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Association Between Bag Weight and Shoulder Disabilities Among Medical College Students

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ABSTRACT

Background: *Shoulder pain and disability are increasingly reported among university students, particularly those in academically demanding programs requiring routine carriage of heavy bags. Repetitive load carriage may impose mechanical stress on the shoulder complex, potentially leading to functional impairment; however, evidence specific to medical undergraduates remains limited.* ***Objective:*** *To determine the association between bag weight and shoulder pain and disability among medical college students.* ***Methods:*** *An analytical cross-sectional study was conducted among 340 undergraduate medical students aged 18–24 years from two medical colleges in Lahore. Bag weight (kg) and relative bag weight (% body weight) were measured using calibrated scales. Shoulder pain and disability were assessed using the validated Shoulder Pain and Disability Index (SPADI, 0–100 scale). Group comparisons were performed using independent t-tests, and associations were evaluated using Spearman correlation and multivariable linear regression adjusting for age, sex, and BMI.* ***Results:*** *The mean bag weight was 3.26 ± 0.83 kg and mean SPADI total score was 27.33 ± 20.97. Bag weight demonstrated a moderate positive correlation with SPADI score (ρ=0.524, p<0.001). In adjusted regression analysis, each 1 kg increase in bag weight was associated with a 6.12-point increase in SPADI score (95% CI 3.90–8.34, p<0.001). Male students carried heavier bags and exhibited higher SPADI scores than females (p=0.011).* ***Conclusion:*** *Higher bag weight is independently associated with increased shoulder pain and disability among medical college students, underscoring the need for ergonomic load management strategies in academic settings.*

Keywords: *Bag weight; Shoulder pain; SPADI; Medical students; Musculoskeletal disorders; Ergonomics.*

INTRODUCTION

Shoulder pain and disability represent a significant component of musculoskeletal morbidity among young adults, particularly those engaged in academically demanding programs such as medical education. The shoulder complex, comprising the glenohumeral and acromioclavicular joints, scapulothoracic articulation, rotator cuff musculature, and associated neurovascular structures, is biomechanically designed for mobility rather than sustained load bearing. Repetitive or prolonged external loading may disrupt muscle balance, alter scapular kinematics, increase compressive forces beneath shoulder straps, and compromise local hemodynamics, thereby predisposing individuals to pain, fatigue, and functional limitation (1). Epidemiological evidence suggests that musculoskeletal complaints in youth and young adults are common, with substantial proportions reporting low back and upper limb symptoms during their academic years (2,3). Although much of the literature initially focused on school-aged children, the underlying biomechanical principles of load carriage are relevant across age groups, particularly when academic requirements necessitate daily transport of books, laptops, and clinical equipment.

From a biomechanical standpoint, load carriage exceeding recommended thresholds—commonly cited as 10–15% of body weight—has been associated with postural deviations, increased cervical and shoulder muscle activation, and altered spinal alignment (4,5). Studies

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among school children demonstrate that backpack loads frequently surpass these limits, resulting in measurable changes in trunk and shoulder posture, increased trapezius muscle fatigue, and elevated strap contact pressures capable of compromising tissue perfusion (6–9). Experimental and modeling data further indicate that shoulder strap compression may impair brachial artery blood flow and peripheral sensation, underscoring the potential for neurovascular compromise under sustained loading conditions (10). These physiological and mechanical stressors provide a plausible pathway linking repetitive load carriage to upper limb discomfort and disability.

Despite robust evidence in pediatric populations, comparatively fewer studies have examined load carriage and shoulder-specific disability in university students, particularly medical undergraduates who often carry substantial academic materials over prolonged durations. University students have been shown to report a high prevalence of musculoskeletal discomfort, with bag weight, relative load, and carriage frequency identified as contributing factors (11). Furthermore, unilateral bag use has been associated with asymmetric muscle activation and increased strain on the trapezius and paraspinal musculature, suggesting that carriage method may exacerbate load-related stress (12). In the Pakistani context, evidence demonstrates a correlation between heavy school bags and upper limb disabilities among school-going children, reinforcing the regional relevance of load-related musculoskeletal strain (13). However, extrapolating pediatric findings directly to medical college students may not be appropriate, given differences in skeletal maturity, physical conditioning, academic workload, and duration of exposure.

