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Ergonomics Assessment and Optimization Recommendations for University Student Dormitories: A Case Study of Our Campus

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Abstract **Original Research Article**

This study presents an empirical ergonomic analysis of university student dormitory environments. Through on-site measurements and behavioral observations across four critical zones, systematic human-machine mismatches are identified: the desk system exhibits desktop depth and knee-clearance height significantly below national standards, causing 78% of students to adopt compensatory postures (equipment stacking and lumbar forward flexion); the corridor system lacks adequate turning clearance, leading to peak-hour congestion; the bunk bed system shows guardrail height and step depth below safety thresholds, increasing fall risks; and the washroom counter height forces users to bend over 30° while washing, compounded by poor drainage creating slip hazards. The findings reveal a fundamental design philosophy prioritizing basic functionality over user-fit. Targeted solutions are proposed, including zone-specific desk reconfiguration, corridor buffer additions, anti-slip retrofitting for beds, and adjustable mirror heights. The study emphasizes the necessity of reconstructing the "human-machine-environment" system synergy through human factors engineering principles.

Keywords: Human Factors Engineering, Student Dormitory, Human-Machine Mismatch, Space-Empowered Development.

Section 1: Introduction

1.1 Research Background and Significance

University dormitories serve as core living and learning spaces for students, and their ergonomic design quality directly affects physical health, mental well-being, and academic efficiency. Surveys indicate that college students spend over 12 hours per day on average within dormitory premises. Yet current dormitory designs commonly suffer from a disconnection between functionality and human-body adaptability. Taking the desk as an example, standard dimensions fail to accommodate modern learning equipment arrangements; measured data show that effective usable desktop area is less than half, causing frequent spatial conflicts when laptops, textbooks, and notebooks are used simultaneously. Public corridor widths often ignore peak-hour pedestrian density, and narrow sections easily lead to physical collisions. In bunk beds, insufficient guardrail height and shallow step depths pose fall hazards; biomechanical analysis indicates that such designs cause joint torque overloads exceeding 30% during climbing motions.

Washrooms exhibit systemic issues including insufficient slip resistance on wet floors and poor mirror height-to-user-height fit.

These phenomena expose the fact that existing dormitory designs have not yet fully integrated human factors engineering principles. Human-machine interaction theory emphasizes that physical environments must deeply align with users' physiological characteristics and behavioral patterns. Particularly in high-density living spaces, minor design flaws in space, furniture, and facilities are geometrically amplified through frequent use, leading to musculoskeletal strains, psychological stress, and even safety accidents [3]. Therefore, systematically evaluating the ergonomic problems in our campus dormitories is not only about improving living comfort but also a practical response to the "student-centered" educational philosophy.

1.2 Research Objectives

Departing from the subjective limitations of traditional questionnaire surveys, this study adopts empirical measurement and behavioral observation to achieve the following goals:

(1) **Problem Identification:** Through on-site mapping and behavioral trajectory tracking, quantify human-fit deficiencies in four spatial zones (desk, corridor, bed, washroom)—e.g., knee-clearance height and visual blind spots at corridor turns.

(2) **Mechanism Analysis:** Combining biomechanics and spatial behavior theory, parse the causal chains between design defects and user discomfort—e.g., the relationship between excessive bed-ladder inclination and foot slippage.

(3) **Optimization Proposals:** Propose progressive improvement measures based on ergonomic standards (e.g., adjustable desk modules, flexible corridor functional zoning) and provide a prioritized action list for dormitory renovations.

1.3 Research Content and Methods

The research unfolds in two layers:

(1) Space and Facility Measurements

Desk System: Measure effective desktop utilization rate and knee-clearance height (compared against Ergonomic Requirements for Furniture).

Corridor System: Record turning radius and emergency evacuation width.

Bed System: Analyze effective guardrail height, step anti-slip coefficient, and joint loads during climbing.

