# Anthropometric Mismatch in Indian Classroom Bench Desk Furniture: A Cross-Sectional Study of Seat Depth, Seat Height, and Desk Height Among Secondary School Students in Ahmedabad

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**Abstract:** ***The discrepancy between the furniture in classrooms and the dimensions of the students is well known around the world, but there is very little empirical data available regarding the combined bench-and-desk type of furniture commonly found in Indian schools, particularly with respect to seat depth. In this study we aimed to calculate mismatch indices (MI) for seat height, desk height, and seat depth between Grade 8 and Grade 9 students and the seven bench-desk units used at a private school in Ahmedabad, India, and also to obtain the students' own assessments of their postural comfort by means of a structured questionnaire. A cross-sectional study was carried out at School S01 in Ahmedabad. Anthropometric measurements were taken for eleven dimensions in a group of 38 students (20 in Grade 8 and 18 in Grade 9; mean age 13.7 ± 0.7 years), and the seven bench-desk units were measured across 31 variables. Mismatch indices were calculated for seat height, desk height, and seat depth, and the under-desk clearance was checked to see whether it met the minimum thigh-clearance requirement (thigh thickness plus 20 mm). The seat height mismatch indices varied from −9.9% to +13.0%, and overall 72% of the student-bench combinations were mismatched. The desk height mismatch indices ranged from +3.7% to +16.4% (76% of the combinations were mismatched). Every single pairing was found to have a mismatch in seat depth: all seven benches (240–256 mm) were considerably below the recommended minimum of 335 mm. Although the under-desk clearance was physically adequate for all students, 92% of them said that they felt they had too little leg room, a situation which 84% of the students attributed to the storage of their schoolbags under the desk. The results from the questionnaire closely matched the physical measurements: 79% of the students reported having no back support, 87% described sitting in a non-neutral posture, and 82% said that discomfort began after 45 minutes. To our knowledge this is the first study to have quantified the seat depth mismatch in Indian classroom furniture using a mismatch-index method, and it shows that seat depth is a universal deficiency which has hitherto remained largely unmeasured. The results provide empirical support for revising BIS IS 4837 and also offer a field-tested protocol for the larger multi-school study which is now being planned.***

**Keywords:** School furniture; ergonomics; anthropometry; mismatch index; bench–desk; seat depth; India

## 1. Introduction

For most school-aged children, the classroom bench–desk is where the school day happens: children spend about 80–90% of their academic time seated at one (Baharampour et al., 2013). How well that furniture fits the body sitting in it is not a cosmetic concern. A large international literature links poor furniture–body fit to musculoskeletal discomfort, postural deviation, and reduced attentiveness in class (Parcells, Stommel, & Hubbard, 1999; Murphy et al., 2004; Gouvali & Boudolos, 2006; Dianat et al., 2013; Castellucci et al., 2016; Arefi et al., 2020).

The methodology in this area originally comes from Parcells et al. (1999), who first proposed the percentage-mismatch (MI) method, a formulation that is still employed in the field to decide whether a piece of furniture matches or does not match a body. However, later research has somewhat complicated this situation: Castellucci, Arezes, and Molenbroek (2015) discovered a great deal of inconsistency in the way various research groups set the acceptable mismatch range for a particular dimension, and Bravo, Bragança, Arezes, Molenbroek, and Castellucci (2018) noted that the accuracy, precision, and reliability of the anthropometric measurement procedures underlying the studies are not consistently reported. Despite this variation in method, the general conclusion that classroom furniture is often designed for a type of student body that does not actually exist has been remarkably consistent in different settings: high mismatch rates have been recorded in primary schools in Greece (Panagiotopoulou et al., 2004), in primary schools in Hong Kong (Chung & Wong, 2007), in Bahrain (Mokdad & Al-Ansari, 2009), in Iranian secondary schools (Dianat et al., 2013), in Australian schools (Milanese & Grimmer, 2004), in Slovenian secondary schools (Podreka, Kastelic, Burnard, & Šarabon, 2021), in middle and university classrooms in Turkey (Kahya, 2018; Satır & Erdoğan, 2021), in Ghanaian and Nigerian schools (Boampong, Effah, & Dadzie, 2015; Fidelis, Ogunlade, & Adelakun, 2020; Fidelis & Ogunlade, 2022), and in primary schools in Brazil (Batistão et al., 2012). In Lagos, Aiyegbusi, Gbiri, Oyeniran, and Balogun (2023) took it a step further by connecting the mismatch between furniture and anthropometric data to objectively measured spinal curvature deformities in secondary-school students this being one of the rare studies in the field to associate a mismatch with a clinically assessed outcome rather than just self-reported discomfort.

