Architecture

SUITABILITY OF REFERENCE STANDARDS TO INTEGRATE ERGONOMICS IN ARCHITECTURE: AN EMPIRICAL STUDY IN BANGLADESH

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Abstract

Introduction: Buildings are a very important part of our lives because we spend so much time there. A primary job of an architect is to assure that the buildings we live in accommodate the human activities that take place within them. Therefore, anthropometric datasets are important tools for the architect. Unfortunately, anthropometric datasets relevant to the functions that take place in buildings are relatively scarce, even as part of the architect's academic experience. Architects mostly depend on a few reference standards that may not fit the local population. **The purpose of the research** described here is to contribute to the filling of this gap with an anthropometric dataset for the Bangladeshi population that can serve as a source of data in the field of architecture. **Methods:** Body measurements of 130 people, 66 male and 64 female, are taken at 38 different postures. The postures are selected from the reference standards and considering the local practice. Then the measurements are examined with descriptive statistics and compared with the reference standards to check the differences. **Results:** This comparison indicates that the Bangladeshi people are considerably smaller; therefore, the practiced reference standards are not appropriate for Bangladesh, and presumably South Asia. Further research is required for a comprehensive anthropometric database. The presented dataset can serve as a source of data for the design of residential and other buildings in Bangladesh as well as other South Asian countries.

Keywords: reference standard, anthropometry, body dimension, Bangladeshi population, architecture, ergonomics.

Introduction

The need for consideration of human factors and ergonomics (HFE) in the design of built environment is obvious, as has been much discussed (Attaianese, 2012, 2014, 2022; Attaianese and Duca, 2012; Charytonowicz, 2000; Costa et al., 2012; Eilouti, 2021; Garneau and Parkinson, 2016; Hendrick, 2008; Olguntürk and Demirkan, 2009; Remijn, 2006). Scholars agree that integrating HFE into the design process of built environment can contribute to, among other things, sustainability (Attaianese, 2014, 2016, 2017; Attaianese and Duca, 2012; Hedge and Dorsey, 2013; Hedge et al., 2010; Radjiyev et al., 2015). Although the need is recognized, there is a relative scarcity of relevant research (Attaianese and Duca, 2012; Costa et al., 2012; Fross, 2014). There are few studies regarding HFE in the built environment, and those that have been done tend to focus on the healthcare sector (for example, Codinhoto et al., 2009; Pinto et al., 2000; Rogers et al., 2013; Springer, 2007; Villeneuve, 2000; Yeoman and Ashmore, 2018). Since good architecture accommodates different human functions expected in the built environment, thus, ergonomic considerations should logically be incorporated into every aspect of the design process. Designers do it sometimes consciously, sometimes intuitively (Fross, 2014; Fross et al., 2015). However, for effective integration of HFE into architecture, it is necessary for the architect to avail good data specific to the local context.

Despite the necessity of anthropometric database for local population, it does not always exist in reality. In the case of Bangladesh, the national building code (BNBC/MoHPW/GoB, 2021), the regulations for building construction in the Dhaka Metropolitan area (MoHPW/GoB 2008) as well as Dhaka Cantonment area (Cantonment Board, 2020) provide guidelines for building design that may contain some ergonomic considerations, although they are not explicitly mentioned. However, good architecture-relevant anthropometric data for Bangladesh simply do not exist.

The present research is an attempt to address this gap. This paper describes an anthropometric study for the Bangladeshi population aimed to determine the male and female body dimensions. Although the study covers only the Bangladeshi population, it is expected to be useful for the populations of other countries with similar anthropometric features.

Anthropometric considerations for architecture

Considerations for HFE in architecture differ somewhat from those of other disciplines, such as industrial design, in the way that architects must consider the space within which activities take place. For architecture, a very clear understanding of human activities for any given function is the starting point. Architectural design starts with a comprehensive understanding of human activities and the space requirements for those activities. Relevant information includes a wide range of attributes such as body dimensions, flexibility, working procedures, equipment to be used, furniture and fixtures, behavioral expectations, sensory abilities, environmental needs, etc. All these considerations require data on specific body dimensions at specific postures related to the activities to be performed. Different types of anthropometric dimensions are required to accommodate different types of human activities.

Integrating HFE into the built environment is not an easy task; it requires proper training. Usually, such training is introduced in architecture education. Scholars agree that teaching ergonomics in design school can improve performance, productivity, safety, and health in the built environment (Attaianese, 2012, 2016; Garneau and Parkinson, 2016; Olguntürk and Demirkan, 2009). The typical curriculum attempts to impart a clear understanding of ergonomic issues to the students at the early stage of the academic program. Topics covered include human activities, movements, postures, relevant body dimensions, etc. Through this training, the students can learn to generate space requirements and determine appropriate dimensions for the relevant furniture and fixtures and design the space in which the intended functions can be performed efficiently.

This study proposes that the HFE education of architects, as well as professional practice, would be enhanced if better data was available. Such data would logically include different dimensions of the human body at different postures (depending on the specific human activity) for different ages, genders, races, nationalities, etc. Although, a perfect design for the user is seldom, if ever, possible, proper considerations of relevant anthropometric data should be able to better ensure comfort and efficiency and avoid discomfort and inefficiency (Klamklay et al., 2008; Mokdad, 2002; Pentikis et al., 2002; Pheasant and Haslegrave, 2006; Sanders and McCormick, 1993).

