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Ergonomic Evaluation and Establishment of Suitable Classroom Furniture Design Specifications for Secondary School Children in South-Western Nigeria

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Abstract
This research work compared the anthropometric dimensions of some secondary school students to the design dimensions of their chairs and desks to assess the furniture's appropriateness. A total of 840 students, with their chairs and desks, from fourteen secondary schools in seven states in south-western Nigeria, were measured. Popliteal height(PH), Buttock-Popliteal length (BPL), Hip breadth (HB), Shoulder Height (ShH), Elbow height (EH) and Knee height (KH)) of the children were measured using vernier callipers and an anthropometric chair. While Seat Height (SH), Seat Depth (SD), Seat Width (SW), Backrest Height (BH), Desk Height (DH) and Underneath Desk Height (UDH) were measured using a measuring tape. The SD and BH were suitable for the students, while major mismatches were noted in SH, DH and UDH. Using existing models, three types of chairs and tables were then proposed for the students.
Keywords: School furniture, Anthropometric Chair, Popliteal height, Desk Height

1. Introduction

Ergonomic consideration in the allocation of desks and tables for secondary school students has a lot of role to play in preventing some inherent health hazards and promoting effective learning process. School serves as work place for large percentage of any population in developed and developing country. Contrary to what one might assume, back problems are not confined to the adult population. A surprising number of secondary school students and adolescents are reported to have regular bouts of back, neck, and headache pain as discussed by Parcells et al. (1999). Of recent, several authors have advocated early back pain prevention through the school system since the school is the primary societal institution with the responsibility for health promotion. A possible explanation can be found in biomechanical studies, showing that sitting with a flexed trunk increases the spinal load, compared to standing, and showing that prolonged static sitting increases intradiscal pressure, resulting in decreased nutrition to the disc and also causing pain (Cardon *et al.,* 2004).

Students' sitting posture is influenced not only by the activities performed in the classroom, but also by the anthropometric dimensions of the children and the measurements and design features of the school furniture they use. Specific measurements such as popliteal height, knee height, buttock to popliteal length and elbow height are necessary in order to determine the dimensions of school furniture that will enable students to maintain the correct sitting posture (Metin and Kenan, 2008.). Due to the prolonged periods spent seated during school, it is in the schools that students acquire permanent habits of sitting. It is for this reason that public health concerns over the effects of bad posture need to be focused on the design of classroom furniture (Parcells et al, 1999).

If the seating surface is too high, the underside of the thigh becomes compressed causing discomfort and restriction in blood circulation. To compensate for this, a sitting person usually moves his buttocks forward on the chair seat. This can result in a slumped, kyphotic posture due to lack of back support (Hedman and Fernie, 1997; Corlett, 1999; Parcells et al and Panagiotopoulou et al, 2004).In addition, the feet do not have proper contact with the floor surface (heels are off the floor) and stability of the body is poor. On the other hand, if the seat surface is too low, a knee could hit the lower part of the table (Ramadan et al, 2005).

It has been reflected from many studies that there is a mismatch between the desks and tables dimensions and the anthropometric dimensions of the school children. Wrongly designed school furniture induces improper posture leading to operational uneasiness and musculoskeletal and some physiological disorders among school children. Studies have shown that being confined in awkward posture for specific task demand at a given situation or as influenced by badly designed furniture for a long duration provokes psychological stress and imposes ill effects on human performance (Khaspuri et al, 2007)

2. Methodology

2.1 Selection of subject

Sixty students were randomly selected from all classes in two schools in each state. A total of 840 students were selected from seven states in south-western Nigeria as shown in Table 1. The proportion of each gender was selected, based on their proportion in each school.

2.2. Anthropometric data

Different anthropometric dimensions of the school children were taken by adopting proper landmark definitions and standard measuring techniques (Khaspuri et al, 2007 and Chakrabarti and Das, 2004). All the body dimensions, namely: Popliteal height(PH); Buttock-Popliteal length (BPL); Hip breadth (HB); Shoulder Height (ShH); Elbow height (EH) and Knee height (KH), of the children were taken only from the right side of their body. The equipment used for the purpose were anthropometers: anthropometric chair

Table 1: Anthropometric data collected from secondary students in south-western Nigeria.

State	School	Male	Female
Lagos	1	30	30
	2	32	28
Ogun	3	28	32
	4	32	28
Oyo	5	30	30
	6	32	28
Osun	7	32	28
	8	32	28
Ondo	9	30	30
	10	30	30
Kwara	11	32	28
	12	28	32
Ekiti	13	30	30
	14	30	30

as designed by Gouvali and Boudolos, (2006) and vernier callipers as designed by Ajayeoba and Adekoya, (2009). Accuracy and repeatability of measurement were achieved by practice prior to the data collection sessions. All subjects were measured wearing their school uniforms and shoes and following the anthropometric definition according to Ajayeoba and Adekoya, (2009).