In India classroom furniture is generally in the form of a combined bench and desk unit, consisting of one fixed and non-adjustable piece which includes the seat, the writing surface and a storage shelf below it. The furniture is in theory regulated by the Bureau of Indian Standards specification IS 4837, this specification dividing the furniture into five size categories (A to E) according to student height and is based on the principles of the Indian anthropometric reference dataset compiled by Chakrabarti in 1997. In reality, however, an increasing amount of evidence indicates that the standard's specifications have not kept up with the anthropometric characteristics of today's Indian students (Salunke et al., 2015; Taifa & Desai, 2016).

Although the body of evidence from India is smaller than the international one, it presents a coherent account. Savanur, Altekar and De (2007) looked at the furniture in Indian schools and suggested revised dimensions for seats and tables after they found that there was widespread non-conformity with the measurements of the students. Chaudhary, Sharma, Grover and Nainwal in 2004 noted a similar discrepancy in the schools of Pantnagar, and Khaspuri, Sau and Dhara in 2007 looked at the anthropometric basis for the design of school furniture in rural areas. In 2009 Dhara, Khaspuri and Sau carried out this study on 621 rural secondary schoolboys in West Bengal and connected the faulty furniture directly to the musculoskeletal complaints that the boys reported during classwork. At the tertiary level, Qutubuddin, Hebbal, and Kumar (2013) and Aravind and Ilangkumaran (2019) each found comparable mismatch in engineering-college furniture. None of these studies, however, appears to have quantified seat depth specifically using a mismatch-index approach a gap this study addresses directly.

A structured narrative review conducted earlier in this doctoral research programme identified four recurring problems with the Indian bench–desk typology: seat heights that sit at or above the upper end of students' popliteal height distributions; desk heights that consistently run oversized relative to seated elbow height; seat depths that are plausibly too shallow relative to buttock–popliteal length; and a storage–clearance conflict created by the integrated under-desk shelf. That review also flagged something more basic: there was simply very little empirical Indian data to confirm or refute any of this.

The present study is a first attempt to close that gap, through a cross-sectional investigation at a single private secondary school in Ahmedabad, Gujarat. Specifically, we set out to:

1) Characterise the anthropometric profile (11 dimensions) of Grade 8 and 9 students at School S01;
2) Document the dimensional characteristics of the seven bench–desk units currently in use;
3) Compute and interpret mismatch indices for seat height, desk height, and seat depth for each student–bench pairing;
4) Assess whether under-desk clearance is adequate relative to students' thigh thickness;
5) Record students' self-reported postural experience and discomfort patterns;
6) Evaluate how well the furniture complies with BIS IS 4837 given this sample's stature profile; and
7) Validate a measurement protocol ahead of the planned multi-school study.

## 2. Methods

### 2.1 Study Design and Setting

We conducted a cross-sectional descriptive study at School S01, a private co-educational secondary school in Ahmedabad, Gujarat, during the 2024–25 academic year. We purposely selected the school as representative of the private-school typology that accounts for most secondary enrolment in urban Gujarat and uses the combined bench–desk furniture characteristic of Indian private classrooms. Two classrooms were included: C01 (Grade 8) and C02 (Grade 9). The necessary ethical approval was secured from the Institutional Committee at GLS University in Ahmedabad, and written information was acquired from the school authorities with the consent of each participant being obtained from the students before the data collection process started.

