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ASSOCIATION OF RELATIVE SCHOOL BAG WEIGHT WITH CRANIOVERTEBRAL ANGLE AND NECK DISABILITY IN SCHOOLCHILDREN: A CROSS-SECTIONAL STUDY

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Abstract

Background: *Heavy school bags are a modifiable load imposed during rapid spinal growth, yet Pakistani evidence linking the load children carry to both cervical posture and neck function is scarce.*
Objective: *To determine the relative school bag weight carried by schoolchildren in Bahawalpur, Pakistan, and to examine its association with craniovertebral angle (CVA) and neck disability.*
Methods: *This analytical cross-sectional study enrolled 277 students of grades 6-10 from government and private schools in Bahawalpur through stratified random sampling between October 2025 and January 2026. Body and bag weights were measured with a calibrated digital scale, and relative bag weight was expressed as a percentage of body weight (%BW). CVA was measured in habitual sitting posture, without the bag, using smartphone photogrammetry analyzed in MicroDicom for angle measurement and neck disability with a nine-item modified Neck Disability Index (NDI). Pearson correlation and independent-samples t-tests (>15% vs ≤15% BW) were applied.*
Results: *Participants (50.5% boys) had a mean age of 13.48 ± 1.73 years. Mean bag weight was 5.54 ± 1.89 kg, equivalent to 12.18 ± 5.07% BW (range 1.6–29.0%) and 185 (66.7%) students carried more than 15% BW. Mean CVA was 46.45 ± 4.40° and mean NDI score was 12.18 ± 4.57. Relative bag weight correlated negatively with CVA ($r = -0.910$, $p < 0.001$) and positively with NDI ($r = 0.967$, $p < 0.001$), and CVA was inversely correlated with NDI ($r = -0.885$, $p < 0.001$). Compared with peers carrying ≤15% BW, students carrying >15% BW had a smaller CVA (mean difference 7.23°, 95% CI 6.44–8.01; $p < 0.001$) and higher NDI scores (mean difference 7.79 points, 95% CI 7.01–8.57; $p < 0.001$).*

Conclusion: *Heavier relative bag loads were associated with a more forward head posture and greater neck disability. Although causality cannot be inferred and unusually strong associations need independent replication, the findings support bag-weight policies, ergonomic education and postural screening in Punjab schools.*

INTRODUCTION

The school-age years are a period of rapid growth in which spinal curvatures and head-on-trunk alignment are still maturing, and postural habits acquired during this period can shape musculoskeletal health into adulthood. Spinal pain is common in children and adolescents and pain reported during the school years predicts pain in early adulthood (Brattberg, 2004; Kamper et al., 2016). Neck pain in young people has been linked to sustained flexed postures during study and device use and to forward head posture (Fares et al., 2017; Ruivo et al., 2014).

Among modifiable mechanical exposures of school life, daily school bag has received sustained attention. A backpack displaces combined center of mass posteriorly; to remain balanced, the child inclines trunk and head forward, which increases demand on cervical extensor muscles (Chen & Mu, 2018; Genitrini et al., 2022). Laboratory studies show that craniovertebral angle (CVA), formed between the horizontal line through the seventh cervical spinous process (C7) and a line joining C7 to the tragus of the ear, decreases as backpack load increases, with meaningful changes appearing at loads of about 10%-15% of body weight (BW) (Chansirinukor et al., 2001; Kistner et al., 2013; Ramprasad et al., 2010). A recent meta-analysis found that, among the postural variables studied, only the CVA showed a significant relationship with backpack weight (Cuenca-Martínez et al., 2023). Limits of 10%–15% BW are therefore widely recommended (Brackley & Stevenson, 2004; Dockrell et al., 2013), although the evidence linking bag weight with pain remains inconsistent (Calvo-Muñoz et al., 2020; Perrone et al., 2018).

