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Anthropometric-Based School Furniture Design for Ethiopian Secondary School Students

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ABSTRACT

Schools are places where students develop their permanent sitting habits. The mismatch between students and school furniture dimensions has been associated with musculoskeletal disorders in adolescents. This paper aims to establish an anthropometric database for secondary school students in Addis Ababa and investigate the mismatch between the anthropometric dimensions of students and the dimensions of current school furniture. Two hundred students from four grades (9-12) and two secondary schools in Addis Ababa were randomly selected and measured for nine anthropometric parameters. Anthropometric data were calculated and displayed with mean, standard deviation, and the 5^{th}, 50^{th}, and 95^{th} percentile values. Results suggested high mismatch percentages between students' anthropometric measures and the school furniture dimensions, especially on seat depth and the upper edge of the backrest. Based on the anthropometric percentile values, acceptable furniture dimension ranges and recommended furniture dimensions were proposed. This study offers an anthropometric database and recommendations for future school furniture design in Ethiopia and subsequently helps to improve students' comfort and health in school.

Keywords: Secondary school students, Anthropometric data, School furniture design, Ethiopia

INTRODUCTION

Ergonomics is the scientific discipline concerned with understanding interactions among humans and other elements to optimize human health and overall system performance (Bridger, 2021). By creating products, furniture, and other gadgets that are suited to the specifications of the human body, we can improve human comfort, physical health, well-being, and performance.

Students take part in one of the most sedentary occupations. They spend an average of 5–8 hours in school daily. About 80% of this time, they sit in the classroom doing activities such as reading, writing, and communicating (Dhara et al., 2009). It has been suggested that schools are places where students develop their permanent sitting habits (Parvez et al., 2018). However, poor sitting posture during the school day causes school-aged children to have musculoskeletal pain, including back, neck, leg, and shoulder pain (Kaya

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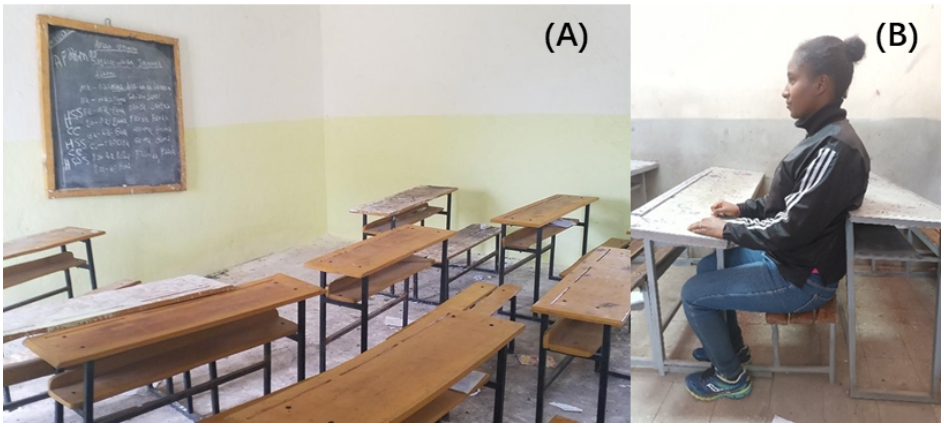

Figure 1: (A) Existing furniture in Ewket Le Hibret secondary school, addis ababa, ethiopia. **(B)** A subject's sitting condition in the classroom.

and Erkarslan, 2019, Milanese and Grimmer, 2004). The mismatch between the students' body and school furniture dimensions was considered a crucial ergonomic factor contributing to poor sitting posture (Saarni et al., 2009). For instance, when a chair is excessively high, the underside of the thigh becomes compressed, and there is improper foot contact with the floor, which causes discomfort and blood flow restrictions. The student is compelled to advance his buttocks on the chair seat as a result of this circumstance. When there is a lack of back support, students may sit with a slouched, kyphotic posture. When the chair is too low, the knee flexion angle decreases, the students' weight is distributed unevenly across the posterior thighs and is transferred to a limited area of the ischial tuberosities (Chung and Wong, 2007), with the pelvis tilts backward. Therefore, suitable and comfortable school furniture for students is necessary. Although many countries have proposed school furniture dimension guidance, least-developed countries (LDCs) such as Ethiopia still lack the support of an anthropometric database for school furniture design (see Figure 1).

This study aims to fill this gap by establishing an anthropometric database of secondary school students in Addis Ababa, Ethiopia, investigating the mismatch between students' anthropometric dimensions and current school furniture dimensions, and providing recommendations for future secondary school furniture design in Ethiopia.