### 2.2 Participants

All the students who were there on the day when the data was collected were eligible, but those who had a musculoskeletal condition, a recent injury, or a physical disability which would have affected the anthropometric measurements were excluded. Of the 88 students who had been enrolled in the two classes, 38 met the inclusion criteria (20 in Grade 8; 18 in Grade 9; 20 males; 18 females; mean age 13.7 ± 0.7 years, age range 13 to 15 years).

### 2.3 Furniture Measurement

Seven bench–desk units were systematically measured across 31 dimensional variables using a calibrated steel measuring tape and a digital vernier calliper (accuracy ±0.5 mm). Variables recorded included seat height, seat depth (front, mid, rear), seat width, seat thickness, desk height, desk length, desk depth (front, mid, rear), desk thickness, desk–bench distance, desk tilt angle, under-desk clearance, backrest height, backrest angle, backrest width, bench length, bag-shelf height, bag-shelf depth, footrest height, seat material, frame material, and edge profile. Under-desk clearance was defined as the vertical distance from the seat surface to the lowest obstruction beneath the desk, either the desk underside or the bag shelf.

### 2.4 Anthropometric Measurement

For each student, eleven anthropometric dimensions were obtained using procedures in accordance with ISO 7250-1:2017. All measurements were taken with the student sitting in a height-adjustable measurement chair, set to a knee and hip flexion angle of 90°, without shoes, and in the standard anatomical position. The dimensions recorded were standing height, standing shoulder height, sitting height, seated eye height, seated shoulder height, elbow height sitting (EHS), shoulder breadth, popliteal height (PH), buttock–popliteal length (BPL), hip width (HW), and thigh thickness (TT). One trained researcher carried out every measurement to eliminate inter-rater variability.

### 2.5 Student Questionnaire

Right after the anthropometric measurements, every student filled out a structured questionnaire consisting of 16 items. The questionnaire had been developed in English and then translated into Gujarati, and both the English and Gujarati versions were tried out with five students who were not part of the study sample. The questions addressed postural comfort (including whether the feet touched the floor, leg comfort, knee pressure, back support, bench width, and seat comfort), task-specific comfort (such as elbow comfort, arm and shoulder comfort, and writing comfort; as well as the perception of desk height), the ergonomic environment (including leg space, interference caused by the schoolbag, and where the bags are kept), and the experience of discomfort (namely when the discomfort started, the sitting posture, how frequently the posture changed, and the feeling of fatigue during mathematics and science lessons). The ways in which the answers were obtained included yes/no questions, a 5-point ordinal scale going from Very Comfortable to Very Uncomfortable, and multiple-choice questions.

### 2.6 Mismatch Index Calculation

For each combination of student and bench we used the formula given by Parcells et al. (1999) to calculate the mismatch index (MI) along three main dimensions:
MI (%) = [(Furniture Dimension − Anthropometric Reference) / Anthropometric Reference] × 100

The standard used for MI_SH was popliteal height; for MI_DH it was the sum of seat height and elbow height when sitting, this sum representing the ideal desk height; for MI_SD the standard was buttock to popliteal length. A pairing was regarded as an acceptable match if |MI| was 5% or less, as stated by Parcells et al. (1999) and Arefi et al. (2020). Seat-depth adequacy was examined separately by referring to the recommended range of 80 to 95% of BPL (Castellucci et al., 2010). The under-desk clearance was checked against the minimum requirement of thigh thickness plus 20 mm (Salunke et al., 2015).

### 2.7 BIS IS 4837 Compliance Assessment

We determined the correct IS 4837 size category for the sample based on the mean standing height of 1597 mm, which falls within Size D (stature range 1500 to 1700 mm). Next, we calculated the MI between the IS 4837 Size D recommended seat height (400 mm) and the sample's mean popliteal height.

