ERGONOMICS AND ANTHROPOMETRICS CONSIDERATIONS IN THE DESIGN OF OFFICE CHAIR FOR WORKERS IN KUMASI TECHNICAL UNIVERSITY IN GHANA

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ABSTRACT

Ergonomics is about 'fit': the fit between people, the things they do, the objects they use and the environments they work in. Sitting at work on a comfortable seat advances the comfort, health, well-being and safety of the person who uses the chair. The objective of the study was to define sizes for the production of a new office chair for office workers. A total of 84 administrative staff whose anthropometric data were collected participated in the study. The dimensions of the chair were derived from the percentiles (5^{th}, 50^{th} and 95^{th}) conversion of the participants' anthropometric data. In addition to the proposed dimensions from the ergonomics design, backward tilt of the seat surface of $20°$ to the horizontal, to prevent buttocks sliding forward and a lumbar support of the back rest inclined at $102°$ to the seat surface were applied in the design. Confirmation of fitness of the new office chair to the body measurements of the workers through evaluation exercise was carried out in the offices of the administration block.

Keywords: Ergonomics design, anthropometry, chair, Kumasi Technical University, Ghana.

INTRODUCTION

The aim of this study was to apply ergonomics principles to design a new office chair to match the body measurements of the workers. Ergonomics is about 'fit': the fit between people, the things they do, the objects they use and the environments they work in (Morag, 2003). Sitting at work on a comfortable seat advances the comfort, health, well-being and safety of the person who uses the chair. The thought of ergonomics is to bring comfort and wellbeing to participants who will patronize the chair. A Chair which is ergonomically designed helps workers to concentrate on office work in a comfortable posture for long periods (Grimes & Legg, 2004; Corlett, 2006; Trevelyan & Legg, 2006). Ergonomically designed products enhance product comfort and easy use (Harris *et al*., 2005; Ryan, 2009). Furniture designed for workplace and user body measurements have become a vital concern in designing furniture that is ergonomically appropriate (Chung & Wong, 2007; Harris *et al*., 2005). The applications of ergonomic design to address uncomfortable work seats in many workplaces today and lack of ergonomic principles in the design of workplaces and the results of health problems in body were discussed in the previous studies (Abeysekera, 1985; Ivelic *et al*., 2002). However, there is no literature on chairs that are non-ergonomically designed in public offices.

The objective of the study was to define sizes for the production of a new office chair for office workers. A total of 84 administrative staff whose anthropometric data were collected participated in the study. The dimensions of the chair were derived from the percentiles (5th, 50th and 95th) conversion of the participants' anthropometric data. This new office chair was also tested to ascertain its suitability to the administrative staff in their various offices. The outcomes from the study are presented in the results and analysis sections, where the study findings were elaborated extensively.

LITERATURE

Anthropometrics is the study of human body dimensions that relates to the initial measure and sizes of a piece of furniture (Deros *et al*., 2009). In designing products, one has to note that users come in many sizes and shapes (Openshaw & Taylor, 2006). The body measurements of the user population are very important as far as workstation design is concerned. This enhances comfortable and healthy posture (Helander, 1997). Anthropometric data are used for proper design of workstation, equipment and furniture (Mirmohammadi *et al*., 2011). Therefore, a human body measurement for a target population that is reliable is important in designing a product to suit the user (Ismaila *et al*., 2012); this may advance the comfort, health, well-being and safety of the one who uses the furniture (Pheasant, 1998; Barroso *et al*., 2005; Tunay & Melemez, 2008).

Sitting becomes tiring and painful if one sits in a poorly designed seat. Sitting is a means of changing posture and bringing rest (Croney, 1971). A chair is an object that is made for sitting (Fugate, 2004). A chair in many forms can be humble or royal and made of traditional wood or metal which is simple in idea or very much in meaning. Primarily, the needs for a chair are few. It is essentially a horizontal surface at a logical height from the ground to support the human body while in sitting position. A vertical surface of a chair is provided for back support. It can have arms or could be armless. While these are the basic elements, a chair is more than the sum of its component parts.

METHODOLOGY

Anthropometric data used for the sizes of new office chair

In this cross-sectional study to measure some anthropometric dimensions, administrative staff aged 24 – 51 years in Ghana was studied. The sample included 84 workers (49 males and 35 females). The data was gathered through dataset sheet. Ergonomics design of the office chair requires some anthropometric data (Ivelic *et al*., 2002). Through the dataset sheet, the anthropometric data relevant to the design of a chair included popliteal height to floor, buttock to popliteal length, elbow to seat height, sitting shoulder height, knee height and width of bitrochanter according to Syed *et al*. (2012). The study calculated the percentile values (5th, 50th and 95th) of the anthropometric data, which were helpful for designing a new office chair to be used by both male and female workers. This study was conducted following two major steps:

Firstly, a survey plan was set up to conduct the study at the administration block of Kumasi Technical University in Ghana. Within this survey plan, 84 workers with different body fit in terms of anthropometric measurements to support the ergonomic design in the office environment were considered.

