

To Study the Impact of Heavy Backpack on Craniovertebral Angle and Handgrip Strength in School Going Students

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Abstract

Backpacks are commonly used by school students to carry books and educational materials; however, excessive backpack weight may contribute to postural alterations and musculoskeletal problems. School-going children are particularly vulnerable to such effects because their musculoskeletal system is still developing. Heavy backpack loads can influence spinal alignment and muscle activity, potentially leading to forward head posture and decreased muscular efficiency. The present study aimed to investigate the impact of heavy backpack loads on craniovertebral angle (CVA) and handgrip strength (HGS) among school-going students.

An experimental repeated-measures design was adopted. Seventy students aged between 8 and 16 years participated in the study. Baseline measurements of CVA and HGS were recorded without backpack load. Participants were then assessed while carrying backpacks weighing 5%, 10%, and 15% of their body weight. CVA was measured using a posture analysis application by marking anatomical landmarks at the tragus of the ear and the spinous process of C7. Handgrip strength was measured using a handheld dynamometer.

The results demonstrated a progressive decrease in craniovertebral angle with increasing backpack weight, indicating increased forward head posture. Additionally, variations in handgrip strength were observed with incremental loading conditions. These findings suggest that heavier backpack loads may adversely affect postural alignment and upper limb muscle performance in school children.

The study highlights the importance of limiting backpack weight and promoting ergonomic awareness among students to prevent long-term musculoskeletal problems.

Keywords: Backpack Load, Craniovertebral Angle, Handgrip Strength, Forward Head Posture, School Children

1. Introduction

Backpacks are widely used by school students as a convenient means of carrying books, stationery, and other educational materials. Although backpacks distribute weight across both shoulders, excessive

backpack loads have become a growing concern because of their potential influence on posture and musculoskeletal health. During the developmental years, children undergo rapid growth of both the skeletal and muscular systems, making them particularly susceptible to postural adaptations caused by external loads [1,2].

Carrying heavy backpacks on a daily basis can alter normal biomechanics of the spine and upper extremities. The additional load applied posteriorly requires the body to compensate in order to maintain balance and stability. As a result, students often lean forward, leading to forward head posture and altered spinal alignment. Such compensatory postural adjustments may increase mechanical stress on cervical structures, including muscles, ligaments, and intervertebral discs [3,4,5]. Over time, these changes may contribute to neck pain, shoulder discomfort, and reduced functional efficiency [6,7].

Forward head posture is a common musculoskeletal deviation characterized by anterior displacement of the head relative to the trunk. One of the most commonly used methods for assessing forward head posture is the craniovertebral angle (CVA). A smaller craniovertebral angle generally indicates a greater degree of forward head posture, whereas a larger angle reflects more neutral cervical alignment [8,9]. Monitoring CVA provides valuable insight into postural changes that occur due to external loads such as backpacks [10].

In addition to postural alterations, carrying heavy loads may also influence muscular performance. Handgrip strength is commonly used as a reliable indicator of upper limb muscle strength and overall functional capacity. It reflects the ability of the forearm and hand muscles to generate force and is frequently used in clinical and research settings to evaluate muscle performance [11,12]. Changes in grip strength may indicate fatigue or altered neuromuscular activation caused by prolonged load carrying [13].

Previous studies have reported that excessive backpack weight may lead to various musculoskeletal problems among school children, including neck pain, shoulder pain, and altered gait patterns [1,6,7]. Several researchers have suggested that backpack weight should not exceed **10–15% of a student's body weight** to minimize adverse effects on posture and physical health [2,4,14]. However, many students continue to carry loads exceeding these recommended limits [15].

Understanding the relationship between backpack load and musculoskeletal parameters is essential for developing preventive strategies and promoting safe load-carrying practices among school children. Evaluating the immediate effects of incremental backpack loads on craniovertebral angle and handgrip strength can provide valuable evidence regarding the biomechanical and functional consequences of heavy backpacks [10,16].

Therefore, the present study was conducted to investigate the impact of heavy backpack loads on craniovertebral angle and handgrip strength among school-going students.

2. Materials and Methods

Study Design

The study employed an experimental repeated-measures design to evaluate the effect of backpack load on craniovertebral angle (CVA) and handgrip strength (HGS) in school-going students.

The study was conducted in various schools located in Ranchi, Jharkhand, India. Data collection was carried out over a period of one month, from April 2, 2025 to May 2, 2025. A total of 70 school-going students aged between 8 and 16 years participated in the study. Both male and female students who were willing to participate and had obtained parental consent were included in the study. Students with recent

systemic illness, any neurological or musculoskeletal disorders, congenital deformities, or a history of recent upper limb surgery were excluded from participation.

