INDIAN JOURNAL OF SCIENCE AND TECHNOLOGY

RESEARCH ARTICLE

# Ergonomic School Bags: Can Additional Straps Make a Difference in Posture?

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OPEN ACCESS

**Received:** 11-09-2023
**Accepted:** 18-10-2023
**Published:** 20-12-2023

**Citation:** Kirthika SV, Sudhakar S, Monika D, Kumar GM, Ramachandran S, Kumar NS (2023) Ergonomic School Bags: Can Additional Straps Make a Difference in Posture?. Indian Journal of Science and Technology 16(46): 4429-4435. https://doi.org/10.17485/IJST/v16i46.2301

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**Funding:** None

**Competing Interests:** None



Published By Indian Society for Education and Environment (iSee)

**ISSN**
Print: 0974-6846
Electronic: 0974-5645

## Abstract

**Objectives:** This study investigates the potential benefits of incorporating additional anterior straps into school backpacks to alleviate postural issues in children aged 10 to 15 years. **Methods:** The research was conducted at a Matriculation Higher Secondary School in Chennai for a duration of 7 months and involved 50 students from grades 4 to 8, encompassing both genders. The study utilized experimental design using pre and post-test measurements. This ergonomic school bag consisted of anterior additional cross straps and horizontal straps which is not usually present in conventional school backpacks. The Craniovertebral Angle, Craniohorizontal Angle and Sagittal Shoulder Posture were measured before and after use of ergonomic bags. **Findings:** Results indicated a significant improvement in postural angles after the use of school bags with additional straps. The Craniovertebral Angle scores increased from 38.47 $\pm$ 3.63 (Pre-test) to 45.63 $\pm$ 3.05 (Post-test). Craniohorizontal Angle scores decreased from 26.89 $\pm$ 2.30 (Pre-test) to 19.98 $\pm$ 1.68 (Post-test), while Sagittal Shoulder Posture scores improved from 61.80 $\pm$ 4.46 (Pre-test) to 52.74 $\pm$ 1.89 (Post-test). The p-value of $\leq$ 0.001 indicated highly significant difference between mean values obtained from pre and post measurements. **Novelty :** A backpack with additional anterior straps was designed which differs from conventional back packs and the effectiveness was tested. Previous literature has not reported the benefits of adding additional anterior straps and this research is the first to have studied the effects of this ergonomic backpack on posture among school going children.

**Keywords:** Backpack; Ergonomics; Posture; School bags; Children; Musculoskeletal pain; Additional straps

## 1 Introduction

School backpacks are an integral part of a child's education experience, helping them carry the necessary materials for school. Ensuring that children use their backpacks safely, maintain an appropriate weight, and wear them properly is crucial for their well-being and comfort. Good posture typically entails having the head naturally balanced above a straight and vertically aligned spine, with subtle, natural curves in the lower back and neck forming a slight S-shape[(1)]. Forward Head Posture (FHP) is a recognized condition where head protrudes forward in the sagittal plane, positioning it anterior to the trunk. FHP, or Forward Head Posture, is marked by an excessive forward bend in the lower part of the neck and upper thoracic area, along with an exaggerated backward tilt in the upper part of the neck[(2)].

Excessive backpack loads can lead to back ache and deformities of spine in children, a condition known as "backpack syndrome."[(3)]. It has been observed that children who carry a load exceeding 10% of body weight are at a higher risk of experiencing pain than those using backpacks that weigh below 10% of body weight[(4)]. Usage of heavy school backpacks can also lead to the deformation of spinal curvatures. Disruption of these curves, particularly in middle as well as lower back region, leads to muscular strain and also discomfort over ribs or spinal joints[(5)].

More than ten thousand clinic visits are attributed to symptoms related to backpack use in children, underscoring the importance of including this concern in school health promotion initiatives. Furthermore, it's worth noting that children who suffer from back pain are more likely to continue experiencing such discomfort into adulthood[(6)]. Consequently, the most effective approach to mitigating the risk of problems associated with carrying heavy loads is to design backpacks that induce minimal alterations in the student's natural posture[(7)].