Washroom System: Assess reachability of operating interfaces (faucet/mirror).

(2) Literature Benchmarking and Standard Validation

Compare findings against the Architectural Design Code for Dormitories and international ergonomic standards to identify deviations; consult relevant ergonomics literature on university dormitories.

Section 2: Literature Review and Theoretical Foundations

2.1 Application Framework of Ergonomics in Residential Spaces

Ergonomics (human factors engineering) aims to optimize the "human-machine-environment" system fit. Its theoretical framework comprises three logical layers:

(1) **Physiological Fit:** Design physical spatial scales based on anthropometric data (static dimensions, dynamic ranges of motion).

(2) **Behavioral Fit:** Plan spatial layouts and facility interaction logic according to user behavior patterns (e.g., study workflows, emergency egress).

(3) **Psychological Comfort:** Reduce cognitive load and psychological stress through environmental regulation (lighting, acoustics, thermal comfort) [4].

As high-density living spaces, dormitories must simultaneously accommodate studying, resting, and cleaning activities. Their design should follow the synergistic principle of "functional zoning – behavioral flow – safety redundancy."

2.2 Ergonomic Design Standards and Existing Conflicts in the Four Zones

2.2.1 Desk System

(1) **Scale Fit:** Desktop depth should be ≥60 cm; however, surveyed university desks are typically 50–55 cm, causing spatial conflict rates exceeding 78% between computers and textbooks. Knee-clearance height should be ≥65 cm, yet most designs provide only 60–62 cm, forcing users to extend legs forward and inducing lumbar compensation.

(2) **Functional Integration Deficiencies:** Bookshelf shelf heights do not account for access frequency of commonly used items (optimal retrieval height between shoulder and elbow, 70–110 cm); upper shelves are underutilized.

2.2.2 Corridor System

(1) **Passage Safety Standards:** Single-person passage width ≥76 cm; two-person side-by-side passage requires ≥150 cm. Under high pedestrian flow, insufficient width causes shoulder collisions.

(2) **Evacuation Vulnerabilities:** Fire codes require a 120-cm visual clearance buffer at corridor turns; however, due to protruding fire cabinets or trash bins, the blind zone often expands to 60–80 cm, delaying evacuation efficiency.

2.2.3 Bunk Bed System

(1) **Structural Safety Deficiencies:** Upper-bed guardrail effective height should be ≥38 cm (to prevent sleep-roll falls); measured values are only 18–22 cm. Step tread depth should be ≥12 cm (full foot support); iron smooth steps measure only 8 cm, increasing slip-off risk by 47%.

(2) **Spatial Oppression Perception:** Insufficient lighting under the bed, combined with the bed panel blocking overhead, creates a "visual deep-well effect," predisposing long-term users to myopia and feelings of oppression.

2.2.4 Washroom System

(1) **Interface Failure:** Sink height should follow the formula "sink height / body height = 4/9"; actual heights of 82–85 cm force users to bend >30°, exceeding cervical spine load safety thresholds.

(2) **Environmental Risk Chain:** Floor slip resistance coefficient R < 9 (safe standard R ≥ 13); insufficient drain density leads to standing water and increased slip accident correlation [5].

2.3 Research Gaps and Theoretical Entry Point of This Study

Existing studies exhibit three limitations:

(1) **Lack of Localized Data:** Most directly cite Western anthropometric data, neglecting the distinctiveness of Chinese student populations (e.g., height distribution, behavioral habits).

(2) **Neglect of Systemic Coupling:** Fail to quantify cross-zonal interaction risks such as desk-bed spatial compression and corridor-washroom wet-area spread.

(3) **Implementation Feasibility Gap:** Propose structural renovations (e.g., wall removal) without assessing implementation costs or student tolerance thresholds.

Section 3: Current Status Survey and Problem Identification

3.1 Survey Methods and Limitations

Basic dimensional measurements and non-intrusive behavioral observations were employed:

Measurement Tools: Tape measure, ruler.

