# ANTHROPOMETRIC DATA FOR DESIGN OF SCHOOL FURNITURE AND FITTINGS

## Introduction

In the process of learning comfort of the learner, in furniture adapted to his body, is likely to increase his learning effectiveness. Design of correctly dimensioned furniture will require dimensions of body segments of the users. Therefore matching of furniture and fittings to the body dimensions of the users is an important issue. Studies undertaken by UNESCO Principal Regional Office for Asia and the Pacific, Bangkok have shown that badly sized furniture can affect the physical development and academic performance of students.

Body dimensions of children of both sexes, between age group of five to fourteen years, increse very rapidly. Therefore, in the design of furniture and fittings for schools, a variety of sizes would be required to cater to the needs of the children. But practically it would not be feasible to provide furniture and fittings as per specific age group in a school and hence grouping of these elements of similar sizes and the subsequent use for several age-groups would be necessary. Thus, part body measurements of the children of different age groups, for which the furniture and fittings are to be designed, are to be known.

## Design Body Dimensions

Body dimensions are the governing factors in furniture design. For example, in case of seat the lower leg measurement from the popliteus is required to fix the seat height, the upper leg measurement from the popliteus to the back of the buttock to fix the depth of the seat, the hip width and the shoulder width to fix the width of the seat. Thus the body dimensions commonly required for the design of school furniture & fittings are shown in Figure 1.
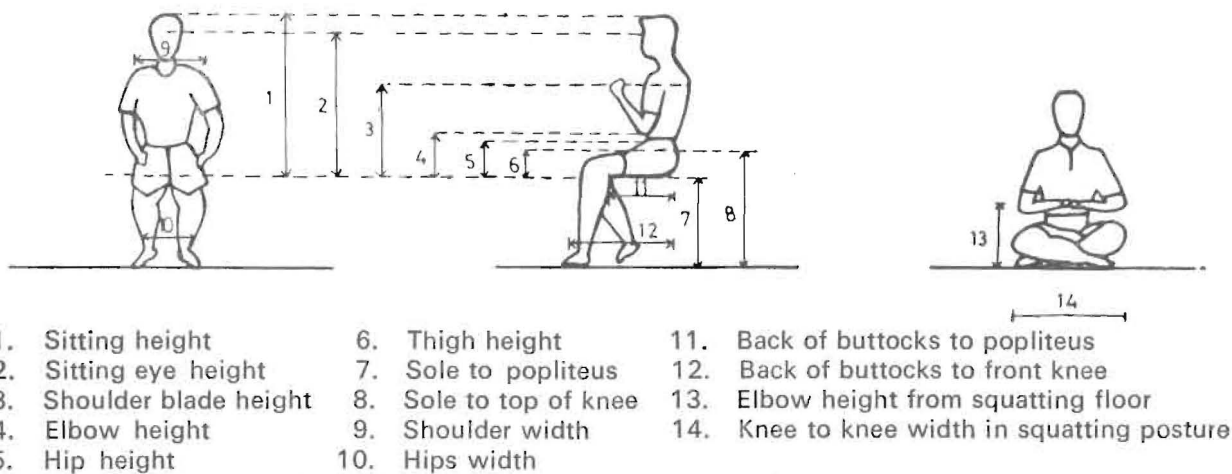


| | | |
|---|---|---|
| 1. Sitting height | 6. Thigh height | 11. Back of buttocks to popliteus |
| 2. Sitting eye height | 7. Sole to popliteus | 12. Back of buttocks to front knee |
| 3. Shoulder blade height | 8. Sole to top of knee | 13. Elbow height from squatting floor |
| 4. Elbow height | 9. Shoulder width | 14. Knee to knee width in squatting posture |
| 5. Hip height | 10. Hips width | |