Moreover, two research studies presented results regarding students' body posture. These findings encompassed an elevation in lumbo-sacral angulations, a reduction in kyphosis curvature in thorax, and an increase in lordosis curvature in cervical area. Meanwhile, when loads reached 15% of student's body weight, alterations in angles pertaining to head, neck as well as lower limbs were observed, which ultimately impacted the overall posture[(8)]. Based on these findings it is necessary to design a backpack which could benefit the school going children.

Recent years have witnessed notable advancements in enhancing school bag utilization among children, with a specific focus on their well-being, comfort, and safety. Despite these progressions, there remain evident deficiencies in tackling posture and musculoskeletal issues. This underscores the imperative for pioneering the creation of novel school backpacks that effectively address these challenges, offering comprehensive solutions for the overall health and comfort of children. It's essential to consider the positioning of the straps and how they redistribute the load to minimize strain and postural changes in any backpack design.

The new design of ergonomic backpacks with anterior straps used in this study have the potential to evenly distribute the backpack's weight across the shoulders and back. This even weight distribution can promote an upright posture and reduce the risk of developing rounded shoulders and other posture-related problems.

Two studies highlighted that wearing a backpack had a notable effect on contact area between foot and ground, resulting in heightened pressure on soles of the feet, especially as the load neared 25% of body weight of students[(9)]. It is vital to support the correct development of the foot's structure and functionality during critical stages of a child's physical maturation[(10)]. Hence, the new idea in this research lies on the addition of anterior straps, can help evenly distribute the load across the entire body, thus alleviating the strain on the back, neck and reduces excess pressure on the sole of the feet as well. This is particularly crucial for children who have to carry substantial amounts of textbooks and school materials.

In one study it was observed that the backpack with a single diagonal strap, known as the mono strap backpack, had a substantial negative impact on respiratory function restricting respiratory capacity and weaken the power of expiratory muscles. As a result, it is advisable to opt for the double-strap backpack, as it does not impede respiratory function to the same extent[(11)]. In our study, the ergonomic backpack was designed in such a way where the additional anterior straps prevent shallow breathing, prevents children from leaning forward and thus preventing chest constriction which could commonly occur using conventional backpacks with back straps alone.

Prior research has furnished evidence indicating that students who bear the burden of heavy backpacks often report various physical discomforts such as pain, inflammation, puffiness, tiredness, and discomfort in the upper or lower sections of the back, upper or lower trapezius muscles, shoulders, neck, or forearm regions[(12,13)]. This new ergonomic backpack with additional anterior straps can help stabilize the backpack, preventing it from swinging or pulling the wearer backward, which can reduce the risk of falls and injuries. Investing in a school backpack that prioritizes posture and musculoskeletal health can have long-term benefits for children. It also lowers the likelihood of children developing persistent issues like chronic back pain, muscle strain, and associated health concerns with the use of conventional back packs.

There remains limited literature which have studied the effect of different back pack designs on children's posture. Majority of the research have only addressed the effect of carrying back packs on posture, gait and other biomechanical perspective.

The primary reason behind developing this backpack is to prioritize the posture and musculoskeletal health of school children. For manufacturers and retailers of school backpacks, introducing innovative designs like those with anterior straps can be a competitive advantage, appealing to parents and schools looking for enhanced products.

This study aims to create a novel backpack design featuring additional anterior straps to offer enhanced support and distribute the weight carried by children. The research assesses how this newly designed backpack affects the posture of schoolchildren, with the results expected to contribute to future efforts in preventing complications related to backpack use.