METHODOLOGY

Sample Selection

For this study, regular secondary school students were considered as the user population. Two hundred students (85 (42.5%) male and 115 (57.5%) female) from four grades (9-12) and two secondary schools in Addis Ababa, Ethiopia, were recruited using the cluster sampling method (mean age 17 ± 1.4 years, mean height 5.4 ± 0.3ft). Every 25 subjects were randomly selected from each grade in each secondary school.

The sample size was set according to suggestions from World Health Organization that 200 is the minimum sample size used for building reference standards (Sellen, 1998). Before testing, all subjects were instructed about the contents of the experiment and provided their consent.

Data Collection

Dimensions of students and school furniture were measured manually by an experienced researcher. Length measurements were done with metallic tape. A plastic ruler was used to set the maximum reference point for measuring stature, sitting height, knee height, popliteal height, and thigh clearance. Nine anthropometric dimensions (see Table 1) and six school furniture dimensions (see Table 2) measurements were taken.

Table 1. Anthropometric measures (Castellucci et al., 2014).

Body dimensions	Descriptions
Stature (S)	The vertical distance between the floor and the top of the head, and measured with the subject standing erect and looking straight ahead
Shoulder Height Sitting (SHS)	The vertical distance from the subject's seated surface to the acromion
Elbow Height Sitting (EHS)	Taken with a 90° elbow flexion, as the vertical distance from the olecranon to the seated surface
Subscapular Height (SUH)	The vertical distance from the inferior angle of the scapula to the seated surface
Popliteal Height (PH)	Taken with 90° knee flexion, as the vertical distance from the floor to the popliteal surface
Thigh Thickness (TT)	The vertical distance from the highest uncompressed point of the thigh to the seated surface
Hip Width (HW)	The horizontal distance measured at the widest point of the hip in the sitting position
Buttock-popliteal Length (BPL)	Taken with a 90° knee flexion, as the horizontal distance from the posterior surface of the buttock to the popliteal surface
Buttock-knee Length (BKL)	Taken with a 90° knee flexion, as the horizontal distance from the posterior surface of the buttock to the front of the kneecap

Table 2. School furniture dimensions (Castellucci et al., 2014).

Furniture Dimensions	Descriptions
Seat Height (SH)	The vertical distance from the floor to the middle point of the front edge of the seat
Seat Depth (SD)	Distance from the back to the front of the sitting surface
Seat Width (SW)	The horizontal distance between the lateral edges of the seat
Upper Edge of Backrest (UEB)	The vertical distance between the middle points of the upper edge of the backrest and the top of the seat
Desk Height (DH)	The vertical distance from the floor to the top of the front edge of the desk
Seat to desk Clearance (SDC)	The vertical distance from the middle point of the front edge of the seat to the lowest structure point below the desk

Data Treatment and Analysis

Anthropometric measures were calculated and displayed using mean, standard deviation, and the 5^{th}, 50^{th}, and 95^{th} percentile values. Based on the percentile values of anthropometric measures and furniture dimensions, combinational formulas of furniture dimensions were set (see Table 3). The

Table 3. Dimension combination formulas (Castellucci et al., 2014, Osquei-Zadeh et al., 2012).

Measures	Formulas
Seat Height (SH) and Popliteal Height (PH)	$(PH + 2) \cos 30° \leq SH \leq (PH + 2) \cos 5°$
Seat Depth (SD) and Buttock-popliteal Length (BPL)	$0.80\ BPL \leq SD \leq 0.99\ BPL$
Seat Width (SW) and Hip Width (HW)	$1.1\ HB \leq SW \leq 1.3\ HW$
Upper Edge of Backrest (UEB) and Shoulder Height Sitting (SHS)	$0.60\ SHS \leq UEB \leq 0.80\ SHS$
Desk Height (DH) and Elbow Height Sitting (EHS)	$(PH + 2) \cos 30° + EHS \leq DH \leq (PH + 2) \cos 30° + 0.85EHS + 0.14\ SHS$
Seat Desk Clearance (SDC) and Thigh Thickness (TT)	$SDC > 2 + TT$

Table 4. Summary of anthropometric measures.

