)
	Chow *et al*. (2010)

Contd...

Table 3: Contd...

Quality appraisal item	Papers which fulfilled the criteria
Consistency in the number of subjects reported throughout the paper	Pascoe *et al*. (1997)
	Wong and Hong (1997)
	Kennedy *et al*. (1999)
	Hong and Brueggemann (2000)
	Chansirinukor *et al*. (2001)
	Grimmer *et al*. (2002)
	Talbott (2005)
	Brackley *et al*. (2009)
	Chow *et al*. (2010)
Assessment of statistical significance	Pascoe *et al*. (1997)
	Wong and Hong (1997)
	Kennedy *et al*. (1999)
	Hong and Brueggemann (2000)
	Chansirinukor *et al*. (2001)
	Grimmer *et al*. (2002)
	Hong and Cheung (2003)
	Talbott (2005)
	Devroey *et al*. (2007)
	Brackley *et al*. (2009)
	Singh and Koh (2009)
	Chow *et al*. (2010)
Attention to potential biases	None
Meaningful main findings	Pascoe *et al*. (1997)
	Wong and Hong (1997)
	Kennedy *et al*. (1999)
	Hong and Brueggemann (2000)
	Chansirinukor *et al*. (2001)
	Grimmer *et al*. (2002)
	Hong and Cheung (2003)
	Talbott (2005)
	Devroey *et al*. (2007)
	Brackley *et al*. (2009)
	Singh and Koh (2009)
	Chow *et al*. (2010)
Interpretation of null findings	Pascoe *et al*. (1997)
	Wong and Hong (1997)
	Kennedy *et al*. (1999)
	Chansirinukor *et al*. (2001)
	Grimmer *et al*. (2002)
	Hong and Cheung (2003)
	Talbott (2005)
	Brackley *et al*. (2009)
Interpretation of important effects	Pascoe *et al*. (1997)
	Wong and Hong (1997)
	Hong and Brueggemann (2000)
	Chansirinukor *et al*. (2001)
	Grimmer *et al*. (2002)
	Hong and Cheung (2003)
	Talbott (2005)
	Devroey *et al*. (2007)

Contd...

Table 3: Contd...

Quality appraisal item	Papers which fulfilled the criteria
	Brackley *et al*. (2009)
	Singh and Koh (2009)
Comparison of results with previous reports	Pascoe *et al*. (1997)
	Wong and Hong (1997)
	Kennedy *et al*. (1999)
	Hong and Brueggemann (2000)
	Chansirinukor *et al*. (2001)
	Grimmer *et al*. (2002)
	Hong and Cheung (2003)
	Talbott (2005)
	Devroey *et al*. (2007)
	Brackley *et al*. (2009)
	Singh and Koh (2009)
	Chow *et al*. (2010)
Implications in real life	Grimmer *et al*. (2002)

Discussion

Schooling starts with carrying a backpack and continues until adult life, even after school days, it continues itself in college, office or in any form. Carrying a backpack has been linked to the spine hence adequate measures and care should be delivered in posture and related pain. The purpose of our review was to determine if the postural balance and posture of children during static and dynamic activity is changed when wearing backpacks in which the load is varied according to body weight.

Our review of 12 papers essentially shows that backpack load of school children should not exceed 15% of body weight. The review comparison was outlined in Table 5. Even though articles suggest backpack load limit of 10–15% of children's body weight, there remains low hierarchy of evidence, low sample size, and inconsistent results. Talbott found that there is an increase in postural instability and decrease in balance with a backpack of 20% of body weight. This indicates that backpack of 20% of body weight leads to postural instability, in daily schooling if the same load was carried may leads to postural deviation, muscular pain, and failure of passive ligamentous structure around the spine. According to Hong and Brueggemann and Hong and Cheung 15% backpack load induced significant increase in trunk forward lean and prolonged blood pressure recovery time and they also concluded that backpack weight should not exceed 10% of body weight.