## 2 Methodology

This experimental study, utilizing a design involving both before and after assessments, was conducted at a Matriculation Higher Secondary School in Ashok Nagar, Chennai, over a period of 7 months. The research included a sample size of 50 students, selected through convenient sampling. Inclusion criteria comprised students aged 10 to 15 years, encompassing both boys and girls, and attending grades 4th through 8th. Exclusion criteria encompassed the presence of recent systemic illnesses, muscular, skeletal, cardiorespiratory, or neurological issues, congenital abnormalities and current or previous reports of back or neck discomfort. The key outcome parameters focused on evaluating CVA, CHA and SSP to assess the impact of the newly designed backpack on the posture of the participating schoolchildren.

### 2.1 Procedure

This study employs an experimental design with pre-test and post-test assessments. A total of 50 school students in the age group 10 to 15 years were selected after finding suitability as per the criteria for inclusion and exclusion. The nature of the study, duration of the intervention and the intervention being used were explained in the best language understood by the students. The study received ethical clearance from University Research and Ethics committee as well as adhered meticulously to guidelines mentioned in 2013 Helsinki Declaration, which is endorsed by the World Medical Association [(14)].

The study began by collecting socio-demographic information from the participants, including their names, ages, genders, and the grade they were attending. Before any procedures commenced, the parents of the students gave their informed consent. Subsequently, the participants were equipped with a newly designed school bag featuring additional anterior cross straps. These bags were used by the students on a daily basis to carry their books to school for a duration of 5 months. For assessing neck, shoulder, and upper back posture, the most commonly used evaluation metrics include the craniovertebral angle, craniohorizontal alignment, and sagittal shoulder positioning [(15)]. During this time frame, measurements for the CVA, CHA, and SSP assessments were recorded both before and after the period.

The Craniovertebral angle was determined by gauging the angle created between a horizontal line drawn from the C7 spinous process to the tragus of the ear. This measurement offers insights into the neck's positioning relative to the upper trunk. The Craniohorizontal angle was computed by measuring the angle formed between a horizontal line passing through the tragus of the ear and a line connecting the tragus of the ear to the outer corner of the eye (extending canthus). Sagittal shoulder posture was evaluated by measuring the angle formed between a horizontal line extending through the C7 spinous process and another line connecting the C7 spinous process to the midpoint of the humerus's head.

The backpack is designed with a pair of shoulder straps crafted from rexin material. These straps extend forward from the acromion process of one shoulder, measuring 70 cm in length and 1 cm in width. They connect to the opposite hip over the 12th rib. Additionally, another strap runs from the opposite shoulder to the opposite hip. The cross strap, positioned at the front, is secured in place using two clip lock buckles. Another strap, which connects both sides in a posteroanterior direction, can be adjusted to accommodate the height and weight of individual students. Importantly, the anterior cross straps are user-friendly, allowing subjects to adjust them according to their comfort and convenience. The cross strap plays a pivotal role in rectifying the positioning of the upper back and thoracic spinal column, simultaneously reducing the strain on the cervical spine. Its function is to enhance the alignment of the head and neck, providing essential stability for the postural muscles in the upper back.

The anterior straps, when properly adjusted, can relieve some of the pressure from the shoulders. In a conventional double-strap backpack, the shoulders bear the brunt of the load, potentially leading to discomfort and pain. The key difference lies in how the weight is apportioned. Traditional double-strap backpacks place the entire load on the shoulders, while backpacks equipped with anterior straps distribute the weight more uniformly across both the shoulders and the front of the body. This even distribution serves to alleviate stress on the back and neck and helps improve posture.

The horizontal waist strap effectively employs a three-point pressure system to counteract the deforming force exerted on the shoulders by backpack weight, which is primarily borne by the lower back area. The cross strap essentially functions like a supportive corset, relieving the cervical spine and postural muscles from undue pressure, thereby resulting in an overall improvement in the posture of the spine and shoulders.