Anthropometric data in Bangladesh

Unfortunately, in Bangladesh, no holistic dataset of anthropometric features is available, although several research projects have covered specific features. There are various studies on anthropometric characteristics relevant to the field of health and nutrition. A large portion of such research relates to malnutrition, particularly in women and children. Research topics that deal with anthropometric features of adults tend to involve maternal anthropometry (Karim and Mascie-Taylor, 1997; Nahar et al., 2007), nutrition (D'Souza and Tandon, 2019; Islam et al., 2004; Mitra et al., 2018; Sultana et al., 2015), age at menarche (Akter et al., 2012; Chowdhury et al., 2000; Hossain et al., 2010; Islam et al., 2017), menstrual health (Hossain et al., 2011b), hypertension (Ali et al., 2018; Choudhury et al., 2014; Chowdhury et al., 2016; Simmons et al., 2021, obesity (Bhowmik et al., 2013, 2014; Biswas et al., 2017; Flora et al., 2009; Ge et al., 2014; Hussain et al., 2013; Islam et al., 2020; Qureshi et al., 2017), diabetes (Asghar et al., 2007; Chowdhury et al., 2015; Fottrell et al., 2018; Islam et al., 2015; Siddiquee et al., 2015), and/or some other issues like gut microbiomes (Osborne et al., 2020), fatty liver diseases (Alam et al., 2014, 2019), etc. However, despite the plethora of studies in the health sector, there is a dearth of adult anthropometric data other than weight and body mass index (BMI) (Flora et al., 2009).

There are also studies that cover detailed dimensions of body parts: for example, the face of Garo women (Akhter et al., 2013), face height of Garo and non-Garo women (Tania et al., 2020), hand of Garo men and women (Asadujjaman et al., 2019), head of Garo women (Akhter et al., 2009), hand anthropometry of men (Imrhan et al., 2006, 2009), hand anthropometry of women (Razzaque et al., 2021), hand of both men and women (Hossain, 2015; Imrhan et al., 2009; Shahriar et al., 2020), various body parts of Santal men (Shah et al., 2015), arm span of Garo men and women (Hossain et al., 2011a), arm span of women (Laila et al., 2010a), forearm of women (Laila et al., 2010b), external ear anthropometry (Asadujjaman et al., 2019), upper limbs of Manipuri women (Hussain et al., 2019), etc. The limitations of these studies are that they only focus on specific body parts and/or specific tribal population in Bangladesh.

More complete studies of anthropometric features are rare. Khadem and Islam (2014) created a dataset with 37 dimensions of Bangladeshi men. Khan (2014) reported data on 37 dimensions for both men and women, and, in a recent study, Parvez et al. (2022a) prepared a dataset with 37 dimensions for male and female university students. These studies are relevant, however, more for industrial engineering and occupational therapy than for architecture. A few studies have also covered anthropometry in relation to furniture, such as classroom and library furniture (Hoque et al., 2014, Parvez et al., 2021, 2022b, 2022 c; Shah et al., 2013), hospital beds (Chakrabortty et al., 2014; Islam et al., 2013), vehicle seat (Hoque et al., 2017), etc. However, again, the relevance to architecture is limited.

In sum, the available studies are not of much use for architecture. As a consequence, the architecture schools tend to rely on a few reference standards for HFE

training (Biswas, 2022; Biswas et al., 2021) rather than robust datasets. What the available studies do indicate, though, is that anthropometric features of Bangladeshi people, such as stature, hand dimensions, and weight, are significantly different from the populations associated with published anthropometric datasets: they are generally somewhat smaller (Imrhan et al., 2009; Khadem and Islam, 2014; Parvez et al., 2022a; Shahriar et al., 2020). Therefore, blind application of reference design standards may result in inappropriate designs for Bangladesh.

Method

The research involved taking a series of measurements of Bangladeshi men and women. The measurements were taken as a part of an academic exercise at the Department of Architecture, Military Institute of Science and Technology (MIST). The exercise was to design a small residential building. Therefore, only the measurements relevant for residential use were considered. All the participants participated in the survey voluntarily with informed consent. The exercise was approved by the academic wing of MIST.

Participants

Measurements were taken from 130 individuals — 66 men and 64 women (Table 1). The age range was from 15 to 65 years, thus covering the range of working age population able to join the labor market. Convenience sampling fitted best to obtain the participants as it was conducted within an academic exercise. The age breakdown of participants is as follows.

Selection of Body Dimensions

For space design, the first task is to know what body dimensions are to be considered for the activities performed and what furniture/fixtures are to be accommodated in that space. The furniture/fixtures are also related to the body dimensions at different postures. For this study, body dimensions were taken at standing, sitting in a chair, and sitting/crawling on the floor positions. The postures were selected based on the relevance for residential functions and on a review of three reference books that are commonly consulted in the practice and education of architecture. The books consulted are:

1. Time Saver Standards for Building Types (De Chiara and Callender, 1990);

2. Human Dimension & Interior Space: A Source Book of Design Reference Standards (Panero and Zelnik, 1979);

3. Architects' Data (Neufert and Neufert, 2012).

The study included 38 body dimensions that are very basic for space designing. 32 of them were derived from the reference books and 6 were added as relevant for the local context. The selected dimensions are presented in Figure. Although residential functions were the focus, the data is expected to be helpful for designing other spaces such as offices, small commercial spaces, etc.

Data Analysis

Statistical analysis involved simple examination of the dataset through descriptive statistics. This included the mean, mode, range, standard deviation, coefficient of variation and selected percentiles. Mean values were compared with reference standards with Z-test and t-test.

For comparison, Human Dimension & Interior Space: A Source Book of Design Reference Standards (Panero and Zelnik, 1979), referred to as HD hereinafter, had preference because of its gender specific and elaborate data. Time Saver Standards for Building Types (De Chiara and Callender, 1990), referred to as TSS hereinafter, and Architects' Data (Neufert and Neufert, 2012), referred to as NAD hereinafter, mostly provide dimensions with gender-neutral figurative drawings, although NAD provides occasional gender identification in the illustrations (such as clothing, body shape, hair style, etc.).

Limitations

This study has some limitations. The number of participants was relatively small, and it did not represent the South Asia or even Bangladesh. This study was conducted within the framework of an academic exercise in architecture education, and it was particularly oriented towards residential architecture in the local context. Additionally, state of the art measurement tools were not available for this study.

Results and Discussion

The results are shown in Tables 2–7: both the measured dimensions and comparison to reference standards. Tables 2 and 3 provide mean, mode, range, standard deviation, reference standards and the difference between the mean and reference standard for men and women. Table 4 provides selected percentile values for both men and women. Tables 5 and 6 present comparison of different body dimensions with the reference standards and Table 7 shows comparison of different ratios with the reference standards.