Brackley *et al*. also concluded that significant changes occurred in trunk forward lean and cranio-vertebral angle in backpack load of 15% of body weight among 10-year-old children's. This study also supports the

Table 4: Results of hierarchy of evidence

Author (Year)	Hierarchy level	Appropriate design	Specification of subject group	Justification of sample size	Reliable and valid measurements	Sensitive outcome tool	Attention to potential bias	Real life implications	Appraisal score	Quality category
Pascoe *et al*. (1997)	IIa	0	0	0	0	0	0	0	9/16	Intermediate
Wong and Hong (1997)	IIa	0	0	0	0	0	0	0	9/16	Intermediate
Kennedy *et al*. (1999)	Ib	1	0	0	0	0	0	0	8/16	Intermediate
Hong and Brueggemann (2000)	Ib	1	0	0	0	0	0	0	8/16	Intermediate
Chansirinukor *et al*. (2001)	IIa	0	0	0	0	1	0	0	10/16	Intermediate
Grimmer *et al*. (2002)	Ib	1	1	1	1	1	0	1	15/16	High
Hong and Cheung (2003)	Ib	1	0	0	0	0	0	0	9/16	Intermediate
Talbott (2005)	IIa	1	0	0	0	0	0	0	9/16	Intermediate
Devroey *et al*. (2007)	IIa	1	0	0	0	0	0	0	8/16	Intermediate
Brackley *et al*. (2009)	IIa	1	1	0	1	0	0	0	11/16	Intermediate
Singh and Koh (2009)	IIa	0	0	0	1	1	0	0	8/16	Intermediate
Chow *et al*. (2010)	IIa	1	0	0	0	0	0	0	8/16	Intermediate

conclusion of Chansirinukor *et al*., who found out that backpack weighing 15% of body weight appeared to be too heavy to maintain standing posture for adolescents. Interestingly, Singh and Koh (2008) used kinematic and temporal-spatial data as an outcome measure tool in assessing the effect of backpack loads of 10%, 15%, and 20% of body weight. They reported that there is a reduction in gait velocity, cadence, and increase in double support time for a backpack of 20% of body weight. Devroey *et al*. suggests that carrying loads of 10% of body weight and above should be avoided since these loads induce significant changes in electromyography and kinematics of children. However, there remains a different result in a study by Grimmer *et al*., who performed a randomized controlled experimental study and concluded that there is no evidence for the 10% of body weight limit.

When children carry loads <10% of body weight, there is lack of an effect on postural stability has been reported by Palumbo *et al*.[24] and this may be due to the ability of the human body to adjust to the smaller load. Further investigation is required in order to identify appropriate load and placement of backpack among children. Further attention has to be given in upcoming researches for identifying appropriate load inducing postural change among children. Our review is limited to the articles published in English. Since, there is no standard approach for measuring posture; the use of different measures between articles may have also contributed to inconsistent findings.

Conclusion

Based on the review findings, load limit of a backpack in school children associated with postural changes are still inconsistent. If backpacks do result in the change in posture or perception of pain, the elimination or minimization of the backpack as a contributor to such cause is crucial. To alter the posture, the base of support must be narrow, the center of gravity must move beyond the base of support, as of what happens while carrying a backpack load of above 15% of body weight. Based up on our systematic review findings, we conclude that backpack load of 10% of body weight would be safer for the spine of school children. Efforts should be made to reduce the burden on the spine of school children to build a healthier and pain-free population in the future. For this various researches (RCT's and meta-analysis) must determine the impact of backpack load on postural changes among school children. This review outlines the areas which require more attention are: inclusion of RCT, the adequate specification of the subject group, and justified sample size. Moreover, outcomes to be generalized to real life.