Sample Scope: One typical four-person room in Building 20.

3.2 Measured Data vs. Standards in the Four Zones

3.2.1 Desk System

Measurement Item	Measured Data	Ergonomic Standard	Deviation
Desktop depth	52.3 ± 1.2 cm	≥60 cm	–7.7 cm
Knee-clearance height	61.5 ± 0.8 cm	≥65 cm	–3.5 cm
Under-desk legroom depth	45.2 ± 2.1 cm	≥50 cm	–4.8 cm

Behavioral Observations: 78% of students had to place laptops sideways to accommodate A4-sized textbooks; elbows were suspended above the desktop while writing. Insufficient knee clearance forced students >175 cm tall to extend legs diagonally, with lumbar forward flexion exceeding 25° (measured by goniometer).

3.2.2 Corridor System

Measurement Item	Measured Data	Safety Standard	Conflict Scenario
Turning clearance buffer	68 ± 5 cm	≥120 cm	Trash bin placement

Behavioral Observations: Notable congestion occurred at corridor turns during peak class-change periods.

3.2.3 Bunk Bed System

Measurement Item	Measured Data	Safety Standard	Risk Value
Upper-bed guardrail height	20.1 ± 0.5 cm	≥38 cm	–17.9 cm
Step tread depth	7.8 ± 0.3 cm	≥12 cm	–4.2 cm

Behavioral Observations: Students climbing to upper beds gripped the top of the guardrail, with wrist dorsiflexion >70°. The under-bed study area created a visually oppressive zone, with average continuous study sessions lasting <45 minutes.

3.2.4 Washroom System

Measurement Item	Measured Data	Ergonomic Standard	Problem Manifestation
Sink height	83.5 ± 1.0 cm	For height 1678 mm, optimal = 755 mm	+8.5 cm deviation

Behavioral Observations: Bending angle during washing exceeded 30° (goniometer measurement), exceeding cervical load safety thresholds. Drainage system deficiencies resulted in standing water accumulation.

3.3 Summary of Key Problems

Cross-validation of measurements and observations reveals four human-machine conflict chains:

(1) **Desk-Body Compensation Chain:** Shallow desktop → equipment stacking → elbow suspension → lumbar forward flexion.

(2) **Corridor-Trash Diffusion Chain:** Trash bin placement → spatial compression → avoidance maneuvers → turn congestion.

(3) **Bed-Visual Oppression Chain:** Low illuminance + overhead panel → visual fatigue → study interruption.

(4) **Washroom-Joint Load Chain:** Excessive counter height → bending while washing → cervical hyperflexion → muscle strain.

Section 4: Ergonomic Analysis and Evaluation

4.1 Desk System: Scale Mismatch and Behavioral Compensation

4.1.1 Core Problems

(1) **Insufficient Desktop Depth:** Causes excessive spatial conflict among learning devices, forcing elbow suspension—violating the "horizontal working area" principle.

(2) **Inadequate Knee-Clearance Height:** Sitting knee height forces students to extend legs diagonally, with lumbar forward flexion >25°, potentially leading to long-term scoliosis risk.

4.1.2 Root Causes of Design Deficiencies

(1) **Lack of Functional Integration:** Upper bookshelf shelves are underutilized; frequently used textbooks are stored outside the shoulder-elbow comfort zone, requiring frequent tiptoeing or bending.

(2) **Conflict between Storage and Study Spaces:** The desk serves dual purposes of storage and study, reducing effective working area—violating the "functional zoning" principle.

4.2 Corridor System: Passage Safety and Evacuation Hazards

4.2.1 Key Conflicts

Turning buffer space encroachment violates the evacuation corridor requirements of the Architectural Design Code for Dormitories, creating bottlenecks during emergency egress.

4.2.2 Systemic Issues

Intersecting Traffic Flows: Trash bin accumulation overlaps with peak pedestrian traffic, further degrading passage efficiency.

