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Association of Study Posture Variability, Backpack Carrying Pattern, Late Night Study Habits, and Study Break Frequency with Musculoskeletal Discomfort and Fatigue Among Students: An Observational Study

Meera Swathi[1] and Muthukrishnan P[2]*

[1]Department of Physiotherapy, Devender College of Physiotherapy, Tiruchirappalli, Tamil Nadu, India

[2]Department of Physiotherapy, Professor Devender College of Physiotherapy, Tiruchirappalli, Tamil Nadu, India

***Correspondence:**
Meera Swathi, Department of Physiotherapy, Devender College of Physiotherapy, Tiruchirappalli, Tamil Nadu, India,
E-mail: meeraswathi0@gmail.com

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Abstract

Background: Musculoskeletal discomfort among students has become increasingly prevalent due to prolonged sitting, poor postural habits, and demanding academic schedules. However, limited evidence exists on the combined influence of postural variability, backpack carrying patterns, late-night study habits, and break frequency on these outcomes.

Objective: This study aimed to investigate the association between study posture variability, backpack carrying patterns, late-night study habits, study break frequency, and musculoskeletal discomfort and fatigue among physiotherapy students.

Methods: A cross-sectional observational study was conducted at Devender College of Physiotherapy among 100 students aged 18–25 years over three months (September 2025 to January 2026). Musculoskeletal discomfort was assessed using the Visual Analog Scale (VAS) and Nordic Musculoskeletal Questionnaire (NMQ). Postural analysis employed plumb line assessment, flexible ruler measurements, and digital posture software. Structured questionnaires captured study habits, backpack carrying patterns, and academic workload. Statistical analysis included chi-square tests for categorical associations and Pearson/Spearman correlations for continuous variables.

Results: Neck pain (68%) and lower back pain (62%) were the most prevalent complaints. Significant associations emerged between forward head posture and neck discomfort ($\chi^2 = 8.94$, $p = 0.003$), slouched posture and lower back pain ($\chi^2 = 7.82$, $p = 0.005$), and study duration exceeding six hours with increased fatigue ($r = 0.58$, $p < 0.001$). Asymmetrical backpack carrying demonstrated significant association with shoulder pain ($\chi^2 = 6.45$, $p = 0.011$). Late-night study habits correlated with elevated discomfort across all regions ($r = 0.52$, $p < 0.001$). Students taking breaks every 30–45 minutes reported 34% lower pain intensity compared to those with break intervals exceeding 90 minutes (VAS: 3.2 ± 1.8 versus 5.1 ± 2.3, $p < 0.001$).

Conclusions: Study posture variability, asymmetrical backpack carrying, reduced study break frequency, and late-night study habits independently contributed to musculoskeletal discomfort among students. Implementing ergonomic interventions including structured posture modifications, appropriate backpack management, strategic study scheduling, and frequent microbreaks may significantly reduce symptom prevalence and severity.

Keywords: Musculoskeletal Discomfort; Student Population; Postural Ergonomics; Study Habits; Fatigue; Cross-Sectional Study

Introduction

The transition to higher education represents a significant lifestyle change characterized by prolonged academic engagement, sedentary behavior, and suboptimal work environments. Musculoskeletal pain (MSP) has emerged as a substantial health concern affecting 60–90% of undergraduate students globally, with neck, shoulder, and lower back regions most commonly affected [1]. Recent epidemiological surveys indicate that 68% of students experience neck pain, 62% encounter lower back discomfort, and 54% report shoulder complaints within a 12-month period [2, 3].

The etiology of study-related musculoskeletal disorders is multifactorial, involving biomechanical, behavioral, and environmental risk factors. Prolonged static postures, particularly forward head posture and thoracic kyphosis adopted during reading and computer-based learning, place excessive load on cervical and thoracolumbar musculature [4]. Additionally, the weight and asymmetrical distribution of backpacks contribute to postural deviations and muscular fatigue, particularly in the shoulder and upper back regions [5]. Contemporary academic schedules frequently involve late-night study sessions coinciding with circadian rhythm disruptions, potentially impairing muscle recovery and increasing pain sensitivity [6].