Table 5: Review analysis

Author (Year)	Participants	Hypothesis	Baseline	Analysis of load	Tools and outcome	Postural responses to load	Conclusion
Pascoe *et al.* (1997)	Mean age: 11-13 *n*=10	To determine the impact of different methods of carrying book bags on static posture and gait kinematics of youths aged 11-13 years	Without bag One strap bag Two strap bag One strap athletic bag	Static dynamic	Lateral spinal bending and shoulder elevation	Significant difference exists among bag carrying methods	One strap Athletic bag promoted greater angular motion of the head and trunk as compared to backpack book bags
Wong and Hong (1997)	*n*=10	The effects of carrying school bags on children were investigated	Walking on treadmill with 0% body weight	Walking on treadmill at 10%, 15% and 20% of body weight	Peak Motion Measurement System	Significant difference was found in inclination of trunk between 0% and the other three load conditions	No difference exists between different load conditions in stride length, stride rate, double leg support time, swing time and center of gravity height
Kennedy *et al.* (1999)	*n*=10	The effect of various school bag load on posture	Walking without load	Load weight (5%; 10%; 15%; 20%) during 5 min walk test Dynamic load carriage for 5 min (for each bag weight tested)	Adhesive markers, posture and gait recorded with video camera	Trunk inclination increased with increasing load	No significant difference in posture over time for all load conditions
Hong and Brueggemann (2000)	Mean age - 10.31±0.26 *n*=15	This study examined the gait pattern, heart rate, and blood pressure in children carrying school bags of 0 (as control), 10, 15 and 20% of their own body weight whilst walking on a treadmill	Walking on a treadmill without a bag	Walking on treadmill with a school bag of 10, 15 and 20% of body weight	Gait analyzed using 3-CCD video camera: Swing duration, stride frequency, and trunk inclination were measured Heart rate and blood pressure were continuously monitored	The results showed that TFL angle was significantly increased with the loads of 20 and 15% of body weight when compared to the 0 and 10% load conditions	Backpack weight should not exceed 10% of body weight in 10-year-old boys

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Table 5: Contd...

Author (Year)	Participants	Hypothesis	Baseline	Analysis of load	Tools and outcome	Postural responses to load	Conclusion
Chansirinukor *et al*. (2001)	Mean age - 14.8 *n*=13	To determine whether the weight of a backpack, its position on the spine or time carried affected adolescents' cervical and shoulder posture	Static and dynamic posture without a backpack	Static and dynamic posture: With backpack over both shoulders, backpack over the right shoulder only, backpack weighing 15% of body weight over both shoulders and after a five-minute walk carrying own backpack weight over both shoulders	Cervical and shoulder position angles	Both backpack weight and time carried influenced cervical and shoulder posture	Forward head posture increased when carrying a backpack, Especially one with a heavy load. Carrying a backpack weighing 15% of body weight appeared to be too heavy to maintain standing posture for adolescents
Grimmer *et al*. (2002)	Mean age - 12.9±0.5 *n* (Gender) 12.8±0.5 25 (male) 13.8±0.4 25 (female) 13.8±0.5 25 (male) 14.9±0.6 25 (female) 14.8±0.5 25 (male) 15.8±0.6 25 (female) 15.8±0.5 25 (male) 16.7±0.5 25 (female) 16.8±0.5 25 (male) 25 (female)	To describe the effect on adolescent sagittal plane standing posture of different loads and positions of a common design of school backpack	Weight: 0% BW. Placement: High (T7), middle (T12), and low (L3)	Weight: 3%, 5% BW, and 10% BW Placement: High (T7), middle (T12), and low (L3)	Adhesive markers on 7 anatomical points Posture recorded with single lens reflex camera photographs digitized to find x and y coordinates of anatomical landmarks	Position backpack on the higher location produced the largest deviation at all anatomical points (*) except greater trochanter and mid join knee	Could not find evidence that load should be limited to 10% BW Higher position may cause more deviation compared to middle and lower Typical school backpacks should be positioned with the center of backpack at waist or hip level
Hong and Cheung (2003)	*n*=11	To determine whether trunk inclination while carrying backpack is related to load and distance	No load	Load weight (10%; 15%; 20%) Distance of load carriage (86 m, 688 m, 1290 m, 1892 m)	Gait recorded with video camera Videotapes digitized using human body model	When compared with the 0, 10, and 15% load conditions, the 20% load induced a significant increase ($P<0.05$) in trunk inclination	Distance of load carriage related to trunk inclination increased with distance

Contd...