4.3 Bunk Bed System: Safety Protection and Physiological Pressure

4.3.1 Human-Machine Fit Failure

Guardrail effective height deviation of –17.9 cm increases fall-risk probability; step tread depth deviation of –4.2 cm results in insufficient foot support.

4.3.2 Psychophysical Dual Pressure

Deep-Well Spatial Effect: Distance from bed panel to desktop is only 112 cm; combined with insufficient illuminance, this creates a perceptually oppressive zone.

Excessive Joint Load: Wrist dorsiflexion during climbing exceeds 70°, potentially leading to carpal tunnel syndrome over time.

4.4 Washroom System: Operational Failure and Environmental Risks

4.4.1 Interface Design Malfunctions

(1) Sink height is inappropriate.

(2) Bending angle during washing exceeds 30°, surpassing cervical load safety thresholds.

4.5 Cross-Zonal Systemic Coupling Effects

Problems across the four zones are strongly interconnected, forming a mutually reinforcing risk chain:

(1) **Desk-Bed Oppression Chain:** Shallow desktop → equipment stacking → elbow suspension → lumbar compensation → plus low under-bed illuminance → accelerated visual fatigue.

(2) **Washroom-Corridor Diffusion Chain:** Excessive sink height → prolonged washing times → peak-hour congregation → corridor avoidance → turn congestion → hampered emergency evacuation.

Design Philosophy Critique: Current dormitory design remains at the "meeting basic functions" stage, neglecting behavioral flow coupling and failing to implement the core ergonomic principle of "human-machine-environment system synergy."

4.6 Summary of Critical Problems

Zone	Core Conflict	Ergonomic Principle Violated	Potential Consequences
Desk	Insufficient depth/knee clearance	Working-area theory, sitting biomechanics	Musculoskeletal disorders
Corridor	Abrupt width changes	Evacuation dynamics, traffic planning	Falls/trampling risks
Bed	Guardrail/step size reductions	Fall-protection criteria, climbing ergonomics	Fall injuries + psychological oppression
Washroom	Height + drainage failure	Interface fit, environmental safety standards	Joint strain + slip accidents

Improvement Direction: Redesign logic from three aspects—scale adaptation, safety redundancy, and systemic decoupling. Specific proposals are elaborated in Section 5.

Section 5: Optimization Recommendations and Discussion

5.1 Basis for Recommendations

Based on core ergonomic principles and identified problems, referencing the following standards:

Spatial Dimensions: Architectural Design Code for Dormitories and anthropometric percentiles.

Safety Redundancy: Guardrail height, step depth, etc., per Furniture Mechanical Safety Standards.

5.2 Specific Optimization Measures

(1) Desk System:

Desk Functional Zoning: Install detachable dividers to separate equipment and writing areas, alleviating equipment stacking conflicts.

Power Outlet Optimization: Add wall-mounted cantilever socket racks to eliminate cable tangling.

(2) Corridor System:

Traffic Management: Prohibit trash bin placement in turning buffer zones during peak hours to ensure passage efficiency.

(3) Bed System:

Step Anti-Slip Retrofitting: Apply anti-slip tape to existing iron steps to enhance foot friction.

Illuminance Compensation: Install magnetic-mount LED light strips above the desk to mitigate the "deep-well visual effect" [2].

(4) Washroom System:

Mirror Height Adjustment: Add adjustable angle brackets at the bottom edge of the mirror.

Drainage Management: Implement a "one faucet, one drain" accountability system [1].

Section 6: Conclusions and Future Outlook

6.1 Research Conclusions

Through basic dimensional measurements and behavioral observations, this study systematically reveals human-fit deficiencies in four core dormitory zones on our campus:

(1) **Desk System:** Desktop depth and knee-clearance height are significantly below ergonomic standards, forcing students to adopt compensatory postures (elbow suspension, lumbar forward flexion), forming a vicious cycle of "equipment stacking → joint overload."