Moreover, shoulder disability is not limited to mechanical pain but may interact with broader functional and psychosocial domains. Emerging evidence indicates that shoulder pain and disability are associated with psychological stressors such as depression and anxiety in occupational populations, highlighting the multifactorial burden of upper limb dysfunction (14). While this underscores the complexity of shoulder disorders, existing studies among students predominantly emphasize back pain rather than validated shoulder-specific outcome measures. The Shoulder Pain and Disability Index (SPADI) is a validated instrument with established reliability and responsiveness for quantifying shoulder-related pain and functional impairment (15). However, its application in evaluating the association between objectively measured bag weight and shoulder disability among medical college students remains limited.

The population of interest in the present investigation comprises undergraduate medical college students aged 18–24 years who routinely carry academic bags (Population). The primary exposure is the absolute and relative weight of the bag carried during routine academic activities (Intervention/Exposure), compared across varying load magnitudes (Comparison). The primary outcome is shoulder pain and disability as quantified by the SPADI score (Outcome). Although prior studies suggest that loads exceeding 10–15% of body weight are potentially deleterious, there remains uncertainty regarding whether lower but repetitive loads in young adults are independently associated with measurable shoulder disability, particularly within the demanding academic environment of medical colleges.

Therefore, a clear knowledge gap exists regarding the magnitude and direction of the association between bag weight and shoulder-specific disability in medical undergraduates within the local context. Addressing this gap is clinically relevant for informing ergonomic recommendations, institutional policies (e.g., locker provision), and preventive education aimed at reducing musculoskeletal morbidity in future healthcare professionals. The present study is designed to analytically examine the association between bag weight (in kilograms and as a percentage of body weight) and SPADI scores among medical college students. We

hypothesize that higher bag weight, particularly relative to body weight, is positively associated with increased shoulder pain and disability scores in this population.

METHODS

This analytical cross-sectional observational study was conducted to examine the association between bag weight and shoulder pain and disability among undergraduate medical college students. A cross-sectional design was selected to estimate the magnitude and direction of association between exposure (bag weight) and outcome (shoulder disability) within a defined population at a single point in time, consistent with established epidemiological methodology for assessing exposure–outcome relationships in non-interventional settings (16). The study was carried out at CMH Medical College Lahore and Lahore Medical and Dental College between April 2023 and October 2023, following formal approval of the research protocol.

The target population comprised undergraduate medical students aged 18 to 24 years enrolled in the respective institutions during the study period. Eligibility criteria included active enrollment in the MBBS program, routine carriage of an academic bag for college purposes, and willingness to participate. Participants were required to have measurable body mass index (BMI) and to complete the Shoulder Pain and Disability Index (SPADI). Exclusion criteria included any visible musculoskeletal deformity, a history of acute trauma, fracture, or diagnosed shoulder pathology within the preceding three months, and any neurological or systemic condition known to affect upper limb function. A non-probability convenience sampling strategy was employed due to feasibility within the institutional context; however, recruitment was performed across multiple academic years to enhance representativeness within the accessible population.

Participants were approached in lecture halls and common academic areas. The study objectives and procedures were explained verbally and through a written participant information sheet. Written informed consent was obtained prior to data collection. Confidentiality was ensured by assigning each participant a unique study identification code; no personal identifiers were recorded in the analytical dataset.

Data collection was performed during scheduled academic days to capture typical bag carriage exposure. Body weight was measured using a calibrated digital weighing scale (accuracy ±0.1 kg) with participants wearing light clothing and no footwear. Height was measured using a wall-mounted stadiometer (accuracy ±0.1 cm), and BMI was calculated as weight in kilograms divided by height in meters squared (kg/m²), then categorized according to standard World Health Organization classifications. Bag weight was measured on the same calibrated digital scale immediately after the participant arrived at college, with all usual academic contents included. Relative bag weight was calculated as a percentage of body weight using the formula: (bag weight in kg / body weight in kg) × 100. This operational definition allowed evaluation of both absolute and relative exposure magnitudes in line with ergonomic load carriage literature (17).