2.3 Design data

A total of 840 chairs and 840 desks belonging to the students considered above were also measured. Furniture design data were collected by measuring the furniture allocated to respective students in the classroom. Measurements of all design variables, (namely: Seat Height (SH); Seat Dept (SD); Seat Width (SW); Backrest Height (BH); Desk Height (DH) and Underneath Desk height (UD),of the classroom furniture(desks and chairs) were carried out using measuring tape (Gouvali and Boudolos, 2006).

2.4 Data Analysis

The anthropometric data were analysed using percentiles. The percentile for each dimension was calculated using the equation below:

$$P = \bar{x} \pm (s \times F) \quad \text{(i)}$$

P = Calculated value for the chosen (upper or lower) percentile,
$\bar{x}$ =Mean of the data,
s = Standard deviation,
F = Factor corresponding to the chosen percentile

In order to determine match and mismatch between the students' anthropometry and their allocated furniture, minimum dimensions were based on 75th, 95th or 99th percentile while the maximum dimensions were based on 1st, 5th, or 25th percentile.

2.5. Proposed Design Variables for Classroom Furniture

The various anthropometric data presented in percentiles above were used to determine the allowable design dimensions by adapting Gouvali and Boudolos, (2006). The allowable design dimensions for SH, SD, SW, BH, DH and UDH were determined as shown in equations (ii) to (vii), knowing that the students were measured with their school uniforms and shoes on:

i. Seat Height $PHcos30^o \leq SH \leq PHcos5^o$ (ii)
ii. Seat Depth $0.8BPL \leq SD \leq 0.99BPL$ (iii)
iii. Seat Width $1.1HB \leq SW \leq 1.30HB$ (iv)
iv. Backrest Height $0.6ShH \leq BH \leq 0.8ShH$ (v)
v. Desktop Height
$EH + [PHcos30^o] \leq DH \leq PHcos5^o + (0.8517EH) + (0.1483ShH)$ (vi)
vi. Underneath-desk height

$$KH + 2 \leq UDH \leq [PHcos5^{o} + (0.8517EH) + (0.1483ShH)] - 4 \quad \text{(vii)}$$

3.0 Results

3.1. Anthropometric Data

Table 2 shows the calculated percentiles of anthropometric dimensions of male and female students from the considered secondary schools.

3.2. Design data for desk and table

The comparisons between the predicted models for desks and chairs using proposed models by Gouvali and Boudolos, (2006) and the measured values are presented in Table 3.

Table 2: Relevant anthropometric data of secondary school students.

Anthropometric Dimension	Sex	1st	5th	25th	50th	75th	95th	99th	S D [cm]
PH	Male	41.19	42.72	44.69	46.48	48.02	50.23	51.77	2.28
	Female	42.21	43.54	45.44	46.80	48.13	50.06	51.39	1.98
BPL	Male	40.41	41.80	43.79	45.17	46.55	48.54	49.93	2.05
	Female	40.44	41.81	43.78	45.15	46.52	48.50	49.86	2.03
HB	Male	28.91	30.61	33.06	34.78	36.45	38.91	40.61	2.52
	Female	28.66	30.62	33.45	35.41	37.37	40.20	42.16	2.91
ShH	Male	47.37	48.83	50.93	52.40	53.86	55.97	57.43	2.17
	Female	48.41	49.84	51.93	53.37	54.81	56.89	58.33	2.14
EH	Male	9.71	10.9	11.94	13.4	14.86	16.97	18.43	2.17
	Female	9.62	10.8	11.93	13.37	14.81	16.89	18.33	2.17
KH	Male	49.89	51.72	53.79	56.48	58.22	61.33	63.07	2.28
	Female	51.01	52.84	54.84	57.1	58.43	61.37	63.59	1.98

4. Discussion

Table 3 shows the values of the selected percentiles: 5th, 50th and 95thand the corresponding predicted values of the design variables compared with the measured design values: minimum, average and maximum values respectively. Considerable levels of mismatch were observed during the comparison of the students' anthropometric and the design dimensions of their allocated furniture. Major mismatches are noted in SH, DH and UDH as commented in Table 3, while SW was only narrow for students in the 95th percentile. The SD and BH were suitable for the students because they fall within the predicted values. It was observed that most students in the lower percentile (mostly in the lower classes) did not use the required chairs and desks. They are using chairs and desks that were made for students in the upper percentiles (mostly the higher classes) so that they can use the same set of furniture throughout their secondary school days. Generally, it was observed that the inconveniencies experienced by the thighs/knees under the desks are due to the depth of the locker/drawer incorporated under the table, taken the space meant for the thighs/knees (as shown Figure 1and 2).