A vital question is how the data reported here differs from that of reference standards. It is observed that all dimensions are smaller than the reference standards, with three exceptions — side width for women and hand length and vertical reach (standing) for men. However, these latter dimensions are slightly

Table 1. **Age distribution of the participants**

Age (years)	15–20	21–30	31–40	41–50	51–60	61–65	Total
Male	17	26	4	5	13	1	66
Female	10	20	8	13	10	3	64
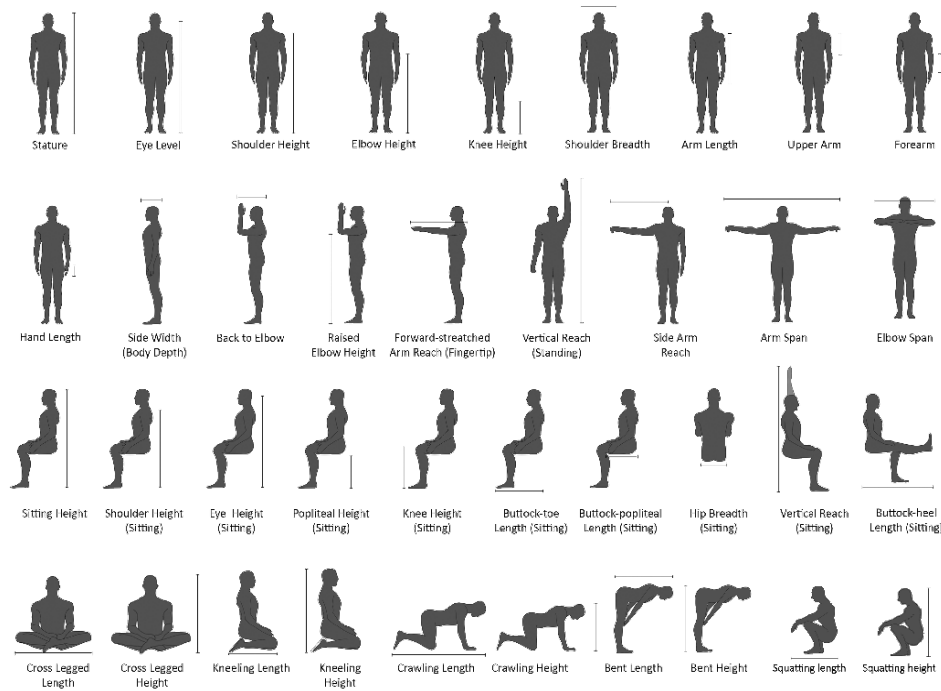
Anthropometric dimensions measured in the study

larger only when the reference is taken from the TSS as the unisex dimensions. In fact, unisex dimensions in references are generally smaller compared to the gender-specific dimensions for reasons that are not clear. The derived dataset suggests that the body dimensions are smaller than those of standard references, sometimes dramatically. Tables 5 and 6 show that most of the comparisons with reference values reach statistical significance.

The dataset is again compared with the reference standards with different ratios. Table 7 shows a comparison of all the derived dimensions and their ratios with stature and arm span for both men and women against the references. This shows that the body dimensions are considerably smaller than the reference values, p-value is 5.42654E-09 for men and 7.00667E-09 for women. The ratio comparison shows an interesting trend: stature ratio for men (p = 0.6036852) and arm span ratio for women (p = 0.07259) are strikingly similar, while stature ratio for women (p = 0.02970065) and arm span ratio for men (p = 0.0001983) are not that close. This may happen because proportions of different body parts may differ for different races and ethnic groups (Akhter et al., 2013; Goel and Tashakkori, 2015; Hovinga and Lerner, 2009; Hussain et al., 2019; Karmegam et al., 2011; Rossion and Michel, 2011, Tania et al., 2020).

This also indicates that a comprehensive anthropometric database is required for application in architecture and other sectors. Further studies can investigate the variations for ethnic groups and comparisons with references to find if multipliers can be used until a widespread database is prepared.

The results suggest that the reference standards are not appropriate for Bangladesh, and, presumably, for other countries in South Asia. Space design standards are vital for integrating HFE in the built environment to ensure users' comfort and health benefits; they are also essential for such architectural design considerations as functional efficiency, workability, space optimization, etc. It follows that the data presented here provides better guidance than the reference standards when one is designing for Bangladesh, or as said above, for South Asia in general.

Conclusion

In this article, an anthropometric dataset is presented that is specifically tailored for architectural design in Bangladesh. Considering the importance of local data, it highlights the significance of using the Bangladeshi dataset when designing for Bangladesh, rather than relying on reference standards that are relevant for other populations.

Although the focus is on architecture and Bangladesh, the data can be applied to other fields, such as product design, and to other populations, such as other countries in South Asia.