### 2.8 Statistical Analysis

The mean, standard deviation, 5th, 25th, 50th, 75th and 95th percentiles, together with the minimum and maximum values, were calculated for all the anthropometric variables using Python 3.12 (with scipy 1.11 and pandas 2.0). Mann–Whitney U tests were carried out to compare the anthropometric dimensions between Grade 8 and Grade 9, as well as between the male and female subgroups (using a significance level of 0.05). The questionnaire responses were presented as frequencies and percentages.

## 3. Results

### 3.1 Sample Anthropometric Profile

Table 1 gives descriptive anthropometric statistics for the full sample. Popliteal height ranged from 361 to 620 mm a 259 mm spread within a single school with a mean of 467.2 ± 62.3 mm and a 5th–95th percentile range of 405–603 mm. Buttock–popliteal length ranged from 320 to 540 mm (mean 440.2 ± 46.5 mm), and thigh thickness ranged from 100 to 200 mm (mean 144.8 ± 26.0 mm). Mean standing height was 1597.1 ± 87.4 mm, placing most of the sample within the BIS IS 4837 Size D category (stature 1500–1700 mm).

**Table 1:** Descriptive Anthropometric Statistics for the Study Sample (n = 38, School S01, Ahmedabad)

| Dimension (mm) | n | Mean | SD | 5th %ile | 25th %ile | Median | 75th %ile | 95th %ile |
|---|---|---|---|---|---|---|---|---|
| Standing Height | 38 | 1597.1 | 87.4 | 1478 | 1540 | 1589 | 1658 | 1750 |
| Shoulder Height | 38 | 1305.7 | 142.8 | 1202 | 1270 | 1328 | 1370 | 1458 |
| Sitting Height | 38 | 844.3 | 113.1 | 738 | 794 | 821 | 854 | 977 |
| Elbow Height Sitting (EHS) | 38 | 225 | 41.9 | 169 | 191 | 215 | 250 | 310 |
| Popliteal Height (PH) | 38 | 467.2 | 62.3 | 405 | 420 | 452 | 490 | 603 |
| Buttock–Popliteal Length (BPL) | 38 | 440.2 | 46.5 | 384 | 410 | 438 | 478 | 522 |
| Thigh Thickness (TT) | 38 | 144.8 | 26 | 109 | 122 | 142 | 160 | 180 |
| Hip Width (HW) | 38 | 348.1 | 53.1 | 277 | 321 | 340 | 370 | 407 |

SD = standard deviation. All dimensions in millimetres. PH = popliteal height; BPL = buttock–popliteal length; TT = thigh thickness; HW = hip width; EHS = elbow height sitting. Measured per ISO 7250-1:2017.

Table 2 compares these dimensions by grade and by gender. None of the differences reached significance at $\alpha = 0.05$. Elbow height came closest to a grade effect (Grade 8: 239.0 ± 47.5 mm vs Grade 9: 209.4 ± 28.4 mm; $U = 246$, $p = 0.057$), and thigh thickness came closest to a gender effect (male: 152.4 ± 26.4 mm vs female: 136.3 ± 23.4 mm; $U = 242$, $p = 0.069$). The absence of a significant PH difference by grade ($p = 0.639$) or gender ($p = 0.124$) should be read with the sample size in mind, a study this small is simply not well powered to detect modest subgroup differences.

**Table 2:** Anthropometric Comparison by Grade and Gender (Mann–Whitney U Test, n = 38)

| Dimension (mm) | Grade 8 Mean±SD (n=20) | Grade 9 Mean±SD (n=18) | p | Male Mean±SD (n=20) | Female Mean±SD (n=18) | p | Sig. |
|---|---|---|---|---|---|---|---|
| Popliteal Height | 479.1±73.9 | 454.1±44.8 | 0.639 | 473.0±43.9 | 460.8±78.9 | 0.124 | ns |
| Buttock–Popliteal Length | 437.4±52.8 | 443.3±39.6 | 0.608 | 445.6±52.2 | 434.2±39.7 | 0.326 | ns |
| Elbow Height | 239.0±47.5 | 209.4±28.4 | 0.057† | 219.5±39.5 | 231.1±44.7 | 0.501 | ns |
| Thigh Thickness | 139.0±29.2 | 151.2±20.9 | 0.163 | 152.4±26.4 | 136.3±23.4 | 0.069† | ns |
| Hip Width | 345.6±67.8 | 350.8±31.4 | 0.395 | 335.9±44.4 | 361.6±59.8 | 0.173 | ns |