Fig. 1   Body Dimensions for Design of School Furniture

## Design Standing Heights

It has been established that there is a constant ratio between part body dimensions and the standing height in any related ethnic groups. Thus, the most important dimension is standing height of the children of various age groups. Mean and design standing heights of Indian children of five to seventeen years age groups of urban and rural children of both the sexes are given in TABLE—1. Design heights have been worked out after eliminating domicile and sex factors, but the difference in height due to sex after puberty has been given due weightage.
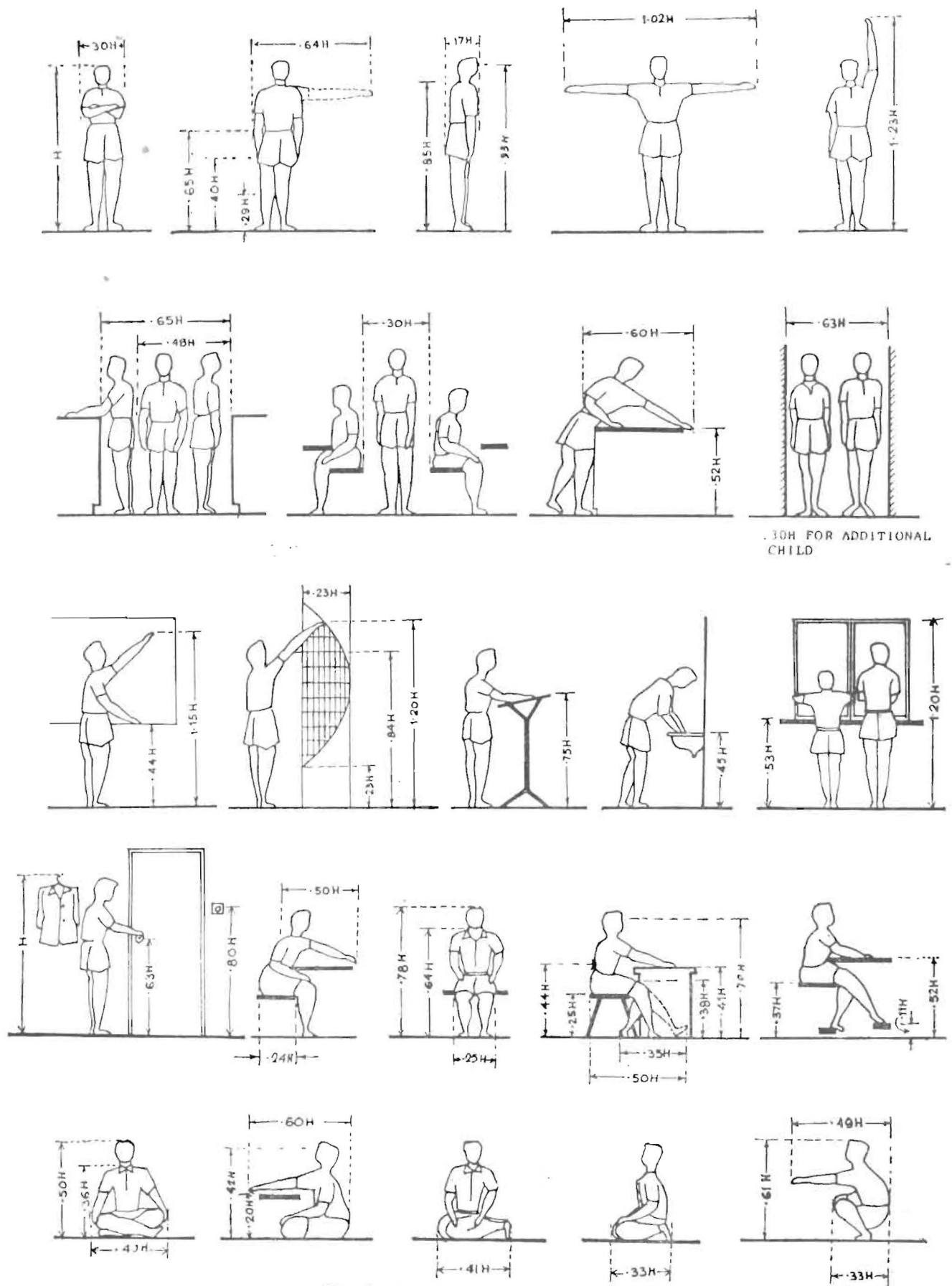
### TABLE 1 MEAN AND STANDARD DEVIATIONS FOR STANDING HEIGHTS OF INDIAN CHILDREN, AGE GROUP 5-17 YEARS