Real-world loads frequently exceed these limits. A critical review reported that students commonly carry more than 15% of their body weight (Perrone et al., 2018), and a recent Thai survey of 489 primary school students found a mean relative load of 17.5% BW, with loads above 10% BW strongly associated with musculoskeletal discomfort (Mongkonkansai et al., 2024). In Pakistan, studies from Karachi and Islamabad have reported heavy bags and a high frequency of musculoskeletal complaints among schoolchildren (Khan et al., 2021; Shahid et al., 2018). Khyber Pakhtunkhwa legislated grade-wise school bag weight limits in 2020 (Government of Khyber Pakhtunkhwa, 2020), but objective data on the loads carried by children in southern Punjab, and on their postural and functional correlates, remain lacking.

Most previous studies have examined posture under experimentally imposed loads in small laboratory samples or have relied on self-reported pain without an objective measure of posture. Few have examined, in the same children, the load actually carried to school, habitual cervical posture and neck-specific functional disability. The only study we identified that combined CVA, backpack load and neck disability in adolescents found no significant correlation between change in CVA and either relative backpack weight or disability (Cheung et al., 2010), leaving the question unresolved. Smartphone-based photogrammetry analyzed with freely available DICOM software now offers a reliable, low-cost means of measuring the CVA in school settings (Mehmood et al., 2025).

This study therefore aimed to determine the relative school bag weight carried by schoolchildren in Bahawalpur, Pakistan and to examine its association with habitual CVA and neck disability. We hypothesized that higher relative bag weight would be associated with a smaller CVA and greater neck disability, and that children carrying more than 15% BW would have a smaller CVA and higher disability scores than those carrying 15% BW or less.

Methods

Study design and setting

This analytical cross-sectional study is reported in accordance with Strengthening the Reporting of Observational Studies in Epidemiology (STROBE) statement (von Elm et al., 2007). It was conducted in eight government and six private schools in Bahawalpur, Punjab, Pakistan, between October 2025 and January 2026.

Participants and sampling

Students of grades 6–10, aged 10–15 years, of either sex, who carried a backpack to school at least five days a week were eligible. Students with a history of spinal surgery or congenital spinal deformity (e.g., structural scoliosis), recent trauma or fracture of the neck or shoulder region or a neurological condition affecting posture or balance were excluded. Stratified random sampling was used: schools were stratified by sector (government and private), and students were stratified by grade and sex using lottery method according to list of class register of students. A sample size of 277 was calculated with the Raosoft sample size calculator.

Ethical considerations

The study was approved by the Ethical Review Committee of the Department of Physical Therapy, The Islamia University of Bahawalpur. Permission was obtained from school principals, written informed consent was obtained from parents or guardians and verbal assent was obtained from each child. Data were coded and kept confidential and study conformed to the Declaration of Helsinki.

Measurements

Data were collected during school hours by trained final-year Doctor of Physical Therapy researchers following a standardised protocol in a separate room at school. Age, sex, grade and hand dominance were recorded on a structured form.

Body weight and school bag weight. Body weight was measured to the nearest 0.1 kg on a calibrated digital scale with the child in light clothing and without shoes. The child's school bag, with contents carried on the day of assessment, was weighed on same scale. Relative bag weight was calculated as bag weight (kg) divided by body weight (kg) × 100 and expressed as %BW. Children were classified as carrying ≤15% BW or >15% BW, the upper bound of commonly recommended limits (Brackley & Stevenson, 2004).

Craniovertebral Angle

The CVA was measured with digital photogrammetry in habitual posture, without school bag. Participants sat on a backless stool of standard height (45–50 cm) with feet flat on the floor and hands resting on the thighs, looking straight ahead in a self-selected, relaxed head position. Adhesive markers were placed on tragus of ear and on C7 spinous process, identified by palpation. A lateral photograph of right side was taken with a smartphone 50MB back camera of Samsung galaxy A57 mounted on a tripod 1.5 m from the participant with the lens at shoulder height. Images were analyzed in MicroDicom (MicroDicom Ltd., Sofia, Bulgaria) v 3.0, and CVA was computed as angle between horizontal line through C7 and line joining C7 to the tragus. Three photographs were taken and their mean was used for analysis. This procedure has shown high intra and inter-rater reliability (Mehmood et al., 2025). A smaller CVA indicates a more forward head posture.