Designing and production of a new office chair for administrative staff
This section went through possible solutions, development of selected solution, working drawing and exploded view, procedure of processes and operations for the production of the new office chair. The possible solutions were imaginative sketches with short notes to solve the problem of mismatches between human body dimensions and the dimensions of the patronized office furniture. Ideally, three or more sketches to solve the problem were thought of before one of them was taken as the selected solution. It was out of the selected solution that the solid object or product was made. In the development of the selected solution, three or more different shapes or forms for each part were developed and the best was selected.

The working drawings were prepared to show the details of the design in such projections as side view, front view and plan view. They were accurately constructed drawings, with dimensions, intended to give all the necessary information on the selected design of the product. Finally, the exploded view showed the components of the new office chair object slightly separated by distance. This section applied the right or appropriate measurements for the design and production of a new office chair. In fact, the production of the chair was controlled to conform to the users' body measurements.

Evaluation of the suitability of the new office chair for the administrative staff
The evaluation exercise was conducted in offices in the administrative block of Kumasi Technical University. Effectively, each user was given evaluation session of 6 hours in the evaluation exercise. Questionnaires on subjective methods (good seat points and chair feature evaluation checklist) were administered at the end of the sixth hour working session for each user. Under the chair feature evaluation checklist, researchers asked questions such as whether Seat Height (SH) was correct, whether Seat Depth (SD) was correct, whether Seat Width (SW) was correct, whether Seat Slope (SS) was correct, and whether Moulded Backrest (MB) fitted well. The study provided a detailed five-point scale which to this study was appropriate [1 = Strongly Agree (SA), 2 = Agree (A), 3 = Neutral (N), 4 = Disagree (D) and 5 = Strongly Disagree (SD)]. To determine the results of the assessment of chair feature evaluation checklist for subjects who patronized the chairs, descriptive statistics (frequencies, percentage) were employed. During the process, the new office chair was moved from office-to-office and data was recorded.

RESULTS

The outcome of the study survey was analyzed with respect to their importance and suitability to design and produce the proposed new office chair. The results were also categorized based on their corresponding anthropometric values, measures and explanations which are presented in the following sub-sections.

Definition of sizes for the design of a new office chair
The dataset consists of six (6) body dimensions relevant to the design of furniture for the administrative staff. The researchers estimated the following values for the most important body measurements used in the ergonomic design of a new office chair: the 5% value for the buttock to popliteal length in a sitting position was 446 mm; the 50% value for popliteal height to floor in a sitting position was 470mm and the 95% value for width of bitrochanter was 420mm (Table 1).

Table 1 Mean, Std. Dev and key percentiles of anthropometric dimensions for administrative staff

Dimensions (mm)	Mean	Std. Dev*	5^{th}	50^{th}	95^{th}
Popliteal height to floor	472.44	33.78	420	470	530
Buttock to popliteal length	501.22	33.98	446	505	552
Elbow to seat height	192.36	15.98	170	190	220
Sitting shoulder height	515.00	42.17	438	515	580
Knee height	606.24	21.86	565	610	640
Width of bitrochanter	372.39	37.03	316	370	420

*Std. Dev = Standard Deviation

Proposed dimensions for the new office chair

The recommended dimensions of the new office chair were arrived at as a result of the conversion of the anthropometric dimensions presented in percentile classification of measures applicable in furniture design by Goldsmith (1976) and Rahman & Shaheen (2008) (Table 2). The recommended dimensions in seat height, seat depth, armrest height, sitting shoulder height, desk clearance and seat width for the new office chair are presented (Table 3).

Table 2: Percentile values of relevant dimensions in anthropometric design of the new office chair

User – dimensions	Chair – dimensions	Percentile examples of application to design problem
Popliteal height to floor	Seat height	50^{th}
Buttock to popliteal length	Seat depth	5^{th}
Elbow to seat height	Armrest height	50^{th}
Sitting shoulder height	Backrest height	50^{th}
Knee height	Desk clearance	95^{th}
Width of bitrochanter	Seat width	95^{th}

Table 3 Recommended dimensions for the new office chair

Measurement	Chair Dimensions
Seat height (mm)	470 + heel height (32.5mm)
Seat depth (mm)	446
Height of armrest above seat pan (mm)	190
Minimum height of backrest (mm)	515
Desk clearance (mm)	640
Seat width (mm)	420
Angle between seat pan and backrest	102°
Seat slope	20°

The design and production of a new office chair for administrative staff of Kumasi Technical University

Possible solutions of a new office chair:

Footnotes

1. There is no orientation of the backrest.
2. There is no seat slope.
3. There is no support for lower back or lumbar region.