| Age in Years | Standing Height as per ICMR, New Delhi ( in mm ) | | | | | | | | Design Height for School Children* ( in mm ) | |
|---|---|---|---|---|---|---|---|---|---|---|
| | Boys | | | | Girls | | | | Boys | Girls |
| | Urban | | Rural | | Urban | | Rural | | Urban Rural | Urban Rural |
| | Mean | S.D. | Mean | S.D. | Mean | S.D. | Mean | S.D. | Mean | Mean |
| 5 | 1027 | 67 | 1011 | 63 | 1021 | 72 | 995 | 72 | 1016 | 1016 |
| 6 | 1093 | 71 | 1074 | 64 | 1080 | 92 | 1063 | 79 | 1079 | 1079 |
| 7 | 1145 | 71 | 1132 | 81 | 1133 | 82 | 1119 | 73 | 1134 | 1134 |
| 8 | 1198 | 74 | 1186 | 73 | 1187 | 80 | 1172 | 74 | 1187 | 1187 |
| 9 | 1241 | 73 | 1230 | 86 | 1234 | 80 | 1222 | 65 | 1233 | 1233 |
| 10 | 1287 | 79 | 1231 | 80 | 1291 | 85 | 1267 | 70 | 1284 | 1284 |
| 11 | 1339 | 79 | 1324 | 83 | 1344 | 99 | 1312 | 73 | 1334 | 1334 |
| 12 | 1388 | 85 | 1374 | 80 | 1398 | 89 | 1367 | 82 | 1386 | 1386 |
| 13 | 1453 | 101 | 1435 | 91 | 1445 | 97 | 1415 | 73 | 1442 | 1442 |
| 14+ | 1514 | 104 | 1483 | 91 | 1480 | 67 | 1453 | 72 | 1504 | 1474 |
| 15 | 1568 | 96 | 1531 | 91 | 1502 | 86 | 1477 | 69 | 1557 | 1496 |
| 16 | 1603 | 98 | 1575 | 88 | 1513 | 75 | 1496 | 60 | 1595 | 1510 |
| 17 | 1619 | 81 | 1604 | 76 | 1518 | 60 | 1501 | 60 | 1615 | 1515 |