## 3 Results and Discussion

The collected data was structured into tables and then subjected to analysis using both descriptive and inferential statistical techniques. Statistical Package for Social Science (SPSS) version 24 was utilized for this purpose. The Shapiro-Wilk test was employed to assess the normality of the data. The results indicated that the data related to the dependent variables, namely CVA Score (p-value 0.502), CHA Score (p-value 0.421), and SSP Score (p-value 0.568), exhibited a normal distribution with p-values greater than 0.05. Consequently, parametric tests were employed to determine within-group statistical distinctions through the paired t-test.

**Table 1. Comparison of Craniovertebral Angle (CVA) Scores Within the Same Group in Pre and Post Test**

| Test | Pre Test | | Post Test | | t - Test | Significance |
|---|---|---|---|---|---|---|
| | Mean | S.D | Mean | S.D | | |
| **Group** | 38.47 | 3.63 | 45.63 | 3.05 | -14.84 | .000*** |

**(***- P ≤ 0.001 - Significant)**

The presented table displays the mean, Standard Deviation (S.D), t-value, and p-value for assessing the difference between pre-test and post-test scores within the group. The examination reveals an extremely significant statistical distinction between the pre-test and post-test results within the group (***- $p \leq 0.001$).

**Table 2. Comparison of Craniohorizontal Angle (CHA) Scores Within Group in Pre and Post Test**

| Test | Pre Test | | Post Test | | t - Test | Significance |
|---|---|---|---|---|---|---|
| | Mean | S.D | Mean | S.D | | |
| **Group** | 26.89 | 2.3 | 19.98 | 1.68 | 22.37 | .000*** |

**(***- P ≤ 0.001 - Significant)**

The presented table displays the Mean, Standard Deviation (S.D), t-value, and p-value for evaluating the contrast between pre-test and post-test outcomes within group. The assessment reveals an extremely significant statistical disparity between the pre-test and post-test values within the group (***- $P \leq 0.001$)

**Table 3. Comparison of S aggital Shoulder Posture (SSP) Scores Within Group in Pre and Post Test**

| Test | Pre Test | | Post Test | | t - Test | Significance |
|---|---|---|---|---|---|---|
| | Mean | S.D | Mean | S.D | | |
| **Group** | 61.8 | 4.46 | 52.74 | 1.89 | 15.9 | .000*** |

When we compare the mean values of Cranio Vertebral Angle scores, we observe a substantial difference between the pre-test ($38.47 \pm 3.63$) and post-test ($45.63 \pm 3.05$) scores within the group using the School Bag with Additional Straps (Table 1). This difference is highly significant, with a p-value of $\leq 0.001$. These post-test values clearly demonstrate that the School Bag with Additional Straps leads to an improvement in children's posture compared to the pre-test. As a result, we reject the null hypothesis.

Comparing the mean values of Cranio Horizontal Angle scores, we observe a substantial difference between the pre-test ($26.89 \pm 2.30$) and post-test ($19.98 \pm 1.68$) scores within the group using the School Bag with Additional Straps (Table 2). This difference is highly significant, with a p-value of $\leq 0.001$. The post-test results unequivocally demonstrate that the School Bag with Additional Straps leads to a marked improvement in children's posture compared to the pre-test. Consequently, we firmly reject the null hypothesis.

Upon comparing the mean values of Sagittal shoulder posture scores, a remarkable difference is evident between the pre-test ($61.80 \pm 4.46$) and post-test ($52.74 \pm 1.89$) scores within the group using the School Bag with Additional Straps (Table 3). This difference is highly significant, with a p-value of $\leq 0.001$. The post-test results unequivocally demonstrate that the School Bag with Additional Straps leads to a substantial improvement in children's posture compared to the pre-test. Consequently, we confidently reject the null hypothesis.