ns = not significant ($p > 0.05$). † = borderline ($0.05 < p < 0.10$). Mann–Whitney U test (two-sided). All dimensions in millimetres.

### 3.2 Bench–Desk Furniture Dimensions

Table 3 gives the dimensional characteristics of the seven bench–desk units, all of which had wood seating/writing surfaces on metal or wood frames. Seat heights ranged narrowly from 454 to 513 mm, and desk heights from 725 to 838 mm. Seat depth was tightly clustered at 240–256 mm across every bench in the school. Only three of the seven benches (B02, B05, B06) had any backrest at all; the other four had none. Bag-shelf height above seat level ranged from 97 to 143 mm.

**Table 3:** Dimensional Characteristics of Seven Bench–Desk Units at School S01

| Bench | Grade | SH (mm) | DH (mm) | SD (mm) | UDC (mm) | Bag Shelf (mm) | Backrest (mm) | n Users |
|---|---|---|---|---|---|---|---|---|
| B01 | 8 | 456 | 761 | 251 | 557 | 143 | None | 7 |
| B02 | 8 | 454 | 800 | 247 | 608 | 114 | 783 | 7 |
| B03 | 8 | 455 | 748 | 245 | 575 | 130 | None | 4 |
| B04 | 8 & 9 | 456 | 762 | 256 | 562 | 110 | None | 8 |
| B05 | 9 | 513 | 838 | 249 | 600 | 97 | 209 | 3 |
| B06 | 9 | 494 | 725 | 240 | 619 | 104 | 211 | 9 |
| Range | | 454–513 | 725–838 | 240–256 | 557–619 | 97–143 | 0–783 | 3–9 |

SH = seat height; DH = desk height; SD = seat depth (mid-point); UDC = under-desk clearance (vertical, from seat surface to lowest obstruction); backrest = height above seat surface (None = absent). B04 was used in both C01 and C02. All dimensions in millimetres.

### 3.3 Mismatch Index Analysis

Table 4 presents the mismatch index results for seat height and desk height, along with the assessment of seat-depth adequacy.

**Table 4:** Mismatch Index Results for Seat Height, Desk Height, and Seat Depth by Bench

| Bench | n | MI_SH Mean±SD (%) | MI_SH Range (%) | % Mismatched SH (\|MI\|>5%) | MI_DH Mean±SD (%) | % Mismatched DH (\|MI\|>5%) | SD: % Too Shallow |
|---|---|---|---|---|---|---|---|
| B01 | 7 | +2.6±6.0 | −7 to +11 | 43% | +16.4±5.9 | 100% | 100% |
| B02 | 7 | −9.9±12.1 | −24 to +8 | 100% | +11.2±7.6 | 57% | 100% |
| B03 | 4 | +10.9±4.1 | +8 to +17 | 100% | +8.4±5.1 | 75% | 100% |
| B04 | 8 | −6.6±13.3 | −26 to +6 | 62% | +13.2±6.9 | 75% | 100% |
| B05 | 3 | +7.0±3.9 | +5 to +12 | 33% | +11.1±6.2 | 100% | 100% |
| B06 | 9 | +13.0±13.9 | −12 to +37 | 89% | +3.7±2.6 | 33% | 100% |
| Overall | 38 | +0.6±13.8 | −26 to +37 | 72% | +10.9±6.8 | 76% | 100% |

$MI\_SH = (SH - PH)/PH \times 100$; $MI\_DH = (DH - [SH+EHS])/(SH+EHS) \times 100$. Acceptable match: $|MI| \leq 5\%$ (Parcells et al., 1999). Seat-depth adequacy assessed against 80–95% of BPL: every bench (SD 240–256 mm) fell below the minimum recommended value (335 mm) for every student who used it.