*Design heights have been worked out after eliminating domicile & sex factors. Mean standing heights have been taken from Technical Report "Growth & Physical Development of Indian Infants and Children" Indian Council of Medical Research, New Delhi.
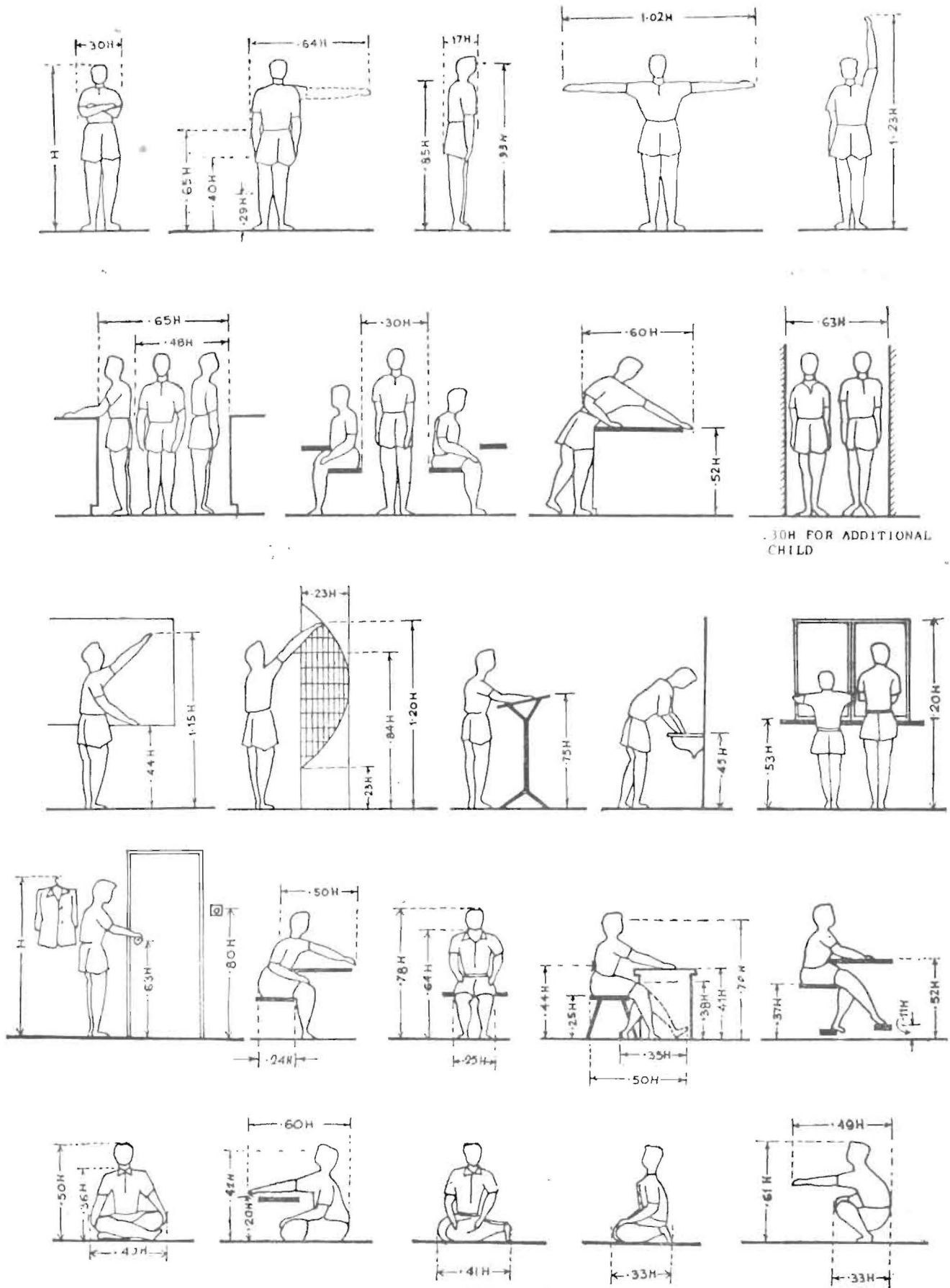
+ Puberty age for girls.

Ratio of body segments to the standing height is graphically presented in FIGURE-2 and listed in TABLE-2. Besides the conventional postures of standing and sitting, other sitting postures such as 'sideways sitting', 'sitting lotus' and 'squatting', are also incorporated.

**Fig. 2   Ratio of Body Segments**

3

**Fig. 2  Ratio of Body Segments**

3

## TABLE 2 RATIOS BETWEEN STANDING HEIGHT AND DIMENSIONS USED IN DESIGNING SCHOOL FURNITURE AND EDUCATIONAL SPACES

| Standing Posture | Ratio | Sitting Posture | Ratio |
|---|---|---|---|
| Standing height | 1.00 H | Seated height | 0.78 H |
| Eye level | 0.93 H | Seated eye level | 0.70 H |
| Depth of body–standing | 0.17 H | Elbow height | 0.41 H |
| Width of body–standing | 0.30 H | Height of seat | 0.25 H |
| Length–arms outstretched | 1.02 H | Width of seat | 0.25 H |
| Height arm vertically upright | 1.23 H | Front of knee to buttock | 0.34 H |