The objective of current research was to find whether newly designed school bags, equipped with additional anterior straps, have a positive impact on the posture of schoolchildren. While there are various factors which can contribute to muscular and skeletal issues among school students, such as more engagement in sports, physical activity, improper sitting attitude, extended inactivity periods, it is evident that carrying heavy backpacks is a prominently suspected factor[16]. Extended use of heavy

backpacks can have detrimental effects on developing bones and result in stress injuries. When children carry backpacks, it shifts their COG in same direction as load. To counterbalance this, children naturally tilt themselves in the opposite direction of the weight [17].

Over time, maintaining a slouched posture can result in various postural alterations and irregularities, including rounded shoulders and Forward Head Posture. Consequently, a school backpack was developed to incorporate supplementary anterior straps arranged in a crossed pattern, along with an extra horizontal strap at the waist. This counteractive anterior cross strap is intended to discourage excessive slouching, enhance comfort during backpack use, and mitigate the development of long-term postural issues.

This study was initiated based on the hypothesis that when the COG moves backward due to the weight of school backpack, students tend to lean forward in an attempt to maintain their balance. The principal aim of this research was to examine whether the inclusion of additional anterior straps in a crossed configuration at the front of a school backpack could result in favourable improvements in the posture of schoolchildren by counter balancing the forward leaning.

Research conducted by Ahmad and Barbosa (2019) examined the impact of backpack weights on gait kinematics and kinetics among school children. Their findings revealed significant differences in the temporal parameters of their gait. The pressure and force distribution on their feet increased in conjunction with both the weight of the load and the school level. Consequently, children who carried loads in their backpacks experienced noteworthy alterations in their gait biomechanics [18]. Conventional backpacks with back straps increases the pressure on the feet, particularly in the heel and forefoot areas. This can contribute to foot fatigue and discomfort. Anterior straps used in this study help prevent overcompensation for the load, which can lead to an uneven gait. By promoting a balanced and centred load, these straps encourage a more natural and efficient walking pattern.

The findings of this study provide support for the experimental hypothesis put forth by Ramadan and Al-Tayyar (2020). This hypothesis proposed that incorporating a horizontal strap on waist into conventional backpack with two shoulder straps, and carrying it with 10% of weight of body, would lead to a noteworthy reduction in the alterations of neck and shoulder positions as compared to loading a conventional backpack with dual shoulder straps [19]. In the present study, the same ergonomic principle is followed and additionally extra anterior straps with a crossed fashion encourage wearers to stand straighter, which can help prevent rounded shoulders and other posture-related issues. Conventional backpacks may not provide the same level of posture support

In one research done by Layuk et al. (2020) revealed that among the reported discomforts related to backpack use, Low Back Pain (LBP) was most commonly mentioned issue, with 33.2% of respondents experiencing it. Subsequently, muscle soreness was reported by 24.4% of respondents, followed by neck pain at 23.5%, upper back pain (UBP) at 10.5%, arm pain at 5.8%, tingling sensations at 4%, and leg pain at 3.6% [20]. The back pack design in our study prevents overloading the spine with excessive weight, which is a common cause of back pain in school children by its force transmission of weight distribution anteriorly.

Our results align with the research conducted by Mandrekar et al. (2019), which concluded that act of carrying school bag had a significant impact on cervical and shoulder posture. This impact was assessed through measurements of various parameters including measurements of CHA, CVA, SSP, and anterior head alignment were taken under all the chosen conditions [21].

As per a study done by Genitrini et al. (2022), increased weight of school bags over the course of one school year were found to contribute to changes in body posture, particularly in terms of rotational parameters. Notably, the asymmetry in backpack strap usage was more pronounced in girls, and the disparities between the straps might influence posturometric parameters [22]. The solution for this disadvantage has been addressed in our research where the new back pack with additional anterior straps help distribute the weight more evenly across the core muscles and back, preventing the development of muscular imbalances, bony malalignments which all can directly contribute to back pain.