Table 2. Male anthropometric dimensions and reference standards

SI	Derived Dimension	Male (n=66)					Male Reference			Unisex Reference		
		Mean	Mode	Max	Min	STDEV.	Reference Dimension	Reference Book	Ref -Mean difference	Reference Dimension	Reference Book	Ref -Mean difference
1	Stature	169.34	170.00	183.00	150.00	7.39	188.6	HD	19.3	175.3	TSS	6.0
2	Eye height	158.02	160.00	173.00	138.00	7.27	174.2	HD	16.2	-	-	-
3	Shoulder height	141.40	143.00	159.00	125.00	7.41	155.7	HD	14.3	-	-	-
4	Elbow height	108.26	107.00	135.00	96.00	7.52	120.1	HD	11.8	-	-	-
5	Knee height	49.43	49.00	61.00	41.00	3.83	-	-	-	53.3	TSS	3.9
6	Shoulder breadth	43.96	44.00	54.00	37.50	3.31	52.6	HD	8.6	45.7	TSS	1.7
7	Arm length	75.93	72.00	90.00	63.00	4.66	-	-	-	-	-	-
8	Upper arm	32.00	30.00	39.00	22.00	2.70	-	-	-	-	-	-
9	Forearm	26.28	27.00	32.00	23.00	1.78	-	-	-	-	-	-
10	Hand length	18.53	18.00	21.70	15.00	1.32	20.5	HD	2.0	17.8	TSS	-0.7
11	Side width (body depth)	24.04	24.00	35.00	16.00	3.58	33.0	HD	9.0	24.1	TSS	0.1
12	Back to elbow	42.36	41.00	58.00	34.00	4.08	-	-	-	43.2	TSS	0.8
13	Raised elbow height	131.86	135.00	156.00	108.00	8.23	-	-	-	137.2	TSS	5.3
14	Forward-stretched arm reach (fingertip)	78.17	80.00	90.60	68.00	4.27	88.9	HD	10.7	87.5	NAD	9.3
15	Vertical reach (standing)	214.73	220.00	235.00	191.00	10.81	224.8	HD	10.1	213.4	TSS	-1.3
16	Side arm reach	88.33	90.00	101.00	77.00	4.75	99.1	HD	10.7	-	-	-
17	Arm span	173.52	174.00	190.00	154.00	8.48	-	-	-	182.9	TSS	9.4
18	Elbow span	87.49	94.00	98.90	69.00	5.83	-	-	-	100.0	NAD	12.5
19	Sitting height	86.58	86.00	146.00	73.00	8.35	96.5	HD	9.9	-	-	-
20	Shoulder height (sitting)	58.44	56.00	68.00	52.00	3.79	69.3	HD	10.9	-	-	-
21	Eye height (sitting)	75.18	74.00	84.00	64.00	3.73	86.1	HD	10.9	-	-	-
22	Popliteal height (sitting)	45.26	45.00	53.00	40.00	2.71	49.0	HD	3.7	-	-	-
23	Knee height (sitting)	53.42	55.00	60.00	45.00	3.13	59.4	HD	6.0	-	-	-
24	Buttock-toe length (sitting)	69.15	69.00	90.00	58.00	6.44	94.0	HD	24.9	-	-	-
25	Buttock-popliteal length (sitting)	46.72	46.00	55.00	39.00	3.31	54.9	HD	8.2	-	-	-
26	Hip breadth (sitting)	35.25	38.00	45.00	24.00	3.31	40.4	HD	5.1	-	-	-
27	Vertical reach (sitting)	130.79	127.00	143.00	110.00	6.48	131.1	HD	0.3	-	-	-
28	Buttock-heel length (sitting)	103.94	97.00	123.00	89.00	7.31	117.1	HD	13.2	-	-	-
29	Cross legged length	69.60	72.00	82.00	60.00	5.34	-	-	-	75.0	NAD	5.4
30	Cross legged height	83.56	86.00	100.00	51.00	6.76	-	-	-	87.5	NAD	3.9
31	Kneeling length	56.88	55.00	71.00	47.00	5.50	-	-	-	62.5	NAD	5.6
32	Kneeling height	99.08	105.00	115.00	86.00	6.76	-	-	-	100.0	NAD	0.9
33	Crawling length	119.60	121.00	143.00	100.30	9.69	147.8	HD	28.2	-	-	-
34	Crawling height	69.24	69.00	92.00	58.00	6.02	77.5	HD	8.3	76.2	TSS	7.0
35	Bent length	79.30	81.00	91.50	62.50	7.20	-	-	-	-	-	-
36	Bent height	106.02	101.00	128.80	90.00	7.81	-	-	-	-	-	-
37	Squatting length	82.43	79.00	111.40	66.00	12.09	-	-	-	-	-	-
38	Squatting height	94.91	95.00	118.00	84.00	6.35	-	-	-	-	-	-