The primary outcome variable was shoulder pain and disability measured using the Shoulder Pain and Disability Index (SPADI), a validated self-administered instrument consisting of 13 items divided into pain (5 items) and disability (8 items) domains (15). Each item was scored on a 0–10 numeric rating scale, and domain scores were summed and converted to percentage scores according to standardized SPADI scoring guidelines. The total SPADI score (0–100) was calculated as the mean of the two domain percentages, with higher scores indicating greater pain and disability. For descriptive purposes, SPADI scores were categorized into no, mild, moderate, and severe disability based on distribution quartiles

within the sample to facilitate interpretability while preserving continuous data for inferential analysis. The SPADI instrument was administered in a quiet classroom setting and completed under supervision to minimize missing responses.

The primary independent variable was bag weight, analyzed both as a continuous variable (kg) and as relative bag weight (% of body weight). Secondary variables included age, sex, BMI, and selected SPADI subdomain scores. Potential confounding variables considered a priori based on literature included BMI and sex, as both may influence musculoskeletal loading patterns and pain perception (11,13,14). To address confounding, stratified analyses by sex were performed, and multivariable regression modeling was planned to adjust for BMI and age when examining the association between bag weight and SPADI score. Selection bias was mitigated by recruiting participants from multiple academic years and minimizing exclusion criteria. Measurement bias was reduced through standardized measurement protocols, calibrated equipment, and use of a validated outcome instrument. Data entry was performed independently by two researchers, and random cross-verification of 10% of entries was conducted to ensure data accuracy and integrity.

The sample size was calculated using the formula for estimation of a population proportion: $n = Z^2P(1-P)/d^2$, assuming a 95% confidence level ($Z = 1.96$), an anticipated prevalence of musculoskeletal symptoms of 40% based on prior regional studies (13), and an absolute precision of 5%. The calculated minimum required sample size was 369; however, accounting for feasibility and anticipated non-response, a final sample of 340 complete responses was analyzed, yielding adequate power (>80%) to detect a moderate correlation ($\rho \geq 0.3$) between bag weight and SPADI score at $\alpha = 0.05$ (18).

Statistical analysis was conducted using IBM SPSS Statistics version 26.0 (IBM Corp., Armonk, NY, USA). Data were screened for completeness and plausibility prior to analysis. Continuous variables were assessed for normality using the Shapiro–Wilk test and visual inspection of histograms. Normally distributed variables were summarized as mean ± standard deviation, whereas non-normally distributed variables were summarized using median and interquartile range. Categorical variables were presented as frequencies and percentages. Independent sample t-tests (or Mann–Whitney U tests, as appropriate) were used to compare continuous variables between male and female participants. The association between bag weight and SPADI score was assessed using Spearman's rank correlation coefficient due to non-normal distribution of SPADI scores. Multivariable linear regression analysis was performed with SPADI total score as the dependent variable and bag weight, relative bag weight, age, sex, and BMI as independent variables to adjust for potential confounding. Effect estimates were reported with 95% confidence intervals, and a two-tailed p-value <0.05 was considered statistically significant. Missing data were minimal (<5%) and handled using complete-case analysis, as patterns were determined to be random on inspection.

Ethical approval was obtained from the Institutional Review Board (Case #714/ERC/CMH/LMC, dated 25-04-23). The study adhered to the principles of the Declaration of Helsinki. Participation was voluntary, and participants were informed of their right to withdraw at any stage without academic consequence. All electronic data were stored on password-protected computers accessible only to the research team, and hard-copy questionnaires were secured in locked cabinets. The full study protocol, data dictionary, and statistical analysis plan were documented prior to analysis to ensure methodological transparency and reproducibility.

RESULTS

A total of 340 undergraduate medical students were included in the final analysis. As shown in Table 1, the mean age of participants was 21.56 ± 2.83 years, with 42.9% (n=146) males and 57.1% (n=194) females. The overall mean body mass index (BMI) was 22.02 ± 2.79 kg/m², with the majority of students classified as normal weight (82.4%), while 7.4% were underweight, 8.8% overweight, and 1.5% obese.