Ethical considerations were maintained throughout the study. Informed consent was obtained from the parents or guardians of all participating students prior to their involvement in the research. The study evaluated the impact of backpack loading on postural and muscular parameters. The independent variable in this study was the backpack load, which was applied at four different levels: 0%, 5%, 10%, and 15% of the participants' body weight. The dependent variables measured were the craniovertebral angle (CVA), which was used to assess forward head posture, and handgrip strength (HGS), which was used as an indicator of upper limb muscular strength.

Procedure

Participants were initially screened according to the selection criteria. After obtaining consent, the height and body weight of each participant were recorded.

Baseline measurements were then obtained without any backpack load. Two primary outcome measures were recorded:

1. Craniovertebral Angle (CVA)
2. Handgrip Strength (HGS)

After baseline measurements, participants wore a standardized backpack containing loads equivalent to 5%, 10%, and 15% of their body weight. Each load condition was maintained for two minutes, after which measurements of CVA and HGS were recorded.

To minimize fatigue, a rest interval of 2–5 minutes was provided between each loading condition.

Measurement of Craniovertebral Angle

CVA was measured to assess forward head posture. Adhesive markers were placed on two anatomical landmarks:

- Tragus of the ear
- Spinous process of the seventh cervical vertebra (C7)

A lateral photograph was taken using a smartphone camera positioned at shoulder height. Using posture analysis software, a horizontal line was drawn through C7 and another line connecting C7 to the tragus. The angle between these lines represented the craniovertebral angle.

Measurement of Handgrip Strength

Handgrip strength was measured using a digital handheld dynamometer. Participants sat comfortably with the shoulder in neutral position, elbow flexed at 90°, and forearm in neutral position. Participants were instructed to squeeze the dynamometer maximally for 3–5 seconds, and the value was recorded.

Statistical Analysis

Data were analyzed using SPSS software. Descriptive statistics were calculated and repeated-measures ANOVA was used to determine the effect of increasing backpack load on CVA and HGS.

3. Results

Demographic Characteristics

A total of 70 school-going students participated in the study. The demographic characteristics of the participants are presented in Table 1. The mean age of the participants was 11.31 ± 1.94 years, indicating that the study population primarily consisted of early to mid-adolescent school children. The mean body weight was 33.96 ± 10.69 kg, while the average height was 4.63 ± 0.59 units. The mean body mass index (BMI) of the participants was 16.87 ± 3.64 , suggesting that most participants fell

within a normal anthropometric range for their age group. These baseline characteristics provided a representative sample for evaluating the effects of backpack load on posture and muscular strength.

Table 1: Descriptive Statistics of Participants (N = 70)

Variable	Minimum	Maximum	Mean	SD
Age (years)	8	16	11.31	1.94
Weight (kg)	19	69	33.96	10.69
Height	3	6	4.63	0.59
BMI	8.95	26.38	16.87	3.64

Effect of Backpack Load on Craniovertebral Angle

Descriptive analysis of craniovertebral angle across different loading conditions is presented in Table 2. The mean craniovertebral angle progressively decreased with increasing backpack load. At baseline (0% body weight), the mean CVA was $51.84^\circ \pm 5.32$, which gradually decreased to $49.35^\circ \pm 5.89$ at 5% load, $47.58^\circ \pm 5.02$ at 10% load, and $45.01^\circ \pm 4.98$ at 15% body weight.

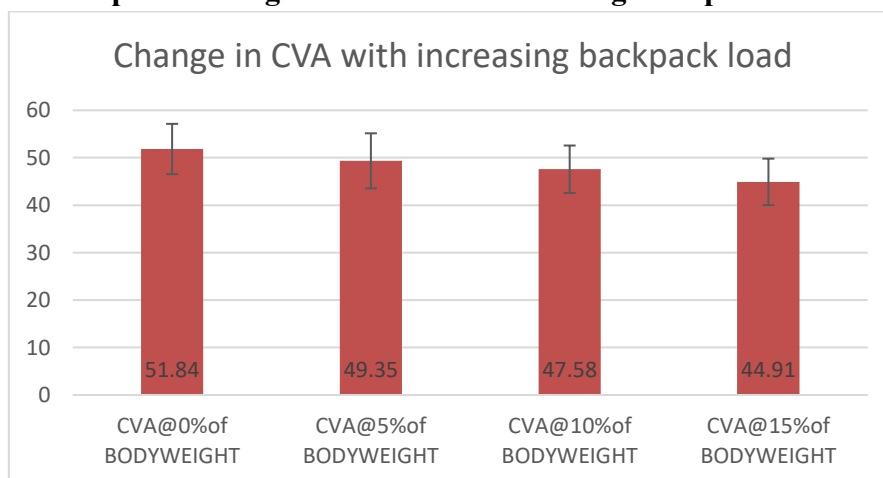
This pattern demonstrates a clear inverse relationship between backpack load and craniovertebral angle, indicating that heavier backpack loads result in increased forward head posture.