Table 3. Female anthropometric dimensions and reference standards

SI	Derived Dimension	Female (n=64)					Female Reference			Unisex Reference		
		Mean	Mode	Max	Min	STDEV.	Reference Dimension	Reference Book	Ref -Mean difference	Reference Dimension	Reference Book	Ref -Mean difference
1	Stature	155.84	156.00	172.70	135.00	7.12	172.8	HD	16.96	175.3	TSS	19.46
2	Eye height	145.11	145.00	160.90	127.00	6.99	162.8	HD	17.69	-	-	-
3	Shoulder height	129.95	142.00	152.00	117.00	6.82	141.4	HD	11.45	-	-	-
4	Elbow height	98.98	98.00	113.00	86.00	5.26	110.7	HD	11.72	-	-	-
5	Knee height	45.45	46.00	53.00	39.50	3.31	-	-	-	53.3	TSS	7.85
6	Shoulder breadth	39.11	37.00	49.00	31.00	4.06	43.2	HD	4.09	45.7	TSS	6.59
7	Arm length	69.81	74.00	79.00	59.00	4.04	-	-	-	-	-	-
8	Upper arm	29.98	31.00	35.00	24.00	2.42	-	-	-	-	-	-
9	Forearm	23.59	23.00	27.00	20.00	1.56	-	-	-	-	-	-
10	Hand length	16.79	16.00	19.70	14.00	1.25	-	-	-	17.8	TSS	1.01
11	Side width (body depth)	26.70	30.00	37.00	20.00	3.58	-	-	-	24.1	TSS	-2.60
12	Back to elbow	39.34	39.00	49.40	31.00	3.72	-	-	-	43.2	TSS	3.84
13	Raised elbow height	120.36	127.00	134.20	105.00	6.57	-	-	-	137.2	TSS	16.80
14	Forward-stretched arm reach (fingertip)	73.15	74.00	88.70	59.00	5.74	80.5	HD	7.35	87.5	NAD	14.35
15	Vertical reach (standing)	194.74	202.00	225.00	108.80	14.19	213.4	HD	18.66	213.4	TSS	18.66
16	Side arm reach	79.11	80.00	90.50	69.00	4.65	96.5	HD	17.39	-	-	-
17	Arm span	156.78	153.00	177.00	138.00	7.71	-	-	-	182.9	TSS	26.12
18	Elbow span	79.71	80.00	93.00	69.00	5.11	-	-	-	100.0	NAD	20.29
19	Sitting height	81.46	78.00	117.50	68.00	8.05	90.7	HD	9.24	-	-	-
20	Shoulder height (sitting)	55.57	56.00	64.00	45.00	3.85	62.5	HD	6.93	-	-	-
21	Eye height (sitting)	69.07	69.00	79.00	53.00	4.90	80.5	HD	11.43	-	-	-
22	Popliteal height (sitting)	42.14	46.00	53.00	34.40	4.18	44.5	HD	2.36	-	-	-
23	Knee height (sitting)	49.67	49.00	58.00	43.00	3.42	54.6	HD	4.93	-	-	-
24	Buttock-toe length (sitting)	65.13	67.00	82.20	49.00	5.90	94.0	HD	28.87	-	-	-
25	Buttock-popliteal length (sitting)	45.02	43.00	54.00	38.30	3.97	53.3	HD	8.28	-	-	-
26	Hip breadth (sitting)	36.88	37.00	46.50	29.90	3.54	43.4	HD	6.52	-	-	-
27	Vertical reach (sitting)	119.90	117.00	139.00	100.00	7.79	124.7	HD	4.80	-	-	-
28	Buttock-heel length (sitting)	98.34	93.00	122.00	81.80	7.87	124.5	HD	26.16	-	-	-
29	Cross legged length	65.31	65.00	114.00	55.50	10.91	-	-	-	75.0	NAD	9.69
30	Cross legged height	78.16	81.00	88.30	59.00	4.91	-	-	-	87.5	NAD	9.34
31	Kneeling length	53.98	53.00	68.00	41.00	6.37	-	-	-	62.5	NAD	8.52
32	Kneeling height	89.40	89.00	106.00	67.00	8.21	-	-	-	100.0	NAD	10.60
33	Crawling length	109.91	100.00	135.50	80.00	10.64	-	-	-	-	-	-
34	Crawling height	65.59	64.00	76.00	52.00	5.25	-	-	-	76.2	TSS	10.61
35	Bent length	73.69	78.00	88.30	55.00	7.80	-	-	-	-	-	-
36	Bent height	102.39	97.00	119.00	84.00	8.35	-	-	-	-	-	-
37	Squatting length	82.43	79.00	111.40	66.00	9.30	-	-	-	-	-	-
38	Squatting height	94.91	95.00	118.00	84.00	6.91	-	-	-	-	-	-

Table 4. Selected percentiles for male and female anthropometric dimensions and reference standards

SI	Derived Dimension	Male (n=66)						Female (n=64)					
		Mean	Mode	Percentile			Reference (M/Unisex)	Mean	Mode	Percentile			Reference (F/Unisex)
				90th	50th	10th				90th	50th	10th	
1	Stature	169.34	170.00	178.5	170.0	159.7	188.6	155.84	156	165.0	155.8	147.4	172.8
2	Eye height	158.02	160.00	167.0	159.3	148.3	174.2	145.11	145	155.0	145.0	137.6	162.8
3	Shoulder height	141.40	143.00	150.1	142.0	131.5	155.7	129.95	142	138.8	129.0	122.2	141.4
4	Elbow height	108.26	107.00	117.00	107.00	98.85	120.1	98.98	98.00	106.20	98.45	93.00	110.7
5	Knee height	49.43	49.00	54.00	49.35	44.55	53.3	45.45	46.00	49.35	45.45	40.48	53.3
6	Shoulder breadth	43.96	44.00	48.50	44.00	40.00	52.6	39.11	37.00	44.35	38.50	34.30	43.2
7	Arm length	75.93	72.00	81.50	76.00	70.00	-	69.81	74.00	74.00	69.90	64.36	-
8	Upper arm	32.00	30.00	35.00	32.00	29.00	-	29.98	31.00	33.00	30.00	27.01	-
9	Forearm	26.28	27.00	28.00	26.00	24.00	-	23.59	23.00	26.00	23.50	21.35	-
10	Hand length	18.53	18.00	20.00	18.45	17.00	20.5	16.79	16.00	18.30	17.00	15.20	17.8
11	Side width (body depth)	24.04	24.00	28.25	24.00	20.00	33.0	26.70	30.00	30.91	26.45	22.00	24.1
12	Back to elbow	42.36	41.00	46.00	42.00	37.50	43.2	39.34	39.00	43.00	39.70	34.37	43.2
13	Raised elbow height	131.86	135.00	140.75	132.05	123.00	137.2	120.36	127.00	129.00	120.75	111.65	137.2
14	Forward-stretched arm reach (fingertip)	78.17	80.00	83.85	78.00	72.90	88.9	73.15	74.00	80.40	74.00	67.09	80.5
15	Vertical reach (standing)	214.73	220.00	227.90	214.50	200.60	224.8	194.74	202.00	206.51	196.15	183.50	213.4
16	Side arm reach	88.33	90.00	93.15	88.65	82.40	99.1	79.11	80.00	84.70	79.10	73.12	96.5
17	Arm span	173.52	174.00	185.00	174.00	162.00	182.9	156.78	153.00	165.35	157.00	146.60	182.9
18	Elbow span	87.49	94.00	94.00	87.70	80.10	100.0	79.71	80.00	85.85	80.00	74.00	100.0
19	Sitting height	86.58	86.00	90.25	86.00	81.00	96.5	81.46	78.00	85.71	80.15	74.65	90.7
20	Shoulder height (sitting)	58.44	56.00	63.55	58.00	54.00	69.3	55.57	56.00	61.00	56.00	50.58	62.5
21	Eye height (sitting)	75.18	74.00	80.00	75.00	70.00	86.1	69.07	69.00	75.80	69.00	64.00	80.5
22	Popliteal height (sitting)	45.26	45.00	49.00	45.00	42.00	49.0	42.14	46.00	47.00	42.15	36.30	44.5
23	Knee height (sitting)	53.42	55.00	57.00	54.00	49.75	59.4	49.67	49.00	54.35	49.30	45.43	54.6
24	Buttock-toe length (sitting)	69.15	69.00	78.00	69.00	61.50	94.0	65.13	67.00	72.14	65.75	58.72	94.0
25	Buttock-popliteal length (sitting)	46.72	46.00	51.00	46.00	42.70	54.9	45.02	43.00	51.00	44.00	41.00	53.3
26	Hip breadth (sitting)	35.25	38.00	39.85	35.00	30.00	40.4	36.88	37.00	41.35	36.50	33.00	43.4
27	Vertical reach (sitting)	130.79	127.00	138.90	130.00	124.30	131.1	119.90	117.00	127.76	119.95	110.12	124.7
28	Buttock-heel length (sitting)	103.94	97.00	114.25	105.00	95.50	117.1	98.34	93.00	109.00	97.25	89.30	124.5
29	Cross legged length	69.60	72.00	76.00	70.10	61.30	75.0	65.31	65.00	71.33	63.80	57.00	75.0
30	Cross legged height	83.56	86.00	89.90	85.00	77.50	87.5	78.16	81.00	83.00	79.00	72.09	87.5
31	Kneeling length	56.88	55.00	65.00	56.00	50.50	62.5	53.98	53.00	62.00	54.00	46.18	62.5
32	Kneeling height	99.08	105.00	108.50	99.00	91.00	100.0	89.40	89.00	98.70	89.50	79.36	100.0
33	Crawling length	119.60	121.00	130.48	120.60	106.20	147.8	109.91	100.00	124.40	110.00	97.36	-
34	Crawling height	69.24	69.00	74.60	69.00	63.00	77.5	65.59	64.00	72.00	64.55	59.59	76.2
35	Bent length	79.30	81.00	87.00	81.00	70.05	-	73.69	78.00	81.97	75.00	60.60	-
36	Bent height	106.02	101.00	115.40	106.00	97.50	-	102.39	97.00	113.28	102.25	90.00	-
37	Squatting length	82.57	94.00	95.50	85.30	64.00	-	82.43	79.00	94.00	82.00	70.86	-
38	Squatting height	99.69	99.69	106.50	100.50	92.00	-	94.91	95.00	103.97	94.00	87.00	-