Neck disability

Neck-related functional limitation was assessed with the Neck Disability Index (NDI) (Vernon & Mior, 1991). The driving item was removed because it does not apply to children, leaving nine items scored 0–5 and a total score of 0-45, with higher scores indicating greater disability**.** The questionnaire was administered in English and a researcher explained items in Urdu whenever a child had difficulty understanding them.

Statistical analysis

Data were analyzed with IBM SPSS Statistics, version 25 (IBM Corp., Armonk, NY, USA). Continuous variables are presented as mean ± standard deviation (*SD*) with range and categorical variables as frequency and percentage. Normality was assessed with Kolmogorov-Smirnov and Shapiro-Wilk tests. Associations among relative bag weight, CVA and NDI were examined with Pearson's correlation coefficient (r), with 95% confidence intervals (CIs) derived through Fisher's z transformation. Because the normality tests were significant, Spearman's rank correlation was computed as a sensitivity analysis. CVA and NDI were compared between ≤15% BW and >15% BW groups with independent-samples t-tests; Levene's test was

used to check equality of variances and Welch-corrected results are also reported.. Effect sizes are reported as Cohen's *d*. All tests were two-tailed and $p < 0.05$ was considered statistically significant.

Results

Participant characteristics

A total of 277 schoolchildren participated (140 boys, 50.5%; 137 girls, 49.5%), with a mean age of 13.48 ± 1.73 years. Grade 8 was the largest group (29.6%), and 224 children (80.9%) were right-handed. Mean body weight was 48.44 ± 13.24 kg (Table 1).

School bag load, craniovertebral angle and neck disability

Mean bag weight was 5.54 ± 1.89 kg (range 1.0–10.0 kg), equivalent to 12.18 ± 5.07% BW (range 1.6–29.0%). Overall, 185 (66.7%) children carried more than 15% BW and 60 (21.6%) carried more than 10% BW. Mean CVA was 46.45 ± 4.40° (range 34-56°), and mean NDI score was 12.18 ± 4.57 (range 2-28). Relative bag weight, CVA and NDI departed from a normal distribution (Kolmogorov–Smirnov $p = 0.020$, $p < 0.001$ and $p < 0.001$; Shapiro–Wilk $p = 0.005$, $p = 0.001$ and $p = 0.001$, respectively).

Table 1 Characteristics of participants (N = 277)

Characteristic	Value
Age, years, mean ± *SD*	13.48 ± 1.73
Sex, n (%)	
Boys	140 (50.5)
Girls	137 (49.5)
School sector, n (%)	
Government	8(57)
Private	6(43)
Grade, n (%)	
6	55 (19.9)
7	25 (9.0)
8	82 (29.6)
9	62 (22.4)
10	53 (19.1)
Hand dominance, n (%)	
Right	224 (80.9)
Left	53 (19.1)
Load and outcome variables, mean ± SD (range)	
Body weight, kg	48.44 ± 13.24 (21.4–92.4)
School bag weight, kg	5.54 ± 1.89 (1.0–10.0)
Relative bag weight, %BW	12.18 ± 5.07 (1.6–29.0)
Bag weight >15% BW, n (%)	185 (66.7)
Craniovertebral angle, degrees	46.45 ± 4.40 (34–56)
Neck Disability Index score (0–45)	12.18 ± 4.57 (2–28)

Note. %BW = percentage of body weight; *SD* = standard deviation.