#### 3.3.1 Seat Height

In total, 72 per cent of the student–bench combinations went beyond the |MI| greater than 5 per cent threshold. The direction of the mismatch varied according to the bench the student was sitting at: benches B02 and B04 showed a tendency towards a negative MI (with seat height below the ideal popliteal-height match), whereas benches B03, B05 and B06 showed a positive tendency (with seat height above the ideal). The bench B06 had by far the largest range (from −12 per cent to +37 per cent), this being due to the fact that the group of students using that particular bench was highly anthropometrically diverse.

#### 3.3.2 Desk Height

Desk height mismatch was uniformly oversized: mean MI_DH ranged from +3.7% (B06) to +16.4% (B01) across five of the six bench types, and B01 and B05 were mismatched for every student who used them. Overall, 76% of student–bench pairings were mismatched on desk height.

#### 3.3.3 Seat Depth: A Universal Mismatch

Seat depth was mismatched for every student on every bench. All seven bench seat depths (240–256 mm) fell well below the minimum recommended for this sample (80% of BPL, i.e. 335–353 mm depending on the student), so no student–bench pairing met the seat-depth criterion. To our knowledge, no prior Indian study has quantified seat-depth mismatch using the |MI| criterion, making this 100% mismatch rate a new addition to the evidence base and a marker of a systematic design deficiency.

#### 3.3.4 Under-Desk Clearance

Under-desk clearance (557–619 mm) was physically adequate for every student on every bench, exceeding the minimum requirement of thigh thickness + 20 mm (120–220 mm). This is at odds with earlier qualitative reports of UDC deficiency in Indian bench–desk units (Salunke et al., 2015), and likely reflects a configuration particular to this school's furniture. The gap between adequate physical clearance and the 92% of students who nonetheless felt cramped is examined in Section 4.

### 3.4 Questionnaire Results

**Table 5:** Student Questionnaire Responses (n = 38)

| Questionnaire Item | Key Response | Interpretation |
|---|---|---|
| Leg comfort during prolonged sitting | No: 68% | Majority report leg discomfort which is consistent with the seat-depth mismatch and poor thigh support |
| Pressure or pain behind knees | Yes: 53% | Posterior knee pressure consistent with a shallow seat depth forcing front-edge contact |
| Backrest supports back | No: 79% | 4 of 7 benches had no backrest at all; those present sat at non-ergonomic heights |
| Bench width sufficient for both occupants | No: 87% | Shared bench configuration provides insufficient lateral space, consistent with the hip-width data |
| Seat surface uncomfortable | Yes: 63% | Discomfort may relate to shallow seat depth and the absence of any seat contouring |
| Arm/shoulder comfort during extended writing | Uncomfortable / Very Uncomfortable: 58% | Consistent with the positive desk-height mismatch (+10.9% overall), which forces shoulder elevation |
| Desk height perception | Too Low: 45%; Just Right: 55% | Despite the desk being objectively oversized, 45% perceive it as too low likely a compensatory forward-lean effect |
| Sufficient leg space under desk | No: 92% | Near-universal, despite physically adequate clearance; driven by schoolbag storage (see below) |
| Bag disturbs leg space / posture | Yes: 84% | Main driver of perceived leg-space insufficiency; 26% store their bag directly under the desk |
| Tiredness / restlessness during class | Yes: 71% | Consistent with sustained non-neutral postures imposed by mismatch across several dimensions at once |
| Discomfort onset | <15 min: 8%; 15–30 min: 39%; 30–45 min: 34%; >45 min: 18% | 82% report onset within 45 minutes; 47% within just 30 minutes |
| Sitting posture (self-report) | Lean fwd: 55%; Slouch: 32%; Straight: 13% | 87% adopt a non-neutral posture as their default sitting behaviour |
| Foot posture (researcher observation) | Flat: 71%; Crossed: 18%; Dangling: 11% | 29% adopt an alternative foot position, consistent with seat-height mismatch |

## 4. Discussion

### 4.1 Principal Findings

This study documents substantial, multidimensional anthropometric mismatch between Grade 8 and 9 students and the bench–desk furniture at a private school in Ahmedabad. Three results stand out.