Underlined text denotes unisex references as gender specific references are not available.

Table 5. Male anthropometric dimensions compared with reference standards

SI	Derived Dimension	Male (n=66)					Reference (M/Unisex)	Z score	p value	p<.05
		Mean	Mode	STDEV	CV	SEM				
1	Stature	169.34	170.00	7.39	0.04	0.91	188.60	-2.61	0.0046	*
2	Eye height	158.02	160.00	7.27	0.05	0.89	174.20	-2.23	0.0130	*
3	Shoulder height	141.40	143.00	7.41	0.05	0.91	155.70	-1.93	0.0268	*
4	Elbow height	108.26	107.00	7.52	0.07	0.93	120.10	-1.57	0.0577	
5	Knee height	49.43	49.00	3.83	0.08	0.47	53.30	-1.01	0.1561	
6	Shoulder breadth	43.96	44.00	3.31	0.08	0.41	52.60	-2.61	0.0045	*
7	Arm length	75.93	72.00	4.66	0.06	0.57	-	-	-	
8	Upper arm	32.00	30.00	2.70	0.08	0.33	-	-	-	
9	Forearm	26.28	27.00	1.78	0.07	0.22	-	-	-	
10	Hand length	18.53	18.00	1.32	0.07	0.16	20.50	-1.50	0.0670	
11	Side width (body depth)	24.04	24.00	3.58	0.15	0.44	33.00	-2.50	0.0061	*
12	Back to elbow	42.36	41.00	4.08	0.10	0.50	43.18	-0.20	0.4200	
13	Raised elbow height	131.86	135.00	8.23	0.06	1.01	137.16	-0.64	0.2595	
14	Forward-stretched arm reach (fingertip)	78.17	80.00	4.27	0.05	0.53	88.90	-2.51	0.0060	*
15	Vertical reach (standing)	214.73	220.00	10.81	0.05	1.33	224.80	-0.93	0.1756	
16	Side arm reach	88.33	90.00	4.75	0.05	0.59	99.06	-2.26	0.0120	*
17	Arm span	173.52	174.00	8.48	0.05	1.04	182.90	-1.11	0.1345	
18	Elbow span	87.49	94.00	5.83	0.07	0.72	100.00	-2.14	0.0160	*
19	Sitting height	86.58	86.00	8.35	0.10	1.03	96.50	-1.19	0.1174	
20	Shoulder height (sitting)	58.44	56.00	3.79	0.06	0.47	69.30	-2.87	0.0021	*
21	Eye height (sitting)	75.18	74.00	3.73	0.05	0.46	86.10	-2.92	0.0017	*
22	Popliteal height (sitting)	45.26	45.00	2.71	0.06	0.33	49.00	-1.38	0.0838	
23	Knee height (sitting)	53.42	55.00	3.13	0.06	0.39	59.40	-1.91	0.0281	*
24	Buttock-toe length (sitting)	69.15	69.00	6.44	0.09	0.79	94.00	-3.86	0.0001	*
25	Buttock-popliteal length (sitting)	46.72	46.00	3.31	0.07	0.41	54.90	-2.47	0.0068	*
26	Hip breadth (sitting)	35.25	38.00	3.31	0.09	0.41	40.40	-1.55	0.0602	
27	Vertical reach (sitting)	130.79	127.00	6.48	0.05	0.80	131.10	-0.05	0.4811	
28	Buttock-heel length (sitting)	103.94	97.00	7.31	0.07	0.90	117.10	-1.80	0.0358	*
29	Cross legged length	69.60	72.00	5.34	0.08	0.66	75.00	-1.01	0.1560	
30	Cross legged height	83.56	86.00	6.76	0.08	0.83	87.50	-0.58	0.2802	
31	Kneeling length	56.88	55.00	5.50	0.10	0.68	62.50	-1.02	0.1532	
32	Kneeling height	99.08	105.00	6.76	0.07	0.83	100.00	-0.14	0.4456	
33	Crawling length	119.60	121.00	9.69	0.08	1.19	147.80	-2.91	0.0018	*
34	Crawling height	69.24	69.00	6.02	0.09	0.74	77.50	-1.37	0.0850	
35	Bent length	79.30	81.00	7.20	0.09	0.89	-	-	-	
36	Bent height	106.02	101.00	7.81	0.07	0.96	-	-	-	
37	Squatting length	82.57	94.00	12.09	0.15	1.49	-	-	-	
38	Squatting height	99.69	99.69	6.35	0.06	0.78	-	-	-	

Underlined text denotes unisex references as gender specific references are not available.