Repeated-measures ANOVA revealed a statistically significant effect of backpack load on craniovertebral angle ($p < 0.05$). The decreasing trend across load levels indicates that even moderate increases in backpack weight can significantly influence cervical alignment in schoolchildren.

Table 2: Descriptive Analysis of CVA with Increasing Load

Load Condition	Mean CVA	N	SD	Standard Error
0% Body Weight	51.84	70	5.32	0.63
5% Body Weight	49.35	70	5.89	0.70
10% Body Weight	47.58	70	5.02	0.60
15% Body Weight	45.01	70	4.98	0.59

Graph 1: Change in CVA with Increasing Backpack Load



The results indicate that increasing backpack load significantly reduces the craniovertebral angle. A smaller CVA reflects a greater degree of forward head posture. Therefore, these findings suggest that heavier backpacks lead to measurable postural deviations in school-going children.

Effect of Backpack Load on Handgrip Strength

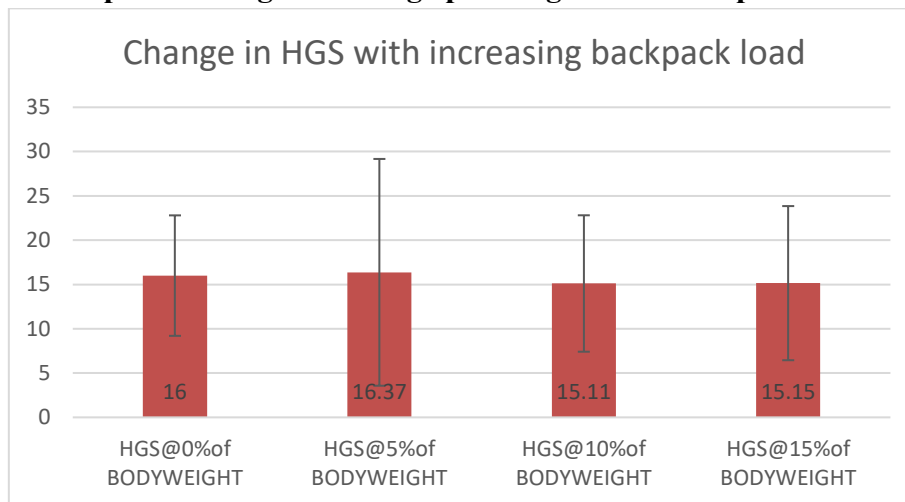
Descriptive statistics for handgrip strength across different load conditions are presented in Table 3. The mean handgrip strength at baseline was 16.00 ± 6.85 kg. When participants carried a backpack weighing 5% of their body weight, the mean grip strength slightly increased to 16.37 ± 12.82 kg. However, further increases in load resulted in a decline in grip strength, with mean values of 15.11 ± 7.76 kg at 10% load and 15.15 ± 8.78 kg at 15% load.

Repeated-measures ANOVA demonstrated that the changes in handgrip strength across load conditions were statistically significant ($p < 0.05$).

Table 3: Descriptive Analysis of Handgrip Strength with Increasing Load

Load Condition	Mean HGS	N	SD	Standard Error
0% Body Weight	16.00	70	6.85	0.81
5% Body Weight	16.37	70	12.82	1.53
10% Body Weight	15.11	70	7.76	0.92
15% Body Weight	15.15	70	8.78	1.04

Graph 2: Change in Handgrip Strength with Backpack Load



The results demonstrate a non-linear pattern in handgrip strength with increasing backpack load. The slight increase at 5% body weight may reflect a compensatory muscular response, whereas the reduction observed at higher loads may indicate muscular fatigue or altered biomechanics associated with heavier backpack carriage.

4. Discussion

The present study investigated the immediate effects of incremental backpack loads on craniovertebral angle (CVA) and handgrip strength (HGS) among school-going students. The findings demonstrate that increasing backpack weight results in measurable postural and functional changes in children. Specifically, a progressive reduction in craniovertebral angle was observed with increasing load,

indicating a gradual shift toward forward head posture. In addition, handgrip strength exhibited a non-linear pattern, with a slight increase at lower loads followed by a reduction at higher load levels.