Parameters (cm)	Gender	Min	Percentiles			Max	Mean	SD
			5^{th}	50^{th}	95^{th}			
Age (years)		15				24	17	1.4
Stature	Male	158	161	172	183	188	172	6.6
	Female	150	150	160	171	183	160	6.3
	Combined	150	152	166	181	188	166	8.8
Shoulder Height Sitting (SHS)	Male	43	44	47	50	51	47	3.1
	Female	42	42	43	46	50	47	3
	Combined	42	42	45	49	51	45	3.3
Elbow Height Sitting (EHS)	Male	22	23	26	30	32	26	2.2
	Female	21	22	25	28	29	25	1.9
	Combined	21	22	26	29	32	26	2.1
Subscapular Height (SUH)	Male	34	35	39	44	46	40	2.8
	Female	25	28	33	39	47	33	3.3
	Combined	25	29	36	44	47	4	4.4
Popliteal Height (PH)	Male	41	42	42	43	43	42	0.5
	Female	40	41	42	43	44	42	0.7
	Combined	40	41	42	43	44	42	0.6
Thigh Thickness (TT)	Male	14	14	18	21	24	18	2.1
	Female	14	15	17	20	24	17	1.7
	Combined	14	14	18	21	24	18	1.9
Hip Width (HW)	Male	31	32	38	43	46	37	3.3
	Female	31	31	35	40	46	35	3
	Combined	31	31	36	42	46	36	3.4
Buttock-Popliteal Length (BPL)	Male	35	39	47	55	56	47	4.9
	Female	35	35	43	51	55	43	4.9
	Combined	35	36	45	54	56	45	5.2
Buttock-Knee Length (BKL)	Male	50	52	58	63	65	58	3.3
	Female	47	48	54	60	65	54	3.6
	Combined	47	50	56	62	65	56	3.9

mismatch percentages between body and furniture dimensions were subsequently calculated. According to Gouvali and Boudolos (2006), a mismatch is determined if the calculated value of the critical dimensions is outside the interval quantity (i.e., lower or shorter than the minimum, or higher or taller than the maximum values).

With the formulas and percentile values of anthropometric dimensions (see Table 4), three recommended chair-desk combinations were proposed for the 5^{th}, 50^{th}, and 95^{th} % of secondary school students in Addis Ababa, Ethiopia.

RESULT

The match and the mismatch percentages were calculated for both males and females (See Table 6). Table 4 shows the anthropometric measures of students. Table 5 shows the dimensions of the existing school furniture. We found that the seat depth and upper edge of the backrest displayed a mismatch percentage of 100%. The desk height was 100% matched with the student's body dimensions. Seat height showed a 17.3% and 15% mismatch percentage for males and females, respectively, when 49.3% and 40% of seat width did not match males and females. Seat-to-desk clearance manifested a mismatch of 13.3% and 20% for males and females, respectively.

Table 5. Existing furniture dimensions (cm).

Furniture Dimensions	Measurements
Seat Height (SH)	42
Seat Depth (SD)	26
Seat Width (SW)	41
Upper Edge of Backrest (UEB)	No backrest
Desk Height (DH)	70
Seat Desk Clearance (SDC)	17

Table 6. Match and mismatch percentages.

Furniture Dimension	Gender	Match	Lower Mismatch	Higher Mismatch	Total Mismatch
Seat Height (SH)	Male	82.6	0	17.3	17.3
	Female	88	0	12	15
Seat Depth (SD)	Male	0	100	0	100
	Female	0	100	0	100
Seat Width (SW)	Male	50.6	49.3	0	49.3
	Female	60	40	0	40
Upper Edge of Backrest (UEB)	Male	0	100	0	100
	Female	0	100	0	100
Desk Height (DH)	Male	100	0	0	0
	Female	100	0	0	0
Seat Desk Clearance (SDC)	Male	86.6	13.3	0	13.3
	Female	80	20	0	20

Table 7. Acceptable furniture dimension range (cm) based on body measurements for the chair-desk combination.

Design	Seat Height	Seat Depth	Seat Width	Upper Edge of Backrest	Desk Height	Seat to Desk Clearance
1st	37–43	29–36	34–40	25–34	59–67	16
2nd	38–44	36–44	40- 47	27–36	64–72	20
3rd	39–45	43- 54	46–55	29–39	68–76	23

Table 8. Recommended furniture dimensions (cm).

Design	Seat Height	Seat Depth	Seat Width	Upper Edge of Backrest	Desk Height	Seat to Desk Clearance
1st 5%	43	29	40	34	67	16
2nd 50%	44	36	47	36	72	20
3rd 95%	45	43	55	39	76	23

Tables 7 and 8 proposed the acceptable furniture dimension range and the recommended furniture dimensions based on the students' anthropometric measures, respectively.

CONCLUSION

In this study, we provided an anthropometric database of secondary school students in Addis Ababa, Ethiopia, and proposed recommendations for school furniture design, which may subsequently improve students' comfort and health in school. The results of this study showed that the chairs and desks of secondary schools in Addis Ababa were designed without considering most of the anthropometric features of students. Most students sit in chairs with seat depths too narrow and without a backrest, which may cause health problems such as back pain in the long term. Except for the desk height, all the rest parameters did not match the measured students' anthropometry.

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