| Working Surface Standing | Ratio | | |
|---|---|---|---|
| | | Height of stool | 0.37 H |
| Height of work surfaces | | Width of stool | 0.20 H |
| | | Depth of stool | 0.16 H |
| General work | 0.52 H | Height of footrest | 0.11 H |
| Ironing/Planning | 0.50 H | Depth of seat | 0.24 H |
| Cooking | 0.48 H | Floor to top of thigh | 0.38 H |
| Filing metal | 0.56 H | Comfortable zone for leg movement | 0.35 H |
| Height of lecture stand | 0.75 H | Top of backrest to floor | 0.44 H |
| Forward Reach–maximum | 0.60 H | Optimum height of back rest to seat | 0.12 H |

| Vertical Surface | Ratio | Working Surface Seated | Ratio |
|---|---|---|---|
| Chalk–board | | Height of desk/table | 0.41 H |
| | | Width of desk/table | 0.40 H |
| Upper reach | 1.15 H | Reach–maximum | 0.50 H |
| Lower reach | 0.44 H | Reach–optimum | 0.39 H |
| Maximum reach | 1.20 H | | |
| Lower convenient height | 0.23 H | | |
| Upper convenient height | 0.84 H | Other Postures | Ratio |
| Convenient depth | 0.23 H | | |

| Circulation Spaces | Ratio | Sitting Lotus | |
|---|---|---|---|
| Width of corridor for 2–children | 0.63 H | Sitting lotus height | 0.50 H |
| Space between 2–standing work surfaces | 0.65 H | Eye–height | 0.42 H |
| Space between 2–seats | 0.30 H | Knee to knee width | 0.40 H |
| | | Sitting lotus depth | 0.31 H |
| Fixtures & Fittings | Ratio | Forward reach | 0.60 H |
| | | Work surface top from floor | 0.20 H |
| Window Pane | | | |
| Upper reach | 1.20 H | Sitting Sideways | |
| Lower reach | 0.53 H | Maximum width | 0.41 H |
| Height of hook | 1.00 H | Maximum depth | 0.33 H |
| Height of doorknob | 0.63 H | | |
| Height of switch | 0.80 H | Squatting | |
| Height of lower edge of mirror | 0.75 H | | |
| Height of sink top | 0.50 H | Squatting height | 0.61 H |
| Height of wash basin top | 0.45 H | Squatting depth | 0.33 H |
| Height of urinal top | 0.41 H | Squatting forward reach | 0.49 H |

## Sizing the Furniture

Furniture sizes required for the children in a particular age–group can thus be worked out with the help of ratios of body segments to standing height. For example, to design a chair or seat, the relevent part–body measurements are–the popliteal height i.e. lower leg height from the heel to the back of the knee to fix the height of the seat; the hip width to fix the width of the seat; measurement from the buttock to the popliteus to fix the seat depth and height of the lumbar vertebrae to fix the height of the back rest. Using Table 2, the designer can directly convert the ratios of body segments to standing height into actual measurements for each furniture size element needed for a school.

It is more feasible, practical and most economical to decide minimum number of furniture sizes to fit the school population. In Figure–3 an attempt has been made to distribute school population in five age ranges–leading to five furniture sizes A, B, C, D and E with size A being the smallest and size E the largest, needed for an Indian School.