Figure 1: First imaginative sketch proposed for a new office chair to solve mismatch measures between body dimensions and office chairs for administrative staff

Footnotes

1. Good angle of backrest which is suitable for office executive seating posture.
2. The seat slope will fix the user in good sitting position.

Figure 2: Second imaginative sketch proposed for a new office chair to solve mismatch measures between body dimensions and office chairs for administrative staff

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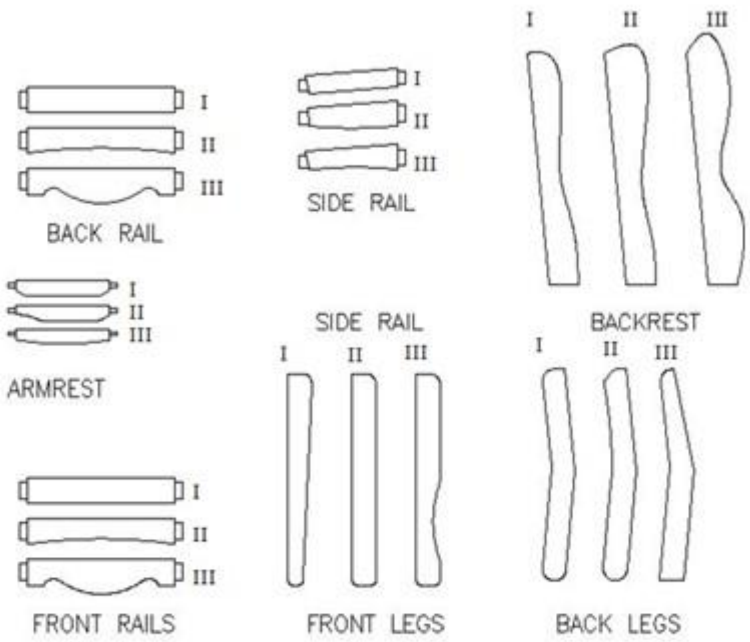
Footnotes

1. Good angle of backrest which is suitable for office seating.
2. The seat slope will fix the user in good seating position.
3. The back legs are made to slope to take off worst abuses such as leaning the chair backwards. Also, it widens its base for stability.

Figure 3: Third imaginative sketch proposed for a new office chair to solve mismatch measures between body dimensions and office chairs for administrative staff

Development of parts proposed for the new office chair:



The third from each set of shapes was used in the production of a new office chair.

Figure 4: Development of parts proposed for a new office chair for Administrative staff

Orthographic projections for the new office chair:

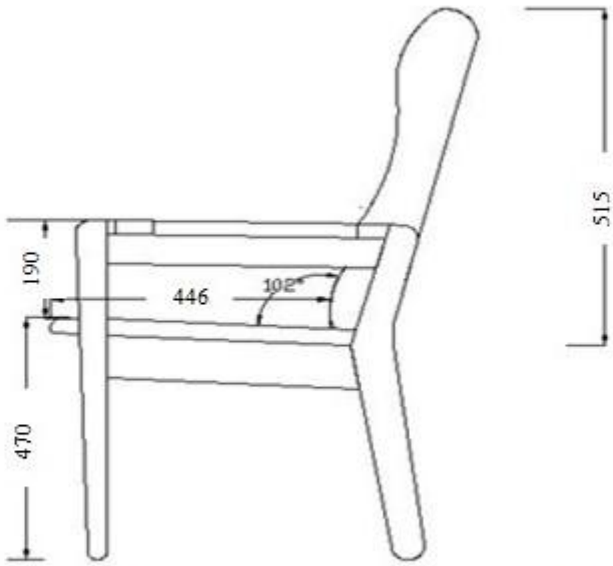


Figure 5a: Illustration of the side view (in millimeters) of the new office chair to be produced for Kumasi Technical University administrative staff