Correlations

Relative bag weight showed a strong negative correlation with CVA (r = −0.910, 95% CI −0.928 to −0.887, p < 0.001) and a strong positive correlation with NDI (r = 0.967, 95% CI 0.958 to 0.974, p < 0.001). CVA was strongly and inversely correlated with NDI (r = −0.885, 95% CI −0.908 to −0.856, p < 0.001) (Table 2). Relative bag weight thus accounted for 82.8% of the variance in CVA and 93.5% of the variance in NDI.

Table 2 Correlations among relative bag weight, craniovertebral angle and Neck Disability Index

Variable pair	Pearson *r* (95% CI)	*p*	Spearman ρ
Relative bag weight – CVA	−0.910 (−0.928, −0.887)	< 0.001	0.816
Relative bag weight – NDI	0.967 (0.958, 0.974)	< 0.001	0.762
CVA – NDI	−0.885 (−0.908, −0.856)	< 0.001	0.812

Note. CVA = craniovertebral angle; NDI = Neck Disability Index; CI = confidence interval (Fisher z transformation). Two-tailed tests; SPSS output p = .000 is reported as p < 0.001.

Comparison by bag-load group

Children carrying more than 15% BW had a CVA 7.23° smaller than those carrying 15% BW or less (95% CI 6.44–8.01; $t(275)$ = 18.11, p < 0.001) and an NDI score 7.79 points higher (95% CI 7.01–8.57; $t(275)$ = −19.74, p < 0.001). Welch-corrected results were virtually identical (CVA: $t(139.1)$ = 18.19; NDI: $t(141.5)$ = −19.98; both p < 0.001) (Table 3).

Table 3 Craniovertebral angle and Neck Disability Index scores by relative bag-weight group

Outcome	≤15% BW (n = 92)	>15% BW (n = 185)	Mean difference (95% CI)	*t* (*df*)	*p*	Cohen's *d*
CVA, degrees	48.5±3.15	41.27 ± 4.63	7.23 (6.44, 8.01)	18.11 (275)	< 0.001	0.625
NDI score	32.65±5.35	22.45 ± 7.82	−7.79 (−8.57, −7.01)	−19.74 (275)	< 0.001	0.712

Note. Mean difference = ≤15% BW group minus >15% BW group. Welch-corrected tests: CVA $t(139.1)$ = 18.19; NDI $t(141.5)$ = −19.98; both p < 0.001. BW = body weight; CVA = craniovertebral angle; NDI = Neck Disability Index.

Discussion

In this sample of 277 schoolchildren from Bahawalpur, the average school bag weighed 12.2% of the child's body weight, and a considerable proportion of children carried more than 15% BW. Higher relative bag weight was strongly associated with a smaller habitual CVA and greater neck disability and children carrying more than 15% BW had a CVA about 7° smaller and an NDI score about 8 points higher than their peers.

The mean relative load observed here exceeds the 10% BW limit supported by physiological, psychophysical and kinematic studies (Bauer & Freivalds, 2009; Orantes-Gonzalez et al., 2019) and lies within the upper part of the 10%–15% range widely recommended (Brackley & Stevenson, 2004). It is lower than 17.5% BW reported in Thai primary school students (Mongkonkansai et al., 2024) but maximum of 29% BW shows that some children carry close to a third of their body weight every school day. Heavy daily curricular loads and the absence of storage at school are plausible contributors, although these factors were not measured in the present study.

The direction of the association between relative load and CVA agrees with experimental work. Chansirinukor et al. (2001) and Ramprasad et al. (2010) showed that forward head posture increases with

backpack load, with significant change in CVA at about 15% BW; Kistner et al. (2013) observed progressive postural compensation in children aged 8–11 years carrying 10%–20% BW; Chen and Mu (2018) reported greater head and trunk flexion at 15% BW; Mosaad and Abdel-Aziem (2015) found a reduced CVA even at 7.5% BW; and Park and An (2020) reported a smaller CVA and greater neck muscle activity at 10% and 15% BW in university students. A meta-analysis confirmed that the CVA is the postural variable most sensitive to backpack weight (Cuenca-Martínez et al., 2023). The present study differs from these laboratory designs because the CVA was measured without the bag, in habitual sitting posture. The association therefore suggests that the effect of repeated daily loading may carry over into habitual head posture, although a cross-sectional design cannot exclude reverse explanations or confounding. In particular, relative bag weight is inversely related to body size, so younger and lighter children carry a higher %BW for the same bag; adjustment for age, body mass index and other determinants is needed.