The reduction in craniovertebral angle observed in this study suggests that schoolchildren adopt compensatory postural adaptations when carrying heavier backpacks. As backpack weight increases, the body attempts to maintain balance by shifting the head and trunk forward. This anterior displacement of the head relative to the cervical spine decreases the craniovertebral angle, which is widely recognized as an indicator of forward head posture. Similar findings have been reported in previous biomechanical studies, which have shown that external loads placed on the back alter spinal alignment and increase mechanical stress on the cervical and thoracic regions of the spine [1,3,17,18].

Forward head posture is known to place additional strain on cervical muscles, ligaments, and intervertebral discs. Prolonged exposure to such postural changes may lead to muscle fatigue, ligamentous creep, and increased compressive forces on the cervical spine [19,20]. In growing children, whose musculoskeletal structures are still developing, these adaptations may increase the risk of musculoskeletal discomfort and long-term postural abnormalities. The findings of this study therefore reinforce concerns that excessive backpack loads may contribute to postural deviations in schoolchildren [6,7,14].

The results related to handgrip strength provide additional insight into the functional consequences of backpack loading. Interestingly, grip strength showed a slight increase when participants carried a backpack weighing 5% of their body weight. This initial increase may reflect a short-term compensatory response in which the upper limb musculature increases activation to stabilize the load and maintain balance. However, as backpack weight increased to 10% and 15% of body weight, handgrip strength showed a reduction. This decline may be attributed to muscular fatigue, altered biomechanics of the upper extremity, or reduced mechanical advantage resulting from forward trunk inclination [13,11,12].

These findings highlight the complex interaction between posture and muscular performance during load carriage. When the body adopts a forward-leaning posture to compensate for heavy backpack loads, the alignment of the shoulder girdle and upper extremity may be altered. Such changes can influence muscle recruitment patterns and reduce the efficiency of force generation in the hand and forearm muscles [3,21]. Consequently, prolonged or repeated exposure to excessive loads may impair muscular function and increase fatigue.

The demographic analysis of the participants indicated considerable variability in anthropometric characteristics such as body weight, height, and body mass index. These variations may partly explain the individual differences observed in the response to backpack loading. Children with lower body mass or reduced muscular strength may experience greater biomechanical strain when carrying equivalent relative loads. Therefore, backpack weight recommendations should take into account the physical characteristics and developmental stage of individual students [2,15].

The results of this study are consistent with ergonomic guidelines suggesting that backpack loads should not exceed **10–15% of body weight**. Loads exceeding these limits appear to increase the likelihood of postural deviations and muscular fatigue [2,4,14]. Schools, parents, and healthcare professionals should therefore encourage safe backpack practices, including reducing unnecessary load, using ergonomically designed backpacks, and promoting awareness about correct carrying techniques [15,16].

From a physiotherapy perspective, early identification of postural changes associated with backpack use is essential. Preventive strategies such as postural education, strengthening exercises for the cervical and shoulder girdle muscles, and ergonomic modifications may help reduce the risk of musculoskeletal

problems in schoolchildren [8,9]. Furthermore, regular monitoring of backpack weight and posture in school settings may help prevent the development of chronic musculoskeletal disorders later in life.

Although the study provides valuable insights into the biomechanical impact of backpack loads, certain limitations should be acknowledged. First, the study evaluated only the immediate effects of backpack loading rather than long-term adaptations. Longitudinal studies are required to determine whether prolonged exposure to heavy backpacks leads to persistent postural changes or musculoskeletal disorders. Second, the study focused on craniovertebral angle and handgrip strength as outcome measures. Future research could include additional parameters such as spinal curvature, gait analysis, muscle fatigue, and balance assessment to provide a more comprehensive understanding of the effects of backpack use [39,45].

Despite these limitations, the present study contributes to the growing body of evidence indicating that excessive backpack loads may negatively affect posture and muscular performance in schoolchildren. The findings emphasize the importance of implementing preventive measures and promoting ergonomic awareness to protect the musculoskeletal health of students [16,21].

5. Conclusion

The present study demonstrated that increasing backpack weight significantly influences craniovertebral angle and handgrip strength among school-going students.

A progressive decrease in craniovertebral angle was observed with increasing backpack load, indicating the development of forward head posture. Additionally, handgrip strength showed a non-linear response, with an initial increase followed by a reduction at higher loads.