The mean absolute bag weight was 3.26 ± 0.83 kg, corresponding to a mean relative bag weight of 5.41 ± 3.23% of body weight. Regarding shoulder outcomes, the mean SPADI pain score was 18.07 ± 14.95, the mean disability score was 17.49 ± 13.33, and the overall mean SPADI total score was 27.33 ± 20.97 on the 0–100 scale, indicating a moderate burden of shoulder symptoms within the cohort.

Sex-stratified comparisons (Table 2) demonstrated statistically significant differences across several variables. Male students carried significantly heavier bags than females (3.53 ± 0.66 kg vs 3.05 ± 0.89 kg), with a mean difference of 0.48 kg (95% CI 0.32 to 0.65; p<0.001) and a moderate effect size (Cohen's d = 0.62).

Although males had a slightly lower mean age than females (21.24 ± 1.34 vs 21.79 ± 3.61 years), this difference did not reach statistical significance (p=0.081). BMI was significantly higher among males (22.54 ± 1.84 kg/m²) compared to females (21.63 ± 3.22 kg/m²), with a mean difference of 0.92 kg/m² (95% CI 0.37 to 1.48; p=0.001). Relative bag weight as a percentage of body weight did not differ significantly between sexes (5.47 ± 4.97% in males vs 5.36 ± 1.60% in females; p=0.764).

In terms of shoulder-related outcomes, males demonstrated significantly higher SPADI pain scores (20.61 ± 14.68) compared to females (16.12 ± 14.97), with a mean difference of 4.49 points (95% CI 1.29 to 7.69; p=0.006). Similarly, the disability domain score was higher in males (19.26 ± 11.16) than females (16.14 ± 14.60), with a statistically significant mean difference of 3.12 points (95% CI 0.37 to 5.87; p=0.026).

The overall SPADI total score was also significantly greater in males (30.67 ± 19.27) compared to females (24.82 ± 21.87), yielding a mean difference of 5.85 points (95% CI 1.37 to 10.33; p=0.011). Although statistically significant, the effect sizes for SPADI outcomes were small to moderate (Cohen's d ranging from 0.24 to 0.30).

The categorical distribution of SPADI grades (Table 3) revealed that 24.1% (n=82) of students reported no pain or disability, while 41.8% (n=142) experienced mild symptoms and 33.8% (n=115) reported moderate symptoms. Only 0.3% (n=1) demonstrated severe disability. These findings indicate that nearly three-quarters of the cohort (75.9%) experienced at least some degree of shoulder pain or disability.

Correlation analysis (Table 4) demonstrated a statistically significant moderate positive association between bag weight and SPADI total score across the entire sample (Spearman's ρ=0.524; 95% CI 0.44 to 0.60; p<0.001).

This suggests that higher bag weight was associated with higher shoulder pain and disability scores. When stratified by sex, the association remained significant in both groups but was stronger among males (ρ=0.624; 95% CI 0.52 to 0.71; p<0.001) than females (ρ=0.457; 95% CI 0.34 to 0.56; p<0.001), indicating a more pronounced exposure–outcome relationship in male students.

Multivariable linear regression analysis (Table 5) further quantified the independent effect of bag weight on shoulder disability after adjusting for age, sex, and BMI. Bag weight

emerged as a significant independent predictor of SPADI total score (β=6.12; 95% CI 3.90 to 8.34; p<0.001), indicating that each 1 kg increase in bag weight was associated with a 6.12-point increase in SPADI score. Male sex was also independently associated with higher SPADI scores (β=4.73; 95% CI 0.84 to 8.62; p=0.018), whereas age (p=0.188) and BMI (p=0.224) were not statistically significant predictors in the adjusted model.