(2) **Corridor System:** Turning buffer space is encroached upon, causing peak-morning congestion risks.

(3) **Bed System:** Guardrail height and step tread depth fall below safety thresholds; under-bed illuminance is low, constituting dual threats of "fall hazard + visual oppression."

(4) **Washroom System:** Counter height exceeds the adaptive value; mirror bottom edge does not accommodate shorter users; insufficient drains lead to high standing-water coverage, forming a risk chain of "bending while washing → cervical hyperflexion → slip on wet floor."

These problems expose the fundamental contradiction of "prioritizing function over fit, and individual units over system integration" in current dormitory design. Human factors engineering principles must be deeply embedded into spatial renovation.

As a high-frequency "second learning space" for students, dormitory design must evolve from "survival-oriented" to "development-oriented." Only by taking ergonomics as the guiding framework and implementing systematic interventions—"scale correction, safety redundancy, and behavioral flow optimization"—can the educational essence of "space-empowered development" be truly realized.

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Appendices

Figure 1 – Washroom

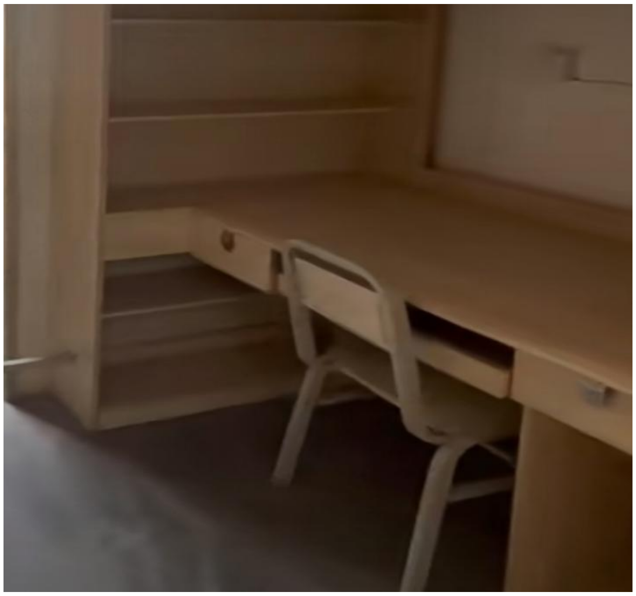

Figure 2 – Desk

Figure 3 – Corridor

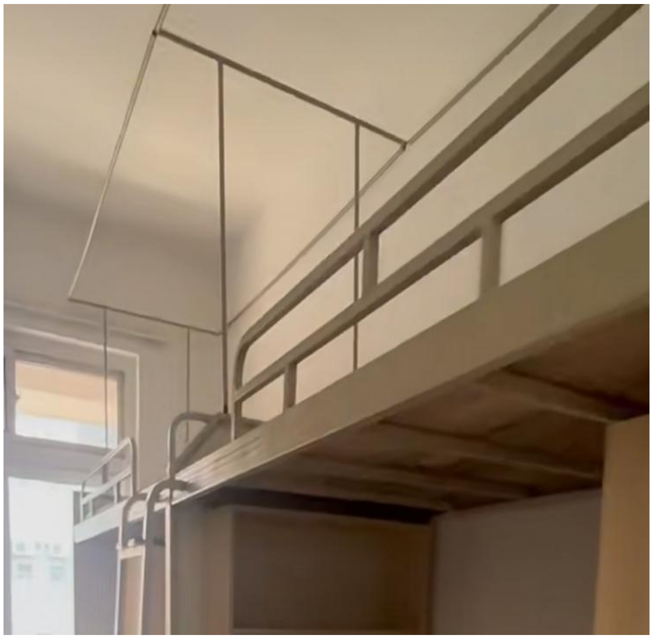

Figure 4 – Bunk Bed