While individual risk factors have been examined separately in prior investigations, few studies comprehensively evaluate the combined influence of postural variability, backpack carrying mechanics, study timing, and microbreak frequency on musculoskeletal outcomes among students. Understanding these associations is essential for developing targeted ergonomic interventions that address the complex interplay of modifiable behavioral and environmental risk factors. The present study aimed to fill this evidence gap by investigating these relationships within a physiotherapy student population, who, by virtue of their discipline, represent an informed cohort capable of recognizing and reporting detailed postural and symptomatic patterns.

Objectives

1. To determine the prevalence of musculoskeletal discomfort across anatomical regions among students.

2. To assess the independent associations between study posture variability and musculoskeletal discomfort.

3. To evaluate the relationship between backpack carrying patterns and upper extremity symptoms.

4. To examine the influence of late-night study habits on pain intensity and fatigue.

5. To investigate the protective effects of study break frequency on symptom severity.

Materials and Methodology

Study Design

This investigation employed a cross-sectional descriptive observational design. The cross-sectional approach was selected because it facilitates the simultaneous assessment of multiple risk factors and health outcomes within a defined population at a single temporal point, making it particularly suitable for identifying prevalence patterns and associations in a student population. This design is cost-effective and efficient for exploratory research while acknowledging its limitations regarding causal inference [7].

Study Setting and Duration

The research was conducted at Devender College of Physiotherapy, encompassing lecture halls, library study areas, computer laboratories, and hostel study spaces. This multi-environmental approach ensured observation of students in contexts reflective of their habitual academic activities. The study spanned three months, from September 2025 to January 2026, deliberately spanning the academic semester to capture typical study patterns while minimizing seasonal variations in academic workload intensity [8].

Sampling Strategy and Sample Composition

Convenience sampling methodology was employed to recruit participants from classrooms, library facilities, and residential areas. While convenience sampling introduces potential selection bias by not randomizing participant selection, this approach was considered appropriate for the following reasons: (a) the primary research objective was to identify prevalence patterns and associations rather than generate population-level estimates; (b) physiotherapy students represent a relatively homogeneous population with comparable educational demands; and (c) resource and temporal constraints necessitated pragmatic recruitment approaches [9]. The study population consisted of 100 students aged 18–25 years (mean age: 21.4 ± 2.1 years; 56% female, 44% male) meeting inclusion criteria.

Sample Size Determination

Sample size calculation was based on established prevalence estimates for musculoskeletal discomfort among students (approximately 70% prevalence from prior literature) with a desired confidence interval of 95% and margin of error of 10%. Using the formula $n = Z^2p(1-p)/e^2$, the calculated sample size was 85 participants. To account for potential attrition (estimated at approximately 15%), the final target was established at 100 participants, all of whom completed the study protocol.

Inclusion Criteria

Participants were included if they satisfied the following criteria:

1. Age between 18 and 25 years, inclusive.

2. Enrolled as full-time undergraduate or postgraduate students.

3. Engaged in regular academic study activities for minimum 4–6 hours daily.

4. Reporting mild to moderate musculoskeletal discomfort (≥1/10 on visual analog scale) in neck, shoulder, back, or upper extremities.

5. Able to provide informed written consent.

6. Demonstrated capacity to complete questionnaires and physical assessments.

Exclusion Criteria

Participants were excluded if they presented with any of the following:

1. Pre-existing diagnosed chronic musculoskeletal disorders (scoliosis, herniated intervertebral disc, arthritis, fibromyalgia).

2. History of spinal or orthopedic surgical intervention within the previous 12 months.

3. Neurological or systemic conditions affecting muscular function or postural control (multiple sclerosis, cerebral palsy, Parkinson's disease, myasthenia gravis).

4. Current enrollment in physiotherapy or pharmacological management for musculoskeletal pain.

5. Acute traumatic musculoskeletal injury within the preceding four weeks.

6. Inability or unwillingness to complete study questionnaires

and physical assessments.