Sizing furniture to fit an age range is more difficult than sizing a set of furniture to fit an indivisual. The concept of 'margins of tolerances' has been used and it has been found that the tolerances arrived at for suggested furniture ranges are well within the permissible limits. 'Margins of tolerances, for suggested five sizes of seat and table heights are given in Table–3. Distribution of furniture types' suitable for various standing heights, age–ranges and class levels are shown in Table–4.
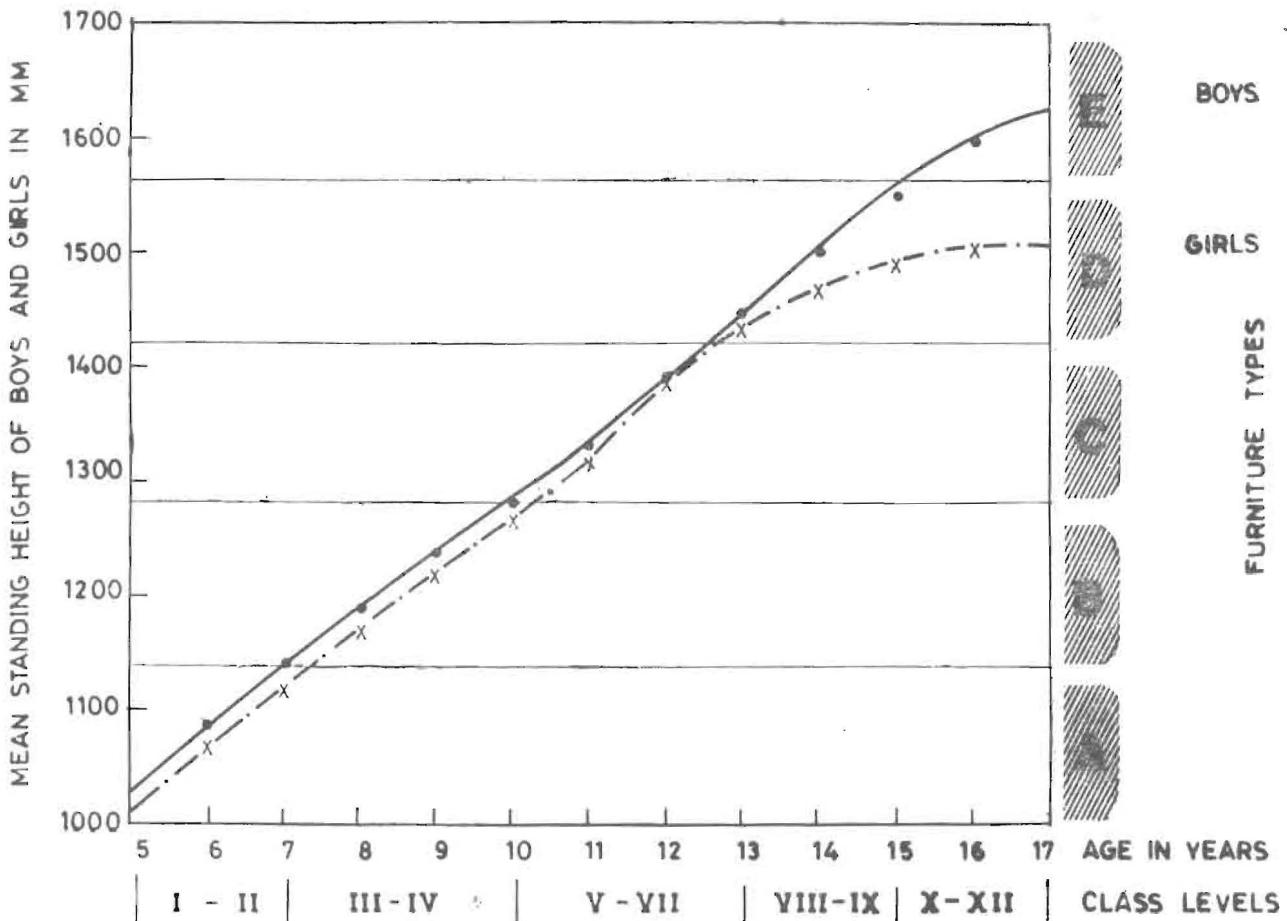