Table 6. Female anthropometric dimensions compared with reference standards

SI	Derived Dimension	Female (n=64)								
		Mean	Mode	STDEV	CV	SEM	Reference (F/Unisex)	Z score	p value	p<.05
1	Stature	155.84	156.00	7.12	0.05	0.88	172.80	-2.38	0.0086	*
2	Eye height	145.11	145.00	6.99	0.05	0.86	162.80	-2.53	0.0057	*
3	Shoulder height	129.95	142.00	6.82	0.05	0.84	141.40	-1.68	0.0466	*
4	Elbow height	98.98	98.00	5.26	0.05	0.65	110.70	-2.23	0.0129	*
5	Knee height	45.45	46.00	3.31	0.07	0.41	53.30	-2.37	0.0089	*
6	Shoulder breadth	39.11	37.00	4.06	0.10	0.50	43.20	-1.01	0.1568	
7	Arm length	69.81	74.00	4.04	0.06	0.50	-	-	-	
8	Upper arm	29.98	31.00	2.42	0.08	0.30	-	-	-	
9	Forearm	23.59	23.00	1.56	0.07	0.19	-	-	-	
10	Hand length	16.79	16.00	1.25	0.07	0.15	17.80	-0.81	0.2085	
11	Side width (body depth)	26.70	30.00	3.58	0.13	0.44	24.10	0.73	0.7663	
12	Back to elbow	39.34	39.00	3.72	0.09	0.46	43.18	-1.03	0.1508	
13	Raised elbow height	120.36	127.00	6.57	0.05	0.81	137.16	-2.55	0.0053	*
14	Forward-stretched arm reach (fingertip)	73.15	74.00	5.74	0.08	0.71	80.50	-1.28	0.1003	
15	Vertical reach (standing)	194.74	202.00	14.19	0.07	1.75	213.40	-1.32	0.0942	
16	Side arm reach	79.11	80.00	4.65	0.06	0.57	96.50	-3.74	0.0001	*
17	Arm span	156.78	153.00	7.71	0.05	0.95	182.90	-3.39	0.0003	*
18	Elbow span	79.71	80.00	5.11	0.06	0.63	100.00	-3.97	0.0000	*
19	Sitting height	81.46	78.00	8.05	0.10	0.99	90.70	-1.15	0.1253	
20	Shoulder height (sitting)	55.57	56.00	3.85	0.07	0.47	62.50	-1.80	0.0359	*
21	Eye height (sitting)	69.07	69.00	4.90	0.07	0.60	80.50	-2.33	0.0099	*
22	Popliteal height (sitting)	42.14	46.00	4.18	0.10	0.51	44.50	-0.56	0.2865	
23	Knee height (sitting)	49.67	49.00	3.42	0.07	0.42	54.60	-1.44	0.0747	
24	Buttock-toe length (sitting)	65.13	67.00	5.90	0.09	0.73	94.00	-4.89	0.0000	*
25	Buttock-popliteal length (sitting)	45.02	43.00	3.97	0.09	0.49	53.30	-2.09	0.0183	*
26	Hip breadth (sitting)	36.88	37.00	3.54	0.10	0.44	43.40	-1.84	0.0327	*
27	Vertical reach (sitting)	119.90	117.00	7.79	0.07	0.96	124.70	-0.62	0.2690	
28	Buttock-heel length (sitting)	98.34	93.00	7.87	0.08	0.97	124.50	-3.32	0.0004	*
29	Cross legged length	65.31	65.00	10.91	0.17	1.34	75.00	-0.89	0.1872	
30	Cross legged height	78.16	81.00	4.91	0.06	0.60	87.50	-1.90	0.0284	*
31	Kneeling length	53.98	53.00	6.37	1.05	0.78	62.50	-8.86	0.0000	*
32	Kneeling height	89.40	89.00	8.21	0.09	1.01	100.00	-1.29	0.0982	
33	Crawling length	109.91	100.00	10.64	0.10	1.31	-	-	-	
34	Crawling height	65.59	64.00	5.25	0.08	0.65	76.20	-2.02	0.0217	*
35	Bent length	73.69	78.00	7.80	0.11	0.96	-	-	-	
36	Bent height	102.39	97.00	8.35	0.08	1.03	-	-	-	
37	Squatting length	82.43	79.00	9.30	0.11	1.14	-	-	-	
38	Squatting height	94.91	95.00	6.91	0.07	0.85	-	-	-	

Underlined text denotes unisex references as gender specific references are not available.