First, seat-depth mismatch was universal: 100% of students–bench pairings across all seven benches. Every bench's seat depth (240–256 mm) fell far short of the recommended 80–95% of the BPL range (335–436 mm for this sample). To our knowledge, this has not been quantified using an MI approach in an Indian-context study. The practical consequence of a systematically shallow seat is that students either perch at the front edge losing lumbar support and increasing spinal load or sit further back and take pressure on the back of the knee from the seat edge itself. The 53% who reported posterior knee pain fit the latter pattern closely. Notably, BIS IS 4837 does not specify seat depth, which is a clear gap in the standard.

Second, the desk-height mismatch was considerable: it amounted to 76% overall, with a uniformly positive MI of +3.7% to +16.4%. This means the sample lies toward the higher end of the international range for desk-height mismatch, as reported by Parcells et al. (1999) and Baharampour et al. (2013). The fact that 58% of people reported experiencing arm and shoulder discomfort when writing for a long time, along with the 55% who leaned forward while writing, is in line with what one would expect from a prolonged positive desk-height mismatch that is, either shoulder elevation or a compensatory forward lean of the trunk.

Third, the questionnaire surfaced a real discrepancy between measured under-desk clearance (physically adequate for every student) and perceived leg space (insufficient for 92% of them). Schoolbag storage explains most of that gap: 84% reported bag interference, and 26% store their bag directly under the desk, which functionally reduces the usable clearance in a way that a static furniture measurement simply does not capture. That is a useful methodological lesson in its own right; a physical UDC measurement alone does not represent what students actually experience during class, and future studies would do well to measure clearance both with and without a bag in place.

### 4.2 A comparison with earlier studies

The 72% overall seat-height mismatch rate found here sits well within the international range of 65–95% reported elsewhere (Table 6), and is notably less extreme than the 93–


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100% mismatch reported for Hong Kong primary-school chairs (Chung & Wong, 2007).

**Table 6:** Seat-Height Mismatch: Present Study vs. International Benchmarks

| Comparision | Seat-Height Mismatch (%) |
|---|---|
| Present study (Ahmedabad, India) | 72% |
| International range (multiple countries) | 65–95% |
| Hong Kong primary schools (Chung & Wong, 2007) | 93–100% (highest reported) |

International range as reported by Parcells et al. (1999), Gouvali & Boudolos (2006), Baharampour et al. (2013), and Arefi et al. (2020).

The positive direction of the desk-height mismatch also matches the pattern seen internationally, echoing the oversized-desk finding reported by Milanese and Grimmer (2004) in Australian schools.

Within India specifically, the present findings sit alongside and extend the mismatch rates reported by Savanur, Altekar, and De (2007) and by Dhara, Khaspuri, and Sau (2009), both of whom documented widespread non-conformity between Indian school furniture and student anthropometry without isolating seat depth as a distinct, quantified parameter. The present study's 100% seat-depth mismatch rate is, in that sense, a sharper and more specific finding than the broader non-conformity these earlier Indian studies described. It is also consistent with the general observation from the African literature that furniture mismatch is rarely confined to a single dimension: Aiyegbusi et al. (2023) linked multidimensional mismatch to measurable spinal deformity in Lagos secondary-school students, and Fidelis and Ogunlade (2022) argued, on the basis of mismatch found across every education level surveyed in Nigeria, for national furniture standards rather than ad hoc procurement an argument the present findings on BIS IS 4837 support independently for the Indian context.