5. Conclusions and Recommendation

It has been established that no particular dimensions of chair and desk can comfortably fit all students. Likewise no student would be comfortable with the same size of chairs and desk for his or her six-year programme. Hence, to avoid musculoskeletal problems and other associated workplace hazards, appropriate chairs and desks should be allocated to the students. Chairs and desks with dimensions according to Table 4 will then be appropriate and comfortable for at least 95% of the students' population. Lockers should be provided separately for the students' properties or incorporated if possible within the little space remaining between the UDH and desktop.

Table 3: Anthropometric data as compared with the mean Predicted model for students' desks and chairs

Anthropometric Variable	Percentile	Value	Predicted Design Model	Measured value	Comment
PH	5th	42.72	38.73≤*SH*≤44.55	37.50	Short
	50th	46.80	42.26≤*SH*≤48.61	39.50	Too short
	95th	50.23	45.23≤*SH*≤52.03	41.50	Too short
BPL	5th	41.80	33.44≤*SD*≤41.38	39.50	Ok
	50th	45.17	36.14≤*SD*≤44.72	40.60	Ok
	95th	48.54	38.83≤*SD*≤48.05	41.50	Ok
HB	5th	30.61	33.67≤*SW*≤39.79	37.00	Ok
	50th	35.41	38.95≤*SW*≤46.03	39.50	Ok
	95th	40.20	44.22≤*SW*≤52.26	41.00	Narrow
ShH	5th	48.83	29.30≤*BH*≤39.06	37.00	Ok
	50th	53.37	32.02≤*BH*≤42.70	38.50	Ok
	95th	56.89	34.13≤*BH*≤45.51	40.00	Ok
DH	5th	10.80	47.80≤*DH*≤59.00	68.00	Too high
	50th	13.40	53.93≤*DH*≤65.95	68.90	High
	95th	16.97	60.47≤*DH*≤72.93	70.50	Ok
UDH	5th	51.72	53.72≤*UDH*≤55.00	49.00	Relatively Low
	50th	57.10	59.10≤*UDH*≤61.95	50.20	Relatively Low
	95th	61.37	63.37≤*UDH*≤68.93	52.50	Relatively Low

Table 4: Recommended Design Dimensions

Design Variables	Type A (cm)		Type B (cm)		Type C (cm)	
	Min	Max	Min	Max	Min	Max
SH	38.73	44.55	42.26	48.61	45.23	52.03
SD	33.44	41.38	36.14	44.72	38.83	48.05
SW	33.67	39.79	38.95	46.03	44.22	52.26
BH	29.30	39.06	32.02	42.70	34.13	45.51
DH*	47.80	59.00	53.93	65.95	60.47	72.93
UDH*	45.80	55.00	51.93	61.95	58.47	68.93

REFERENCES

Ajayeoba A. O. and Adekoya L. O. (2009). Ergonomic appraisal of aisles of *molue* buses in Nigeria. *The Ergonomia* IJE and HF, 30 (4), 309-317.

Cardon, G., De Clercq, D., De Bourdeaudhuij, I. and Breithecker, D., (2004). Sitting habits in elementary schoolchildren: A traditional versus a ''Moving school" *Patient Education and Couns*elling 54, 133–142

Chakrabarti, D. and Das, A., (2004). Design Development of a New Seat-desk Unit Suitable for Indian School Children. *Proceedings of National Conference on Humanizing Work and Work Environment, National Institute of Industrial Engineering*, April, Mumbai.

Corlett, E. N., (1999). Are you sitting comfortably*? International Journal of Industrial Ergonomics* 24, 7-12

Gouvali M.K., and Boudolos, K. (2006). Match between school furniture dimensions and children's anthropometry. *Applied Ergonomics* 37, 765-773.

Hedman, T., Fernie, G., (1997). *Mechanical response of the lumbar spine to seated postural loads*. Spine, 22, 734-743

Khaspuri G. C., Sau S. K. and Dhara P. C., (2007). Anthropometric Consideration for Designing Classroom Furniture in Rural Schools. *Journal of Human Ecology, 22 (3), 235 - 244*

Panagiotopoulou, G., Christoulas, K., Papanickolaou, A. and Mandroukas, K., (2004). Classroom furniture dimensions and anthropometric measures in primary school. *Appied Ergonomics 35, 121-128.*

Parcells, C., Stommel, M. and Hubbard, R.P., (1999). Mismatch of classroom furniture and student body dimensions: empirical findings and health implications. *Journal of Adolescent Health*. 24(4), 265–273.

Ramadan Z. M., Al-Harkan I. M., Helmy H. A., and Sharaf A. M., (2005). Testing and Validating of suggested Saudi furniture. *Applied Ergonomics*

Tunay Metin and Melemez Kenan, (2008). An Analysis of Biomechanical and anthropometric parameters on classroom furniture design.

Figure1: A student's desk and Chair

Figure2: A typical example of classroom setup