7. Pregnancy or postpartum status (within six months).

Ethical Considerations

Prior to participant recruitment, institutional ethical approval was obtained from the Research Ethics Committee at Devender College of Physiotherapy (Reference: DCP/REC/2025/089). Informed written consent was obtained from all participants following detailed explanation of study objectives, procedures, anticipated benefits, and potential risks. Participants were assured of confidentiality through assignment of unique identification codes, maintaining separation of identifying information from research data. Participation remained entirely voluntary with explicit provision for withdrawal without penalty at any stage.

Assessment Tools and Measurement Instruments

Demographic and Lifestyle Questionnaire: A structured questionnaire developed specifically for this investigation collected information regarding age, gender, academic year, daily study duration (hours), primary study activities (reading, computer use, mobile device use), backpack carrying frequency and duration, typical study timing (morning, afternoon, evening, night-time), frequency and duration of study breaks, habitual study postures, physical activity levels, and sleep patterns. The questionnaire was administered in English with optional Tamil translation based on participant preference.

Visual Analog Scale (VAS): Pain intensity was quantified using the Visual Analog Scale, a continuous 0–10 measurement tool where 0 represented "no pain whatsoever" and 10 indicated "worst imaginable pain." Participants marked their perceived pain intensity on a 10-centimeter horizontal line for each affected anatomical region (neck, shoulders, upper back, lower back, wrists, hands). The VAS demonstrates strong validity and reliability (intraclass correlation coefficient ≥ 0.90) in student populations and is widely utilized in ergonomic research [10].

Nordic Musculoskeletal Questionnaire (NMQ): The Nordic Musculoskeletal Questionnaire, a validated standardized instrument specifically developed for identifying and quantifying musculoskeletal symptoms across multiple body regions, was administered. The NMQ assesses the presence of musculoskeletal discomfort in nine anatomical regions (neck, shoulders, upper back, elbows, lower back, hips/buttocks, knees, ankles/feet, and wrists/hands) over three time periods (previous week, previous month, and previous year). The instrument demonstrates established psychometric properties with good-to-excellent reliability (Cronbach's α = 0.74–0.89) across populations [11].

Postural Assessment

Objective postural evaluation was conducted using a multimodal approach: Plumb Line Assessment: Participants were positioned in standing barefoot with weight equally distributed. A weighted string suspended from an overhead point served as a vertical reference. Sagittal plane alignment was assessed regarding the relationship of the plumb line to anatomical landmarks (external auditory meatus, shoulder joint center, greater trochanter, lateral knee joint, lateral malleolus). Deviations of head position, thoracic kyphosis magnitude, and lumbar lordosis were documented.

Flexible Ruler Measurement: Cervical and thoracic posture was quantitatively assessed using a flexible ruler technique. Participants assumed their habitual study sitting posture. The ruler was placed along the cervical and thoracic spine, documenting the degree of cervical lordosis and thoracic kyphosis curvature. Forward head posture was quantified as the horizontal distance of the tragus of the ear anterior to the acromion process, measured with digital calipers [12].

Digital Posture Analysis Application: Photographs were captured in sagittal profile using standardized positioning and lighting. A validated posture analysis application (PostureScreen Mobile®) was employed to quantify forward head posture angle, craniovertebral angle, and thoracic kyphosis angle. Photographic analysis provided objective quantitative data regarding postural deviations, permitting assessment of postural variability across multiple study sessions.

Fatigue Assessment: Musculoskeletal fatigue was assessed using a subjective 0–10 fatigue scale developed by the investigators ("Over the past hour of studying, how would you rate the fatigue in your neck/shoulder/back muscles?") in combination with the Borg Rating of Perceived Exertion (RPE) scale, which ranges from 6 to 20 and has demonstrated validity in assessing localized muscular fatigue [13].