An unexpected finding relates to the BIS standard itself; the seat height of 400 mm recommended for Size D in IS 4837 yielded an MI of −14.4% in comparison with the mean popliteal height of the sample, which is 467 mm this showing that the standard's recommendation is actually well below, not above, the height that students really need. That points to the anthropometric reference data behind IS 4837 being out of date quite possibly still anchored to the Chakrabarti (1997) dataset compiled nearly three decades ago and not reflecting the secular increase in stature among Indian schoolchildren over recent decades (Taifa & Desai, 2016). Interestingly, the seat heights actually in use at this school (454–513 mm) already run well above the IS 4837 figure, suggesting local manufacturers have quietly adjusted upward on their own, without any formal anthropometric basis for doing so.

The 100% seat-depth mismatch finding goes further than anything documented in prior Indian-context studies, and as far as we have been able to establish from the available literature further than has been reported using a comparable |MI| criterion in any of the international studies reviewed above. It establishes seat depth as a universal mismatch parameter that warrants specific inclusion both in any revision of BIS IS 4837 and in future Indian classroom-furniture ergonomics research more broadly.

### 4.3 Implications for BIS IS 4837

These findings support three concrete revisions to the standard. Seat-height recommendations should be recalibrated upward to reflect contemporary Indian popliteal-height distributions: a range of 430–470 mm would fit the 25th–75th percentile of this sample considerably better than the current 400 mm figure. A minimum seat-depth specification should be introduced; 340–380 mm (roughly 80–90% of this sample's median BPL) would accommodate most students. And a desk-depth specification adequate for a notebook and a textbook to sit open side by side should be mandated, rather than left to individual manufacturers.

### 4.4 Limitations

This study has five main limitations: it draws on a single school, limiting generalisability; the sample size (n = 38) limits statistical power for subgroup comparisons; the MI_DH calculation assumes an optimally fitted seat height, which somewhat compounds the estimate on benches where seat height is itself mismatched; the questionnaire was purpose-built for this study and has not been externally validated; and posture was captured through self-report and single point-in-time observation rather than video analysis or formal RULA/REBA scoring.

### 4.5 Protocol Validation and Future Research

A secondary aim of this study was to test-drive the measurement protocol ahead of the planned multi-school study, and it held up well: the full 31-furniture-dimension, 11-anthropometric-dimension protocol was completed within the available data-collection window. Three refinements are worth carrying forward into the larger study. Under-desk clearance should be measured both with and without a bag in place. The Nordic Musculoskeletal Questionnaire body map should supplement the custom questionnaire used here. And RULA/REBA scoring should be added for at least a subsample, to put postural risk on a more quantitative footing. The planned multi-school study will extend this protocol to at least four school types (government, aided, private, and CBSE) across Ahmedabad, aiming for n ≥ 200 to support more robust statistical comparison.

## 5. Conclusion

This study provides the first quantified mismatch-index analysis of bench–desk furniture at a private school in Ahmedabad, India. Three results carry particular weight: a 72% seat-height mismatch rate, a 76% desk-height mismatch rate, and most consequentially a universal seat-depth mismatch of 100% across all seven benches, a parameter that Indian classroom-furniture research has not previously quantified. Under-desk clearance was physically adequate throughout, yet 92% of students perceived it as insufficient, largely because of schoolbag storage, a finding with direct implications for how clearance should be measured in future work.

The questionnaire data lined up closely with the physical measurements: 71% of students reported tiredness or restlessness, 87% adopted non-neutral sitting postures, and 82% reported discomfort within 45 minutes of sitting down. The BIS IS 4837 Size D recommendation of 400 mm for seat height produced an MI of −14.4% against the sample's mean popliteal height, indicating that the standard is substantially out of step with the stature of today's Indian students.

Taken together, these findings offer empirical support for revising BIS IS 4837 particularly its seat-depth and seat-height specifications and leave behind a field-validated measurement protocol ready for the larger, more representative multi-school study that will follow.

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