These findings suggest that excessive backpack loads may contribute to postural alterations and muscular fatigue in school children. Therefore, awareness regarding safe backpack weight limits and ergonomic practices should be promoted among students, parents, and school authorities to prevent long-term musculoskeletal problems.

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References

1. Pascoe DD, Pascoe DE, Wang YT, Shim DM, Kim CK. Influence of carrying book bags on gait cycle and posture of youths. *Ergonomics*. 1997 Jun;40(6):631–41.
2. Dockrell S, Simms C, Blake C. Guidelines on schoolbag use: Messaging to inform the stakeholders. *Work Read Mass*. 2016 Jun 16;54(2):489–92.
3. Brackley HM, Stevenson JM, Selinger JC. Effect of backpack load placement on posture and spinal curvature in prepubescent children. *WORK J Prev Assess Rehabil*. 2009 Mar;32(3):351–60.
4. Milanese S, Grimmer-Somers K. Backpack weight and postural angles in preadolescent children. *Indian Pediatr*. 2010 Jul;47(7):571–2.

5. Altered cervical posture kinematics imposed by heavy school backpack loading: A literature synopsis (2009–2019).
6. Mwaka ES, Munabi IG, Buwembo W, Kukkiriza J, Ochieng J. Musculoskeletal pain and school bag use: a cross-sectional study among Ugandan pupils. *BMC Res Notes*. 2014 Apr 9;7:222.
7. Janakiraman B, Ravichandran H, Demeke S, Fasika S. Reported influences of backpack loads on postural deviation among school children: A systematic review. *J Educ Health Promot*. 2017;6(1):41.
8. TITCOMB DA, MELTON BF, MIYASHITA T, BLAND HW. The Effects of Postural Education or Corrective Exercise on the Craniovertebral Angle in Young Adults with Forward Head Posture: A Randomized Controlled Trial. *Int J Exerc Sci*. 2023 Aug 1;16(1):954–73.
9. TITCOMB DA, MELTON BF, BLAND HW, MIYASHITA T. Evaluation of the Craniovertebral Angle in Standing versus Sitting Positions in Young Adults with and without Severe Forward Head Posture. *Int J Exerc Sci*. 2024 Jan 1;17(1):73–85.
10. Abaraogu UO, Ezenwankwo EF, Nwadike IB, Nwafor GC, Ugwuele BO, Uzoh PC, et al. Immediate responses to backpack carriage on postural angles in young adults: A crossover randomized self-controlled study with repeated measures. *Work Read Mass*. 2017;57(1):87–93.
11. Sayer AA, Syddall HE, Dennison EM, Martin HJ, Phillips DIW, Cooper C, et al. Grip strength and the metabolic syndrome: findings from the Hertfordshire Cohort Study. *QJM Mon J Assoc Physicians*. 2007 Nov;100(11):707–13.
12. Hand grip strength as a proposed new vital sign of health: a narrative review of evidences.
13. Carpentier A, Duchateau J, Hainaut K. Motor unit behaviour and contractile changes during fatigue in the human first dorsal interosseus. *J Physiol*. 2001 Aug 1;534(Pt 3):903–12.
14. Walicka-Cupryś K, Skalska-Izdebska R, Rachwał M, Truszczyńska A. Influence of the Weight of a School Backpack on Spinal Curvature in the Sagittal Plane of Seven-Year-Old Children. *BioMed Res Int*. 2015;2015:817913.
15. Talbott NR, Bhattacharya A, Davis KG, Shukla R, Levin L. School backpacks: it's more than just a weight problem. *Work Read Mass*. 2009;34(4):481–94.
16. Genitrini M, Dotti F, Bianca E, Ferri A. Impact of Backpacks on Ergonomics: Biomechanical and Physiological Effects: A Narrative Review. *Int J Environ Res Public Health*. 2022 May 31;19(11):6737.
17. Singh T, Koh M. Effects of backpack load position on spatiotemporal parameters and trunk forward lean. *Gait Posture*. 2009 Jan;29(1):49–53.
18. Effects of backpack load and positioning on nonlinear gait features in young adults.
19. Cervical Spine Functional Anatomy and the Biomechanics of Injury Due to Compressive Loading.
20. Edmondston SJ, Sharp M, Symes A, Alhabib N, Allison GT. Changes in mechanical load and extensor muscle activity in the cervico-thoracic spine induced by sitting posture modification. *Ergonomics*. 2011 Feb;54(2):179–86.
21. Golriz S, Walker B. Can load carriage system weight, design and placement affect pain and discomfort? A systematic review. *J Back Musculoskelet Rehabil*. 2011;24(1):1–16.