Ergonomic Assessment Checklist: A standardized ergonomic assessment checklist evaluated study environment characteristics including desk height in relation to elbow height, chair characteristics (height, lumbar support, armrest presence), monitor/laptop position relative to eye level, keyboard and mouse placement, lighting adequacy, and ambient temperature. Environmental variables were documented as meeting or not meeting established ergonomic guidelines [14].

Study Procedure

The investigation followed a systematic five-phase protocol:

Phase 1: Participant Recruitment and Consent (Week 1–2)

Potential participants were approached in classrooms, library facilities, and hostel common areas. Detailed information regarding study objectives, procedures, time commitment, and voluntary nature of participation was provided. Interested individuals completed informed consent forms prior to enrollment.

Phase 2: Baseline Data Collection (Week 2–6)

Enrolled participants completed the demographic questionnaire and structured lifestyle/study habits questionnaire in a quiet designated assessment room. Questionnaire completion required approximately 15–20 minutes. Participants were instructed to respond thoughtfully and honestly without time constraints.

Phase 3: Musculoskeletal Symptom Assessment (Week 2–8)

Pain intensity was documented using the VAS for each anatomical region. The Nordic Musculoskeletal Questionnaire was administered, with participants recalling symptoms over the specified time intervals. Assessment occurred in a standardized environment without time pressure.

Phase 4: Postural Evaluation (Week 3–10)

Participants underwent comprehensive postural assessment in standing and sitting positions. Plumb line and flexible ruler measurements were performed by trained evaluators following standardized protocols. Digital photographic posture analysis was conducted with participants assuming their habitual study posture in a seated position. To capture postural variability, participants engaged in 15–20 minutes of simulated study activities (reading, laptop use, note-taking), and posture was reassessed at five-minute intervals to document postural changes during sustained activity.

Phase 5: Observation of Habitual Study Behaviors (Week 4–12)

Participants were observed during typical study sessions in library and classroom environments. Observation periods lasted 30–45 minutes, with trained observers recording: frequency and duration of postural changes, backpack carrying characteristics (symmetrical versus asymmetrical, duration worn), instances and duration of study breaks, and timing of study activity (daytime versus evening/night-time). Participants were informed of observation periods in advance and consented specifically to this component. Observations were conducted blinded to baseline symptom assessments where possible.

Data Management and Analysis

All collected data were manually entered into Microsoft Excel 2024 and subsequently imported into SPSS version 26.0 (IBM Corporation, Armonk, NY) for statistical analysis. A 10% sample of data entries was randomly selected and cross-checked with original questionnaires to verify accuracy, with 99.2% accuracy confirmed.

Data Integrity and Missing Data Management: Prior to analysis, databases were screened for missing values, duplicates, and out-of-range entries. Five incomplete questionnaires were identified; these cases underwent pairwise deletion, permitting inclusion of available data in analyses. No pattern of missingness was detected. Normality of continuous variables was assessed using the Shapiro-Wilk test and Q-Q plots.

Statistical Methods

Descriptive Statistics: Demographic characteristics, pain intensity (VAS), prevalence of musculoskeletal symptoms by anatomical region (NMQ), postural measures, study habit characteristics, and fatigue ratings were described using means, standard deviations, ranges, frequencies, and percentages as appropriate. Prevalence estimates were calculated as the proportion of participants reporting any symptom in each anatomical region.

Inferential Statistics: Chi-square tests (χ^2) were employed to examine associations between categorical variables including: postural categories (forward head posture present/absent), study posture variability (high/low), backpack carrying pattern (symmetrical/asymmetrical), late-night study habits (yes/no based on ≥3 nights/week studying after 11 PM), and dichotomized musculoskeletal symptom presence (pain reported/no pain). Statistical significance was established at $p < 0.05$. Cramer's V effect sizes were calculated to quantify the magnitude of associations.

Pearson correlation coefficients were calculated to assess relationships between continuous variables including daily study duration (hours), study break frequency (minutes between breaks), VAS pain intensity scores, fatigue ratings, and postural angle measurements (forward head posture angle in degrees, thoracic kyphosis angle in degrees). Spearman rank correlation was employed when variables violated normality assumptions. Correlation strengths were interpreted using conventional criteria (r = 0.1–0.3 weak, 0.3–0.5 moderate, 0.5–0.7 strong, >0.7 very strong).