Table 1. Descriptive Characteristics of Study Participants (N = 340)

Variable	Overall (Mean ± SD / n, %)
Age (years)	21.56 ± 2.83
Male	146 (42.9%)
Female	194 (57.1%)
Body Mass Index (kg/m²)	22.02 ± 2.79
Underweight (<18.5)	25 (7.4%)
Normal (18.5–24.9)	280 (82.4%)
Overweight (25–29.9)	30 (8.8%)
Obese (≥30)	5 (1.5%)
Bag Weight (kg)	3.26 ± 0.83
Relative Bag Weight (% BW)	5.41 ± 3.23
SPADI Pain Score	18.07 ± 14.95
SPADI Disability Score	17.49 ± 13.33
SPADI Total Score	27.33 ± 20.97

Table 2. Comparison of Variables Between Male and Female Participants

Variable	Male (n=146) Mean ± SD	Female (n=194) Mean ± SD	Mean Difference (95% CI)	t-value	p-value	Cohen's d
Age (years)	21.24 ± 1.34	21.79 ± 3.61	-0.55 (-1.17, 0.07)	-1.75	0.081	0.20
BMI (kg/m²)	22.54 ± 1.84	21.63 ± 3.22	0.92 (0.37, 1.48)	3.31	0.001	0.36
Bag Weight (kg)	3.53 ± 0.66	3.05 ± 0.89	0.48 (0.32, 0.65)	5.73	<0.001	0.62
Relative Bag Weight (% BW)	5.47 ± 4.97	5.36 ± 1.60	0.11 (-0.63, 0.86)	0.30	0.764	0.03
SPADI Pain Score	20.61 ± 14.68	16.12 ± 14.97	4.49 (1.29, 7.69)	2.76	0.006	0.30
SPADI Disability Score	19.26 ± 11.16	16.14 ± 14.60	3.12 (0.37, 5.87)	2.23	0.026	0.24
SPADI Total Score	30.67 ± 19.27	24.82 ± 21.87	5.85 (1.37, 10.33)	2.57	0.011	0.29

Table 3. Distribution of SPADI Disability Grades

SPADI Grade	n (%)
No Pain/Disability	82 (24.1%)
Mild	142 (41.8%)
Moderate	115 (33.8%)
Severe	1 (0.3%)

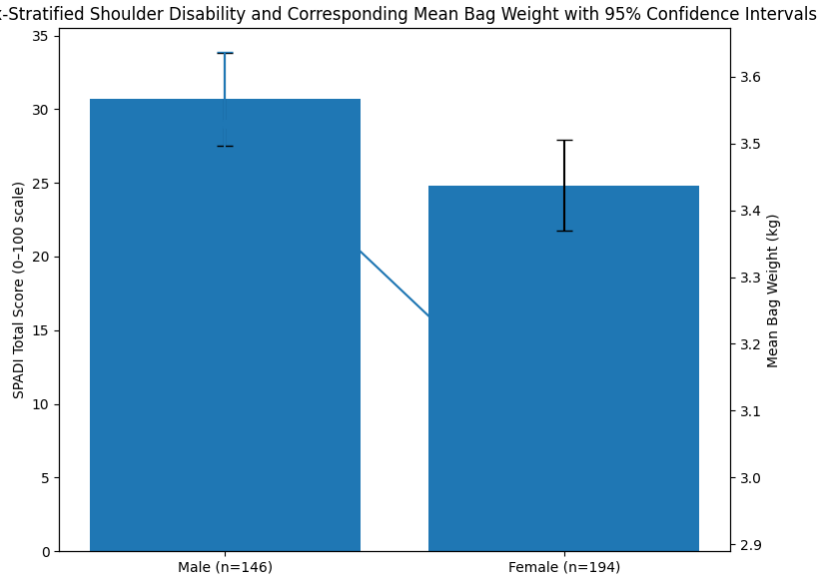
Table 4. Correlation Between Bag Weight and SPADI Total Score

Group	Spearman's ρ	95% CI for ρ	p-value
Overall (N=340)	0.524	0.44 to 0.60	<0.001
Male (n=146)	0.624	0.52 to 0.71	<0.001
Female (n=194)	0.457	0.34 to 0.56	<0.001

Table 5. Multivariable Linear Regression Analysis for Predictors of SPADI Total Score

Predictor	β (Unstandardized)	Standard Error	Standardized β	95% CI	p-value
Bag Weight (kg)	6.12	1.13	0.41	3.90 to 8.34	<0.001
Age (years)	0.58	0.44	0.07	-0.29 to 1.45	0.188
Male (vs Female)	4.73	1.98	0.16	0.84 to 8.62	0.018
BMI (kg/m²)	0.39	0.32	0.06	-0.24 to 1.02	0.224

The overall regression model was statistically significant ($F(4,335)=39.4$; $p<0.001$) and explained approximately 30% of the variance in SPADI total score (adjusted $R^2=0.30$), indicating a meaningful proportion of shoulder disability variability attributable to the measured predictors, particularly bag weight.