The strength of the associations observed here is, however, considerably greater than in previous work and should be interpreted with caution. Cheung et al. (2010) found no significant correlation between change in CVA and relative backpack weight or neck disability in 60 adolescents, and Yip et al. (2008) reported only a moderate correlation ($r = -0.31$) between CVA and neck disability in adults with neck pain. Moore et al. (2007) found that relative backpack weight was associated with upper and mid-back pain but not with neck pain, and neither Assiri et al. (2020) nor a meta-analysis by Calvo-Muñoz et al. (2020) found an association between relative bag weight and back pain. Correlations above 0.9 between a single physical exposure and a multidimensional, self-reported disability score are rare in musculoskeletal research. Possible contributors include the absence of assessor blinding, because the same researchers weighed the bags, photographed the children and assisted with the questionnaire; assisted administration of an English-language instrument to children; and shared determinants such as body size. Independent replication with blinded assessors and multivariable analysis is needed before these effect sizes are used to set thresholds.

The inverse relationship between CVA and NDI is consistent with evidence that forward head posture is associated with neck pain and disability. Yip et al. (2008) found that a smaller CVA was associated with greater disability, and Ruivo et al. (2014) reported that adolescents with neck pain had a lower cervical angle than those without pain. Biomechanically, anterior translation of the head increases the external flexion moment acting on the cervical spine, which raises the sustained demand on the cervical extensors and posterior structures and may lead to fatigue, discomfort and activity limitation (Fares et al., 2017). The NDI scores in this sample were generally low (range 2–28 of a possible 45), indicating mostly mild disability, which is consistent with an early, potentially reversible stage of neck dysfunction.

These findings have practical implications. School bag load is a modifiable exposure and results support provincial guidance in Punjab comparable to Khyber Pakhtunkhwa legislation (Government of Khyber Pakhtunkhwa, 2020), together with storage facilities in schools, timetables that reduce the number of books carried each day, regular bag-weight checks and education of children and parents on using both shoulder straps. Because a single numerical limit may not suit every child (Dockrell et al., 2013), such policies should be combined with periodic postural screening. Smartphone photogrammetry is a feasible and inexpensive screening tool for school health programmes (Mehmood et al., 2025).

Strengths and limitations

The strengths of this study include a relatively large sample drawn from government and private schools, measurement of the load actually carried on a school day, objective assessment of cervical posture with a reliable photogrammetric method and use of a neck-specific functional outcome. Several limitations should be acknowledged. First, the cross-sectional design does not permit causal inference. Second, assessors were not blinded to bag weight, which may have introduced measurement bias. Third, NDI was modified by removing the driving item, administered in English with verbal assistance and has not been validated in children; a validated Urdu version is available for adults (Farooq et al., 2017) and should be considered in future studies. Fourth, potential confounders, including body mass index, physical activity, screen time, duration and mode of travel to school and bag-carrying style, were not measured. Fifth, the

study was confined to one city, which limits generalizability. Finally, dichotomizing relative load at 15% BW discards information and the analyses were unadjusted.

Conclusion

Schoolchildren in Bahawalpur carried, on average, about 12% of their body weight in their school bags and some carried nearly 30%. Higher relative bag weight was associated with a more forward head posture and greater neck disability and children carrying more than 15% BW had a smaller CVA and higher NDI scores than their peers. Because the design is cross-sectional and associations are stronger than previously reported, longitudinal studies with blinded assessment and adjustment for confounders are needed. Meanwhile, limiting school bag weight, providing storage at school and screening posture through school health programmes are reasonable preventive measures.

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