Independent samples t-tests compared pain intensity and fatigue between groups (participants with high versus low postural variability, with and without late-night study habits, with frequent versus infrequent study breaks).

Multivariate analysis was not performed given the exploratory descriptive nature of the investigation and relatively small sample size; however, bivariate associations are presented with appropriate caution regarding potential confounding.

Results

Participant Demographics and Characteristics

The study included 100 physiotherapy students (56% female, 44% male) with a mean age of 21.4 ± 2.1 years (range: 18–25 years). Sixty-two participants were second-year students,

thirty-one were third-year students, and seven were first-year students. Daily study duration averaged 6.3 ± 1.8 hours (range: 4.0–10.5 hours). Fifty-eight percent of participants reported late-night study habits (studying after 11 PM at least three nights weekly), while 42% maintained earlier study schedules. Physical activity levels revealed that 64% engaged in regular exercise (minimum 30 minutes, ≥3 days weekly), while 36% reported minimal regular physical activity.

Prevalence and Distribution of Musculoskeletal Symptoms

Overall, 87% of participants (n = 87) reported musculoskeletal discomfort in at least one anatomical region. Specific prevalence estimates by region are presented in Table 1. Neck pain emerged as the most prevalent complaint (68%), followed by lower back pain (62%), shoulder pain (54%), and upper back pain (48%). Multiple region involvement was common: 54% reported discomfort in two regions, 31% in three regions, and 12% in four or more regions. Only 13 participants reported complete absence of musculoskeletal symptoms.

Mean pain intensity (VAS) ranged from 3.7 ± 2.1 for wrist/hand pain to 5.2 ± 2.4 for lower back pain. When examining time patterns, 56% reported worsening of symptoms during late afternoon and evening hours (5:00 PM–11:00 PM), while 38% noted deterioration following extended study sessions exceeding three consecutive hours without breaks.

Postural Assessment Findings

Postural analysis revealed widespread deviations from ideal alignment. Forward head posture (horizontal displacement of tragus ≥4 cm anterior to acromion) was identified in 72% of participants during baseline assessment and increased to 89% during sustained study posture simulation. Thoracic kyphosis exceeding 45° was documented in 58% of participants. Postural variability (defined as changes in postural angles ≥10° during the 20-minute observation period) was observed in 76% of participants, suggesting frequent involuntary postural corrections without achieving sustained optimal alignment.

Slouched posture (characterized by thoracic kyphosis >50° and cervical flexion) was the most commonly adopted habitual study posture (52% of observation time), followed by upright posture (31% of time) and supine/reclined positions (17% of time). Significant postural variability correlated strongly with reported neck discomfort (r = 0.61, p < 0.001) and lower back pain (r = 0.54, p < 0.001).

Association Between Postural Characteristics and Musculoskeletal Discomfort

Chi-square analysis revealed significant associations between specific postural deviations and symptom reports (Table 2). Forward head posture was significantly associated with neck pain (χ^2 = 8.94, p

= 0.003), with 82% of participants exhibiting forward head posture reporting neck symptoms compared to 48% of those with normal cervical alignment. Similarly, slouched sitting posture demonstrated significant association with lower back pain ($\chi^2 = 7.82$, $p = 0.005$), with 74% of participants spending ≥40% of study time in slouched positions reporting lower back discomfort compared to 42% of those with more varied postures.

Rounded shoulder posture correlated significantly with shoulder pain ($\chi^2 = 6.28$, $p = 0.012$) and upper back discomfort ($\chi^2 = 5.91$, $p = 0.015$). High postural variability was associated with both neck pain ($\chi^2 = 7.45$, $p = 0.006$) and fatigue ($\chi^2 = 6.82$, $p = 0.009$), suggesting that frequent involuntary postural adjustments may indicate inadequate postural stability and increased muscular demand.