Fig. 3 Age Ranges Versus Mean Standing Height

## TABLE 3 ACCEPTABLE MARGINS OF TOLERANCES FOR SEAT AND TABLE HEIGHTS

| Age in Yrs. | Male Children | | | Recommended | | | Tolerances | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| | Design standing height | Seat height | Table height | Seat height | Table height | Furniture type | Below fit | | Above fit | |
| | | | | Dimensions in mm | | | | | | |
| 5 | 1016 | 254 | 417 | | | | | | | |
| 6 | 1079 | 270 | 442 | 270 | 440 | A | 14 | seat | 16 | |
| 7 | 1134 | 284 | 465 | | | | 25 | table | 23 | |
| 8 | 1187 | 297 | 487 | | | | | | | |
| 9 | 1233 | 308 | 506 | 300 | 500 | B | 21 | seat | 3 | |
| 10 | 1284 | 321 | 526 | | | | 26 | table | 13 | |
| 11 | 1334 | 334 | 547 | | | | | | | |
| 12 | 1386 | 347 | 568 | 340 | 560 | C | 21 | seat | 6 | |
| 13 | 1442 | 361 | 591 | | | | 31 | table | 13 | |
| 14 | 1504 | 376 | 617 | 375 | 620 | D | 14 | seat | 1 | |
| 15 | 1557 | 389 | 638 | | | | 18 | table | 3 | |
| 16 | 1595 | 399 | 654 | 400 | 660 | E | 4 | seat | 1 | |
| 17 | 1615 | 404 | 662 | | | | 2 | table | 6 | |

*Seat and Table heights are within permissible limits.*

## TABLE-4 FURNITURE TYPES, SUITABLE AGE RANGES AND CLASS LEVELS

| Furniture type | A | B | C | D | | E |
|---|---|---|---|---|---|---|
| Class level | I–II | III–IV | V–VII | VIII–IX | VIII–XII | X–XII |
| | M+F | M+F | M+F | M | F | M |
| Design standing height in mm | 1016–1134 | 1135–1284 | 1285–1442 | 1443–1557 | 1443–1515 | 1558–1615 |
| Average standing height in mm | 1076 | 1210 | 1362 | 1501 | 1488 | 1589 |

| Age ranges | | | | | | |
|---|---|---|---|---|---|---|
| 5–7 M+F | | | | | | |
| 7–10 M+F | | | | | | |
| 10–13 M+F | | | | | | |
| 13–15 M | | | | | | |
| 13–17 F | | | | | | |
| 15–17 M | | | | | | |

M–Male, F–Female

Furniture Type 'A', which fits standing heights of 1016–1134 mm, will be used by 5–7 year old boys and girls; type 'B', 1135–1284 mm, by 7–10 year old boys and girls; type 'C', 1285–1442 mm, by 10–13 year old boys and girls; type 'D', 1443–1557 mm, by 13–15 year old boys and 13–teenage year old girls and type 'E', 1558–1615 mm, by 15–teenage year old boys. Design dimensions for furniture types with respect to ratios of the body segments have been worked out in Table–5 as a ready reckoner for the designer.