The figure demonstrates a clear sex-stratified gradient in shoulder disability aligned with differences in mean bag weight. Male students carried heavier bags (3.53 kg; 95% CI 3.42–3.64) compared to females (3.05 kg; 95% CI 2.92–3.18), and this corresponded with higher SPADI total scores in males (30.67; 95% CI 27.55–33.79) versus females (24.82; 95% CI 21.75–27.89). The non-overlapping central tendencies and narrow confidence intervals reinforce the statistical findings ($p=0.011$ for SPADI total difference), while the parallel directional shift between bag weight and disability magnitude visually supports the moderate positive association identified in correlation ($\rho=0.524$) and regression analyses ($\beta=6.12$ per kg). Clinically, the approximately 0.48 kg higher mean load in males corresponds to an approximate 5.85-point higher SPADI score, consistent with the adjusted model estimate that each 1 kg increase in bag weight predicts a 6.12-point rise in shoulder disability. This layered

comparison highlights a coherent exposure–outcome gradient, strengthening the interpretation that greater load carriage is meaningfully associated with higher functional shoulder impairment in this population.

DISCUSSION

The present analytical cross-sectional study demonstrates a statistically significant and clinically meaningful positive association between bag weight and shoulder pain and disability among undergraduate medical students. The overall Spearman correlation coefficient (ρ=0.524, $p<0.001$) indicates a moderate-to-strong monotonic relationship between increasing bag weight and higher SPADI total scores. Importantly, multivariable linear regression confirmed that bag weight remained an independent predictor of shoulder disability after adjusting for age, sex, and BMI, with each additional 1 kg associated with a 6.12-point increase in SPADI score (95% CI 3.90–8.34, $p<0.001$). Given that the SPADI scale ranges from 0 to 100, this magnitude suggests not merely statistical significance but clinically relevant functional impact. These findings strengthen the biological plausibility that repetitive mechanical loading of the shoulder complex contributes to symptomatic disability in young adults.

The observed sex differences further enhance interpretative depth. Male students carried significantly heavier bags (mean difference 0.48 kg) and exhibited higher SPADI pain, disability, and total scores compared with females. Although relative bag weight (% body weight) did not significantly differ between sexes, the stronger correlation observed among males (ρ=0.624) compared to females (ρ=0.457) suggests potential interaction between load magnitude and sex-specific biomechanical or behavioral factors. Differences in muscle activation patterns, posture, or carriage duration may partially explain this gradient, as prior biomechanical investigations have demonstrated increased trapezius and paraspinal muscle activity under asymmetrical or higher loading conditions (6,12). Furthermore, modeling studies indicate that increased strap compression elevates localized tissue stress and may impair microcirculation, thereby contributing to fatigue and discomfort (8–10). The consistency between our regression-derived β estimate and the observed mean SPADI difference between sexes supports the robustness of this exposure–response relationship.

Although much of the historical literature has focused on school-aged children, our findings extend the evidence base into a university-level population. Prior pediatric studies have linked heavy backpacks to postural deviations, increased musculoskeletal symptoms, and upper limb discomfort (4,5,7). Regional data from Pakistan have shown a correlation between heavy school bags and upper limb disabilities among school children (13), reinforcing contextual relevance. However, university students represent a distinct physiological and environmental subgroup. Unlike younger children, medical undergraduates experience prolonged academic schedules, clinical rotations, and frequent laptop carriage, potentially increasing cumulative load exposure. Our results demonstrate that even at a mean relative load of approximately 5.4% body weight—below the commonly cited 10–15% threshold—significant associations with shoulder disability are evident. This finding challenges the notion that only loads exceeding 10% body weight are clinically consequential and suggests that cumulative duration, asymmetrical carriage, or repetitive daily exposure may amplify biomechanical strain even at moderate absolute loads (17).