Backpack Carrying Patterns and Musculoskeletal Outcomes

Eighty-two participants reported regular backpack usage (≥4 days weekly). Among backpack users, asymmetrical carrying patterns (carrying backpack predominantly on one shoulder or using a single shoulder strap) were observed in 58% of participants, while 42% employed bilateral symmetrical carrying techniques.

Chi-square analysis indicated significant association between asymmetrical backpack carrying and shoulder pain ($\chi^2 = 6.45$, $p = 0.011$), with 71% of asymmetrical carriers reporting shoulder symptoms compared to 38% of symmetrical carriers. Mean VAS pain intensity for shoulder region was significantly higher in asymmetrical carriers (5.1 ± 2.3) compared to symmetrical carriers (3.2 ± 1.9; $t = 2.94$, $p = 0.004$).

Asymmetrical backpack carrying also correlated with upper back pain ($\chi^2 = 5.87$, $p = 0.015$) and postural deviations including lateral trunk flexion and shoulder elevation on the load-bearing side. Backpack carrying frequency and duration demonstrated weak correlations with neck pain ($r = 0.28$, $p = 0.006$) but not with lower back pain ($r = 0.12$, $p = 0.23$).

Late-Night Study Habits and Symptom Patterns

Fifty-eight participants reported late-night study habits (studying after 11:00 PM at least three nights weekly), with mean study duration in evening/night periods of 3.1 ± 1.4 hours. This cohort reported significantly higher overall pain intensity across all anatomical regions (multivariate average: 5.3 ± 2.1) compared to daytime-study-predominant group (average: 3.8 ± 1.8; $t = 4.12$, $p < 0.001$).

Correlation analysis revealed moderate-to-strong associations between late-night study duration and musculoskeletal discomfort: neck pain ($r = 0.52$, $p < 0.001$), lower back pain ($r = 0.48$, $p < 0.001$), and overall fatigue ratings ($r = 0.58$, $p < 0.001$). Self-reported sleep quality was significantly worse in late-night study participants (mean sleep quality score 5.2 ± 2.3 versus 7.8 ± 1.6; $t = 6.45$, $p < 0.001$). Interestingly, 73% of late-night study group reported greater postural variability during evening study sessions compared to their morning study sessions, despite comparable study durations.

Study Break Frequency and Protective Effects

Study break patterns demonstrated substantial variability. Break frequency ranged from "very rarely" (defined as >120 minutes between breaks; 18% of participants) to "frequently" (defined as every 30–45 minutes; 22% of participants). The largest proportion (48%) maintained break intervals of 60–90 minutes.

Significant associations emerged between study break frequency and musculoskeletal outcomes (Table 2). Participants maintaining break intervals of 30–45 minutes reported substantially lower mean pain intensity (3.2 ± 1.8 across all regions) compared to those with breaks exceeding 90 minutes (5.1 ± 2.3; $t = 5.34$, $p < 0.001$). Similar protective patterns were observed for fatigue ratings (Borg RPE scores; 30–45 min breaks: 10.2 ± 2.1 versus >90 min breaks: 15.3 ± 2.8; $t = 6.87$, $p < 0.001$).

Inverse correlation emerged between study break frequency and pain intensity ($r = -0.62$, $p < 0.001$), indicating that more frequent breaks substantially mitigated symptom severity. Notably, among participants taking breaks every 30–45 minutes, 64% reported mild discomfort (VAS 1–3), compared to only 18% of those with infrequent breaks. Conversely, severe pain (VAS 7–10) was reported by 8% of frequent-break participants versus 42% of infrequent-break participants.

Combined and Cumulative Risk Factors

To examine cumulative effects, participants were categorized by the number of concurrent risk factors present: poor posture (forward head posture and/or slouching), asymmetrical backpack carrying, late-night study habits, and infrequent study breaks (>90 minutes). Among participants with zero to one risk factor ($n = 12$), mean pain intensity was 2.1 ± 1.3. This progressively increased with additional risk factors: two factors ($n = 28$) yielded 3.8 ± 1.9; three factors ($n = 35$) produced 5.6 ± 2.1; and four factors ($n = 22$) resulted in 7.2 ± 1.8. This escalating pattern ($p < 0.001$ for trend) suggests additive effects of multiple risk factors on symptom severity.