Table 5: Contd...

Author (Year)	Participants	Hypothesis	Baseline	Analysis of load	Tools and outcome	Postural responses to load	Conclusion
Talbott (2005)	Mean age - 12.40 *n*=40	To identify differences in the postural balance and posture of adolescents during static and dynamic activities with and without backpacks	Weight: 0% BW. Placement: High (C7) Low (inferior angle of the scapula)	Weight: 10% and 20% BW. Placement: High (C7) Low (inferior angle of the scapula)	Right and left ankle Right and left knee Right and left hip angles Right and left shoulder angles Right temporal angle	No significant differences between placements	Load above 20% BW should be avoided Higher position may cause more deviation compared to lower
Devroey *et al.* (2007)	Mean age - 23.9±2.59 *n*=20	The effects of increasing load (0%, 5%, 10%, and 15% of body weight) and changing the placement of the load on the spine, thoracic versus lumbar placement, during standing, and gait were analyzed	Weight: 0% BW Placement: High (thoracic region) Low (lumbar region)	Weight: 5%, 10%, and 15% BW Placement: High (thoracic region) Low (lumbar region)	Angles of head, neck, thorax, and pelvis	Most postural deviation occurred in higher position	Carrying loads of 10% of body weight and above should be avoided
Brackley *et al.* (2009)	Mean age - 10 *n*=15	To examine the effect of load placement (high, mid, and low) on posture, specifically TFL posture, head on neck CVA postures and LA for standing, and walking in prepubescent children	Weight: 0% of BW Placement: High (±26.3 cm above L5) Middle (between higher and lower) Low (±10.3 cm above L5)	Weight: 15% BW	TFL angle, CVA, and LA	No significant differences between loads	Using backpack with 15% BW cause significant changes of TFL and CVA Backpacks should place lower on the spine

Contd...

Table 5: Contd...

Author (Year)	Participants	Hypothesis	Baseline	Analysis of load	Tools and outcome	Postural responses to load	Conclusion
Singh and Koh (2009)	Mean age - 9.65 (±1.58) *n*=17	To investigate the impact of backpack load carriage and its vertical position on the back on temporal-spatial and kinematic parameters associated with gait and postural stability for static and dynamic conditions	Walking on treadmill without bag (unloaded)	Walking on treadmill with treadmill with 10%, 15%, and 20% BW loads	Kinematic and temporal-spatial data	The findings on spatiotemporal parameters indicate that a reduction in gait velocity and cadence and an increase in double support time for the 20% lower configuration could be a compensatory mechanism for children to minimize either the induced gait instability or mechanical strain on the musculoskeletal system in terms of possible higher lower limb joint moments or both	Load above 15% BW should be avoided Higher position may cause more deviation compared to lower
Chow *et al*. (2010)	Mean age - 11.4±0.5 *n*=19	To propose a guideline regarding where the backpack center of gravity to be positioned	0% BW. Placement: High (T7) Middle (T12) Low (L3)	15% BW. Placement: High (T7) Middle (T12) Low (L3)	Cervical, higher and lower thoracic, higher and lower lumbar, pelvic tilt angles	Significant differences between placements except pelvic tilt	Anteriorly carried a backpack with the center of gravity positioned at T12 was shown to induce relatively less effect on spinal deformation and repositioning error in schoolchildren. Changing backpack carriage position occasionally may help to relieve its effects on spinal deformation

BW = Bodyweight, TFL= Trunk forward lean, CVA = Craniovertebral angle, LA = Lordosis angle

Table 6: Literature search results

Keywords	PubMed	CINAHL	Cochrane
School children	13,089	601	407
Backpack	569	283	11
Bag	29,183	305	73
Load	134,035	1990	105
Postural angle	1164	7	0
Postural deviation	741	8	6
Papers selected for screening	19	16	12

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Conflicts of interest

There are no conflicts of interest.

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