6

## TABLE 5—DESIGN DIMENSIONS FOR VARIOUS FURNITURE TYPES

| Furniture types | A | B | C | D | E |
|---|---|---|---|---|---|
| Design standing height ranges | 1016–1134 | 1135–1284 | 1285–1442 | 1443–1557 | 1558–1615 |
| Average heights | 1076 | 1210 | 1362 | 1501 | 1589 |
| Ratio | Design Dimensions in mm | | | | |
| 0.11 | 118 | 133 | 150 | 165 | 175 |
| 0.16 | 172 | 194 | 218 | 240 | 254 |
| 0.17 | 183 | 206 | 232 | 255 | 270 |
| 0.20 | 215 | 242 | 272 | 300 | 318 |
| 0.23 | 247 | 278 | 313 | 345 | 365 |
| 0.24 | 258 | 290 | 327 | 360 | 381 |
| 0.25 | 269 | 303 | 341 | 375 | 397 |
| 0.30 | 323 | 363 | 409 | 450 | 478 |
| 0.31 | 334 | 375 | 422 | 465 | 493 |
| 0.33 | 355 | 399 | 449 | 495 | 524 |
| 0.34 | 366 | 411 | 463 | 510 | 540 |
| 0.35 | 377 | 424 | 477 | 525 | 556 |
| 0.37 | 398 | 448 | 504 | 555 | 588 |
| 0.38 | 409 | 460 | 518 | 570 | 604 |
| 0.39 | 420 | 472 | 531 | 585 | 620 |
| 0.40 | 430 | 484 | 545 | 600 | 636 |
| 0.41 | 441 | 496 | 558 | 615 | 652 |
| 0.42 | 452 | 508 | 572 | 630 | 667 |
| 0.44 | 473 | 532 | 599 | 660 | 699 |
| 0.45 | 484 | 545 | 613 | 675 | 715 |
| 0.48 | 516 | 581 | 654 | 720 | 763 |
| 0.49 | 527 | 593 | 667 | 736 | 779 |
| 0.50 | 538 | 605 | 681 | 751 | 795 |
| 0.52 | 560 | 629 | 708 | 781 | 826 |
| 0.53 | 570 | 641 | 722 | 796 | 842 |
| 0.56 | 603 | 678 | 763 | 841 | 890 |
| 0.58 | 624 | 702 | 790 | 871 | 922 |
| 0.60 | 646 | 726 | 817 | 901 | 953 |
| 0.61 | 656 | 738 | 831 | 916 | 969 |
| 0.63 | 678 | 763 | 858 | 946 | 1001 |
| 0.64 | 689 | 774 | 872 | 961 | 1017 |
| 0.65 | 699 | 787 | 885 | 976 | 1033 |
| 0.70 | 753 | 847 | 953 | 1051 | 1112 |
| 0.75 | 807 | 908 | 1022 | 1126 | 1192 |
| 0.78 | 839 | 944 | 1062 | 1171 | 1239 |
| 0.80 | 861 | 968 | 1090 | 1201 | 1271 |
| 0.84 | 904 | 1016 | 1144 | 1261 | 1335 |
| 0.93 | 1001 | 1125 | 1267 | 1396 | 1478 |
| 1.00 | 1076 | 1210 | 1362 | 1501 | 1589 |
| 1.02 | 1098 | 1234 | 1389 | 1531 | 1621 |
| 1.10 | 1184 | 1331 | 1498 | 1651 | 1748 |
| 1.15 | 1237 | 1392 | 1566 | 1726 | 1827 |
| 1.20 | 1291 | 1452 | 1634 | 1801 | 1907 |
| 1.23 | 1323 | 1488 | 1675 | 1846 | 1954 |

## Furniture Allocation

It is important to note that there is no significant difference in the mean standing heights for boys and girls from 5 to 13 year age groups. The difference becomes considerable at the age of puberty i.e. after the age of 13 years when male height increases rapidly compared to that of females. Thus in primary and middle schools, the same furniture can be used by both sexes of the same age groups. For secondary and higher secondary schools i.e. the schools with children of 14 years and above, boys schools may require a different furniture distribution than that of girls schools. In schools with co-education, percentage of students of both sexes as per age ranges for a class level can be worked out and furniture can be provided accordingly. Though the furniture types have been linked with the class levels, the correct distribution of furniture type will depend upon class-wise age distribution of the school children for rural and urban situations.

In case, different furniture types are provided in a particular class, the furniture frequently becomes mis-matched. This will result class children using small chairs with large tables and vice-versa. To avoid this situation, it is important that furniture types A,B,C,D, and E may have clear coding, boldly marked on the furniture elements to ensure their correct matching and use.

## Conclusion

This Technical Research Note is part of the R&D work carried out in the area of educational buildings at the Institute. The data has been presented in a manner which could be easily used by the designers of educational furniture and fittings. Advantages envisaged through the new range of furniture types should give impetus to further research in this hitherto neglected area of furniture and fittings for schools.

There is a continuing world-wide trend towards increase in height and other part body dimensions of the children. This has been probably possible due to increase in per capita income, availability of protein-food coupled with more awareness to nutritional values and improved fooding habits of the children and their parents. Therefore it is suggested that anthropometric dimensions may be reviewed and, if need be, revised once in a decade.