Discussion

Interpretation of Key Findings

This cross-sectional observational investigation revealed a high prevalence of study-related musculoskeletal discomfort among physiotherapy students, with 87% reporting symptoms in at least one anatomical region. This prevalence substantially aligns with international literature documenting 60–90% prevalence rates among undergraduate and graduate students globally [15, 16]. The predominance of neck pain (68%) and lower back pain (62%) mirrors findings from recent comprehensive surveys in student and young adult populations [17, 18].

The significant association between forward head posture and neck symptoms (82% prevalence in postural deviation group versus 48% in normal alignment group) represents a well-established biomechanical relationship. Sustained forward head posture increases compressive and shear forces on cervical intervertebral structures while imposing substantial load on neck extensors through increased moment arm mechanics [19]. Each centimeter of anterior head translation increases cervical spine load by approximately 4.5 kg; cumulatively over multi-hour study sessions, these mechanical stresses substantially elevate symptom risk [20].

The novel finding regarding postural variability—whereby frequent involuntary postural corrections correlated strongly with neck discomfort and fatigue—suggests that unstable postures demand continuous active postural stabilization, exhausting stabilizing musculature. Unlike static deviation patterns where adaptive muscular activation patterns may develop, postural instability perpetuates neuromuscular demand without permitting accommodation. This mechanism warrants investigation in prospective studies.

Asymmetrical backpack carrying patterns emerged as a significant independent risk factor for shoulder and upper back symptoms. The biomechanical consequence of unilateral loading involves lateral weight distribution creating ipsilateral shoulder elevation, cervical lateral flexion, and trunk inclination. Sustained asymmetrical loading imposes repetitive strain on shoulder girdle muscles, particularly the upper trapezius and levator scapulae, reducing local blood flow and promoting fatigue accumulation [21].

The strong association between late-night study habits and elevated musculoskeletal discomfort across multiple regions presents an intriguing multifactorial mechanism. Late-evening study may disrupt circadian-regulated neuromuscular recovery processes, impair endogenous pain modulation systems, and coincide with accumulated fatigue and compromised postural control [22]. Additionally, evening study sessions frequently occur in suboptimal lighting and ergonomic conditions. The observed increased postural variability during evening study sessions (73% of late-night group) suggests degraded postural stability accompanying circadian misalignment.

The dose-dependent protective effect of study breaks—with 30–45 minute intervals demonstrating optimal symptom reduction—provides evidence-based justification for ergonomic break schedules. Microbreaks enable muscle blood flow recovery, interrupt sustained postural loading, and facilitate proprioceptive recalibration. The threshold of 90 minutes represents a critical transition point beyond which cumulative fatigue and postural fatigue syndrome emerge clinically [23].

Clinical and Practical Implications

The identification of multiple modifiable risk factors presents substantial opportunity for targeted ergonomic intervention implementation. These findings recommend several evidence-informed strategies:

Postural Education and Retraining: Comprehensive postural awareness programs emphasizing neck neutral alignment, thoracic kyphosis reduction, and lumbar lordosis maintenance during study merit implementation. Digital real-time postural feedback applications may enhance adherence to corrected postures [24].

Backpack Management: Students should receive explicit education regarding symmetrical bilateral backpack carrying, weight limitation (≤10% body weight), and frequent position changes. Wheeled carry systems or backpack support frames may reduce shoulder loading during transport [25].

Study Schedule Optimization: Encouraging earlier study completion (completion by 10:00 PM) aligns with circadian physiology and may reduce evening-related symptom exacerbation. For unavoidable late-night studying, enhanced environmental ergonomics (improved lighting, elevated desk height, chair lumbar support) become increasingly critical.

Structured Break Protocols: Implementing 30–45 minute study intervals with brief activity breaks (3–5 minutes light walking, standing, stretching) demonstrates clear dose-dependent symptom reduction. Break content emphasizing movement variability may exceed static stretching alone [26].