Table 7. Survey mean and reference ratio comparison

Sl	Derived Dimension	Male (n=66)						Female (n=64)					
		Survey Mean	Reference (M/Unisex)	Survey Mean/Stature Ratio	Reference/Stature Ratio	Survey Mean/Arm Span Ratio	Reference/Arm Span Ratio	Survey Mean	Reference (M/Unisex)	Survey Mean/Stature Ratio	Reference/Stature Ratio	Survey Mean/Arm Span Ratio	Reference/Arm Span Ratio
1	Stature	169.34	188.6	1.00	1.00	0.98	1.03	155.84	172.8	1.0	1.0	0.99	0.94
2	Eye height	158.02	174.2	0.93	0.92	0.91	0.95	145.11	162.8	0.9	0.9	0.93	0.89
3	Shoulder height	141.40	155.7	0.83	0.83	0.81	0.85	129.95	141.4	0.8	0.8	0.83	0.77
4	Shoulder breadth	43.96	52.60	0.26	0.28	0.25	0.29	39.11	43.20	0.25	0.25	0.25	0.24
5	Elbow height	108.26	120.1	0.64	0.69	0.62	0.66	98.98	110.7	0.64	0.64	0.63	0.61
6	Knee height	49.43	53.3	0.29	0.28	0.28	0.29	45.45	53.3	0.29	0.31	0.29	0.29
7	Hand length	18.53	20.5	0.11	0.11	0.11	0.11	16.79	17.8	0.11	0.10	0.11	0.10
8	Side width (body depth)	24.04	33.0	0.14	0.17	0.14	0.18	26.70	24.1	0.17	0.14	0.17	0.13
9	Back to elbow	42.36	43.2	0.25	0.23	0.24	0.24	39.34	43.2	0.25	0.25	0.25	0.24
10	Raised elbow height	131.86	137.2	0.78	0.73	0.76	0.75	120.36	137.2	0.77	0.79	0.77	0.75
11	Forward-stretched arm reach (fingertip)	78.17	88.9	0.46	0.47	0.45	0.49	73.15	80.5	0.47	0.47	0.47	0.44
12	Vertical reach (standing)	214.73	224.8	1.27	1.19	1.24	1.23	194.74	213.4	1.25	1.23	1.24	1.17
13	Side arm reach	88.33	99.1	0.52	0.53	0.51	0.54	79.11	96.5	0.51	0.56	0.50	0.53
14	Arm span	173.52	182.9	1.02	0.97	1.00	1.00	156.78	182.9	1.01	1.06	1.00	1.00
15	Elbow span	87.49	100.0	0.52	0.53	0.50	0.55	79.71	100.0	0.51	0.58	0.51	0.55
16	Sitting height	86.58	96.5	0.51	0.51	0.50	0.53	81.46	90.7	0.52	0.52	0.52	0.50
17	Shoulder height (sitting)	58.44	69.3	0.35	0.37	0.34	0.38	55.57	62.5	0.36	0.36	0.35	0.34
18	Eye height (sitting)	75.18	86.1	0.44	0.46	0.43	0.47	69.07	80.5	0.44	0.47	0.44	0.44
19	Popliteal height (sitting)	45.26	49.0	0.27	0.26	0.26	0.27	42.14	44.5	0.27	0.26	0.27	0.24
20	Knee height (sitting)	53.42	59.4	0.32	0.31	0.31	0.32	49.67	54.6	0.32	0.32	0.32	0.30
21	Buttock-toe length (sitting)	69.15	94.0	0.41	0.50	0.40	0.51	65.13	94.0	0.42	0.54	0.42	0.51
22	Buttock-popliteal length (sitting)	46.72	54.9	0.28	0.29	0.27	0.30	45.02	53.3	0.29	0.31	0.29	0.29
23	Hip breadth (sitting)	35.25	40.4	0.33	0.21	0.20	0.22	36.88	43.4	0.37	0.25	0.24	0.24
24	Vertical reach (sitting)	130.79	131.1	0.77	0.70	0.75	0.72	119.90	124.7	0.77	0.72	0.76	0.68
25	Buttock-heel length (sitting)	103.94	117.1	0.61	0.62	0.60	0.64	98.34	124.5	0.63	0.72	0.63	0.68
26	Cross legged length	69.60	75.0	0.41	0.40	0.40	0.41	65.31	75.0	0.42	0.43	0.42	0.41
27	Cross legged height	83.56	87.5	0.49	0.46	0.48	0.48	78.16	87.5	0.50	0.51	0.50	0.48
28	Kneeling length	56.88	62.5	0.34	0.33	0.33	0.34	53.98	62.5	0.36	0.36	0.34	0.34
29	Kneeling height	99.08	100.0	0.59	0.53	0.57	0.55	89.40	100.0	0.57	0.58	0.57	0.55
30	Crawling length	119.60	147.8	0.71	0.78	0.69	0.81	109.91	-	0.71	-	0.70	-
31	Crawling height	69.24	77.5	0.41	0.41	0.40	0.42	65.59	76.2	0.42	0.44	0.42	0.42
	p-value for paired *t*-test	5.42654E-09		0.6036852			0.000198362	7.00667E-09		0.029700651			0.072590005

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ПРИГОДНОСТЬ СТАНДАРТОВ ДЛЯ ИНТЕГРАЦИИ ЭРГОНОМИКИ В АРХИТЕКТУРЕ: ЭМПИРИЧЕСКОЕ ИССЛЕДОВАНИЕ В БАНГЛАДЕШЕ

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Аннотация
Введение: Здания — важная часть нашей жизни, потому что мы проводим в них очень много времени. Основная задача архитектора состоит в обеспечении соответствия зданий, в которых мы живем, происходящей в них человеческой деятельности. Поэтому антропометрические данные — важный инструмент для архитектора. К сожалению, антропометрические данные, относящиеся к функциям, выполняемым в зданиях, относительно скудны даже в рамках академического опыта архитектора. Архитекторы в основном полагаются на несколько стандартов, которые могут не соответствовать местному населению. **Цель описанного здесь исследования** — внести вклад в восполнение этого пробела с помощью составления справочных антропометрических таблиц для населения Бангладеш, которые могут служить источником данных в области архитектуры. **Методы:** Антропометрические показатели 130 человек, 66 мужчин и 64 женщин, были измерены в 38 различных позах. Позы выбраны из стандартов и с учетом местной практики. Затем измерения были исследованы с помощью описательной статистики и подверглись сравнению со стандартами для проверки различий. **Результаты:** Сравнительный анализ показывает, что показатели населения Бангладеш значительно меньше; следовательно, применяемые стандарты не подходят для Бангладеш и, предположительно, Южной Азии. Для создания всеобъемлющей антропометрической базы данных необходимы дальнейшие исследования. Представленные измерения могут служить источником данных для проектирования жилых и других зданий в Бангладеш, а также в других странах Южной Азии.

Ключевые слова: стандарт, антропометрия, параметры тела, население Бангладеш, архитектура, эргономика.