In a recent study conducted by Jain in 2022, the research delved into the idea of incorporating a sensor into a backpack. It explored practical recommendations for enhancing the understanding of a child's spine development among parents. This special backpack comprises both hardware and software components equipped with sensor technology, allowing for the real-time collection of data [23]. Adding sensor technology, hardware, and software components would substantially increase the cost of the backpack, making it less accessible to the majority of parents in India who are price-sensitive. Sensor-equipped backpacks require maintenance and may need repairs for the electronic components. Moreover, understanding should lead to adoption of using a better school backpack which could ultimately serve as a solution to all these concerns. Hence, this research focused on modification of back packs by adding additional straps which remains cost effective as well as budget friendly.

Our study reveals that the post-test results for Cranio Vertebral Angle (CVA) ($45.63 \pm 3.05$) indicate an improvement in the posture of children when using the School Bag with Additional Straps compared to the pre-test ($38.47 \pm 3.63$). Additionally, the post-test results for Cranio Horizontal Angle (CHA) ($19.98 \pm 1.68$) demonstrate an enhancement in posture among children with the School Bag with Additional Straps as opposed to the pre-test ($26.89 \pm 2.30$). Furthermore, the post-test values for Sagittal Shoulder Posture (SSP) ($52.74 \pm 1.89$) indicate improved posture in children when using the School Bag with Additional

Straps compared to the pre-test (61.80 ± 4.46).

In summary, backpacks with additional anterior straps are designed with a focus on improving weight distribution, posture, stability, and overall comfort, particularly when carrying heavier loads. While conventional double-strap backpacks have been the standard for many years, the innovative design of anterior strap backpacks offers several advantages in terms of health and ergonomics.

Consequently, it becomes clear that the incorporation of supplementary anterior cross straps along with horizontal waist straps is immensely advantageous for schoolchildren, as it significantly enhances posture. This improvement in posture is crucial in preventing the development of various musculoskeletal problems and deformities. Therefore, it is strongly advisable to implement this modification, as it has the potential to alleviate pain syndromes and mitigate postural abnormalities among schoolchildren who carry heavy backpacks.

## 4 Conclusion

The creation of backpacks featuring anterior straps directly aligns with the emphasis on children's well-being, rendering it a novel development within the realm of school bags. In a market dominated by traditional backpack designs, the incorporation of anterior straps emerges as a distinctive and innovative concept. This distinctiveness has the potential to capture the attention of parents, educational institutions, and authorities in search of inventive solutions for students.

In conclusion, the study strongly recommends the incorporation of additional straps in school backpacks for children who carry heavy loads to school. The inclusion of these extra straps effectively redistributes the load, preventing rounded shoulders and Forward Head Posture in children. Moreover, this modification has demonstrated notable improvements in posture, as indicated by changes in the Craniovertebral Angle which nearly increased from 38.47 ± 3.63 to 45.63 ± 3.05, Craniohorizontal Angle decreased from 26.89 ± 2.30 to 19.98 ± 1.68, and Sagittal Shoulder Posture improved from 61.80 ± 4.46 to 52.74 ± 1.89. Therefore, it is highly advisable to implement the use of additional straps in school backpacks, as it holds the potential for long-term benefits.

The strength of this research lies in the statistically significant findings obtained from the outcome measures proving the efficacy of the product. Nonetheless, there is a necessity for further research to explore the connections between load and the duration of exposure, pinpointing the specific threshold at which the risk escalates and verifying whether statistically significant discoveries indeed hold clinical significance. Future studies are required to explore the potential benefits of using this ergonomic school bags by analysing the muscle activation patterns using EMG and posturography. The inclusion of additional anterior straps lies in the sole benefit of improving posture, preventing rounded shoulders and musculoskeletal pain among school children. However, additional features can be incorporated in future research improving the appearance of this ergonomic bag as some children may not be satisfied with the look of this bag as the anterior crossed straps are visible on to the front.

## 5 Acknowledgement

The research was self-funded. The authors are thankful to the management of Dr. M.G.R. Educational and Research Institute for providing the needed facilities to complete this research activity.

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