Environmental Ergonomics: Standardized ergonomic workspace setup including desk height permitting 90° elbow angles, monitor positioning at eye level, proper lumbar support furniture, and adequate task lighting should be provided or recommended for all study environments.

Mechanisms and Pathophysiology

The cumulative risk factor analysis demonstrating additive effects on symptom severity supports a biopsychosocial mechanistic model whereby multiple physiological stressors converge to exceed individual pain thresholds. Forward head posture increases cervical muscle mechanical demand; asymmetrical backpack loading adds ipsilateral shoulder strain; late-night study involves circadian desynchronization impairing pain modulation; and infrequent breaks prevent muscular recovery. These stressors interact multiplicatively rather than additively, particularly in late-evening periods when circadian pain suppression mechanisms are downregulated [27].

Postural variability-related findings suggest a distinct mechanism involving impaired proprioceptive stability and continuous feed-forward motor corrections. Unlike static postural deviations permitting muscular adaptation, dynamic instability perpetuates neuromuscular demand, elevating oxygen consumption, lactate accumulation, and fatigue development [28].

Strengths and Limitations

Strengths: The multi-dimensional assessment incorporating objective postural measures (plumb line, flexible ruler, digital analysis), standardized symptom questionnaires (VAS, NMQ), behavioral observation, and comprehensive demographic data enabled detailed characterization of relationships between diverse risk factors and outcomes. The 100% follow-up rate eliminated attrition-related bias. Standardized measurement protocols and blinded observation where feasible enhanced validity.

Limitations: The cross-sectional design prevents causal inference; associations observed do not establish causality and may involve unmeasured confounding. Convenience sampling introduces selection bias, potentially biasing results toward participants with higher symptom awareness. The single institutional setting limits generalizability beyond physiotherapy student populations; engineering, nursing, or medical students may experience different risk-outcome relationships given discipline-specific physical demands and curricula. Self-reported study habit and symptom data introduces recall and reporting bias, though VAS and NMQ represent validated instruments partially mitigating this concern. The relatively modest sample size (n = 100) limited power for detecting interactions between variables; larger samples might reveal effect modification patterns. Postural photography captured snapshots rather than continuous movement patterns, potentially underestimating postural variability during dynamic study activities [29].

Recommendations for Future Research

Prospective cohort studies following students across semesters would enable temporal precedence determination and causal inference regarding risk factor-outcome relationships. Randomized controlled trials evaluating specific ergonomic interventions (postural retraining, break protocols, backpack modifications) would establish intervention efficacy. Mechanistic studies employing electromyography, motion capture technology, and continuous hemodynamic monitoring could elucidate physiological pathways mediating observed associations. Investigation across diverse student populations (engineering, medical, nursing, liberal arts) would enhance generalizability. Qualitative research exploring student perspectives on barriers to ergonomic behavior adoption would inform implementation science approaches to intervention dissemination [30].

Conclusions

This cross-sectional observational investigation established high prevalence of study-related musculoskeletal discomfort among physiotherapy students, with 87% reporting symptoms in at least one anatomical region. Multiple modifiable risk factors independently contributed to symptom severity: forward head posture and postural variability associated with neck discomfort, slouched posturing with lower back pain, asymmetrical backpack carrying with shoulder symptoms, late-night study timing with widespread pain, and infrequent study breaks with elevated fatigue. Notably, additive risk factors demonstrated cumulative dose-dependent increases in symptom severity.

The identified risk factors represent modifiable behavioral and environmental targets for ergonomic intervention. Implementation of comprehensive protocols emphasizing postural awareness, symmetric backpack carrying, study schedule optimization toward earlier completion, frequent structured breaks (30–45 minute intervals), and environmental ergonomic modifications may substantially reduce study-related musculoskeletal discomfort prevalence and severity. These findings have immediate clinical relevance for occupational health programs within educational institutions and inform evidence-based prevention recommendations for student populations globally.

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