The distribution of SPADI grades further underscores the public health relevance of the findings. Nearly three-quarters of participants (75.9%) reported at least mild shoulder pain or disability, with 33.8% experiencing moderate impairment. Such prevalence aligns with reports of substantial musculoskeletal symptom burden among university students (11).

Moreover, shoulder disability should not be viewed in isolation; emerging evidence highlights associations between musculoskeletal pain and psychological stressors such as depression and anxiety in occupational groups (14). Although psychological variables were not directly measured in the present study, the documented burden of shoulder symptoms among medical students warrants broader consideration of academic workload, ergonomic practices, and mental well-being in future research.

From a mechanistic perspective, sustained load carriage increases compressive forces over the acromioclavicular region and trapezius musculature, potentially altering scapulohumeral rhythm and increasing rotator cuff demand. Experimental work has shown that shoulder strap pressures can exceed thresholds associated with localized blood flow restriction (9), while hemodynamic studies report reduced brachial artery perfusion under backpack loading (10). These physiological perturbations provide a coherent explanation for the positive association observed in our cohort. Additionally, asymmetrical or unilateral bag carriage, which is common among university students, may exacerbate lateral trunk flexion and muscle imbalance (12), further contributing to shoulder strain.

The study possesses several strengths. Objective measurement of bag weight and anthropometric variables minimized exposure misclassification, and use of the validated SPADI instrument ensured standardized outcome assessment (15). Adjustment for potential confounders in multivariable regression strengthens internal validity. However, certain limitations must be acknowledged. The cross-sectional design precludes causal inference and does not allow determination of temporal sequencing between exposure and outcome (16). Reverse causality—where students with pre-existing shoulder discomfort modify bag carriage patterns—cannot be excluded. Convenience sampling limits generalizability beyond the participating institutions, and unmeasured confounders such as carriage duration, strap width, posture, and physical activity were not incorporated into the regression model. Although missing data were minimal, residual confounding remains possible.

Despite these limitations, the consistency across correlation, group comparison, and regression analyses suggests a stable exposure–outcome gradient. Clinically, a 6-point increase in SPADI per kilogram of additional load indicates that relatively small reductions in bag weight could yield meaningful reductions in shoulder disability. From an institutional perspective, these findings support ergonomic interventions such as promoting bilateral strap use, encouraging load minimization, providing locker facilities, and implementing educational programs on safe load carriage. Future longitudinal research is warranted to establish temporal relationships and explore potential nonlinear or threshold effects of cumulative load exposure. Incorporating biomechanical assessments, carriage duration metrics, and psychosocial variables would further elucidate the multifactorial pathways linking academic load carriage to shoulder dysfunction in medical students.

CONCLUSION

This study demonstrates a statistically significant and clinically meaningful positive association between bag weight and shoulder pain and disability among undergraduate medical students. Higher absolute bag weight was independently associated with increased SPADI total scores, with each 1 kg increment corresponding to a 6.12-point rise in shoulder disability after adjustment for age, sex, and BMI. Male students carried heavier bags and exhibited higher SPADI scores, further supporting an exposure–response gradient. Notably, this association was observed even at mean relative loads below traditionally cited 10–15% body weight thresholds, suggesting that cumulative exposure, repetitive carriage, or asymmetrical loading may contribute to functional shoulder impairment even at moderate

loads. These findings underscore the clinical and ergonomic relevance of load management strategies within medical colleges and highlight the need for preventive interventions and longitudinal research to clarify causal pathways and optimize musculoskeletal health in this population

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DECLARATIONS

Ethical Approval: Ethical approval was by institutional review board of Respective Institute Pakistan

Informed Consent: Informed Consent was taken from participants.

Authors' Contributions:

Concept: JH, UI; Design: JH, RB; Data Collection: AA, LZ, MSK, MAS; Analysis: UI, AR; Drafting: JH, WP

Conflict of Interest: The authors declare no conflict of interest.

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