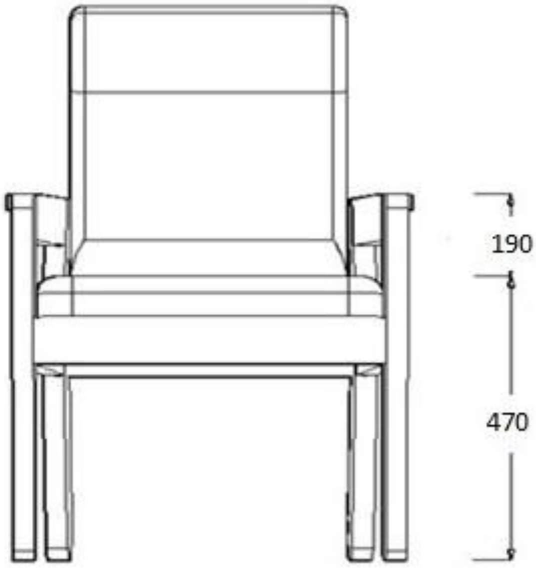


Figure 5b: Illustration of the front view (in millimeters) of the new office chair to be produced for Kumasi Technical University administrative staff

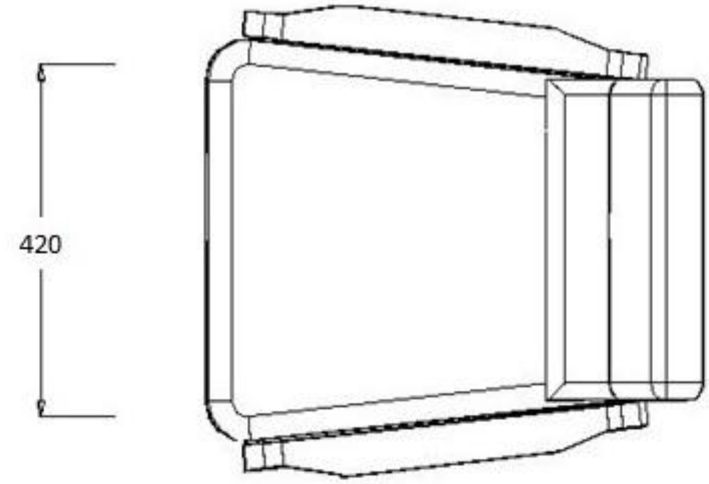


Figure 5c: Illustration of the plan view (in millimeters) of the new office chair to be produced for Kumasi Technical University administrative staff

Exploded view for the new office chair

Figure 6: Illustration of the exploded view of the new office chair to be produced for Kumasi Technical University administrative staff

Actual production for the new office chair

Operational sequence is the process which involves the planning of the production. It gives a general working procedure that can be followed in order to complete a designed project (Table 4). The general working procedures for the construction of most jobs are the selection of tools, setting out, cutting out, marking out of templates, cutting out of shapes (or pieces for the various parts), marking out of joints and cutting joints, try assembling, reassembling of joints, gluing of joints, final assembling and finishing. Machining operations that were undertaken included: shooting, ripping, planing, resawing, sanding, shaping, boring of mortise and cutting of tenon.

Table 4: Orderly procedure of the processes and operations for the production of the new office chair

No	Operation	Activities	Machine & Tools
1	Setting out	Preparing of template of the various chair components. One face and one edge of the beams are planed.	Surface planer
2	Marking out of templates	Mark out the templates on the work piece.	Pencil and tape measure
3	Cutting out	Ripping of beams to the required size (boards), plane to the required thickness.	Circular saw, thicknesser planer
4	Cutting out of shapes	Shaping through the work piece to obtain the various chair components.	Band-saw
5	Marking out of joints	Mark out mortise and tenon joints.	Marking gauge, pencil, tape measure, try square
6	Boring and cutting out tenon	Boring of mortise and cutting of tenon.	Mortiser and tenoner
7	Try assembling	Join corresponding components together and check for squareness and closed joints.	Mallet, try square, tape measure and Sash clamp
8	Reassembling of joints	Reassemble the various components and check for squareness and closed joints.	Mallet, try square, tape measure and Sash clamp
9	Gluing of mortise and tenon joint	Applying P.V.A. adhesive onto the mortise and tenon joints for the final assembling.	Brush
10	Final assembling	The various components were fixed together and clamped.	Mallet, sash clamp, try square and tape measure
11	Finishing	Surfaces and edges were prepared by fine sanding and dusted off. Primary coat was applied and sanded off twice. Finishing coat was applied and sanded off twice. Final coat was applied and left to cure.	Sanding paper, clean cloth and spraying machine

Chair feature evaluation checklists

Participants who agreed to the fact that the chair was of standard features ranged from 72 (85.71%) to 82(97.62%) (Strongly agree and agree were added) (Figure 7).

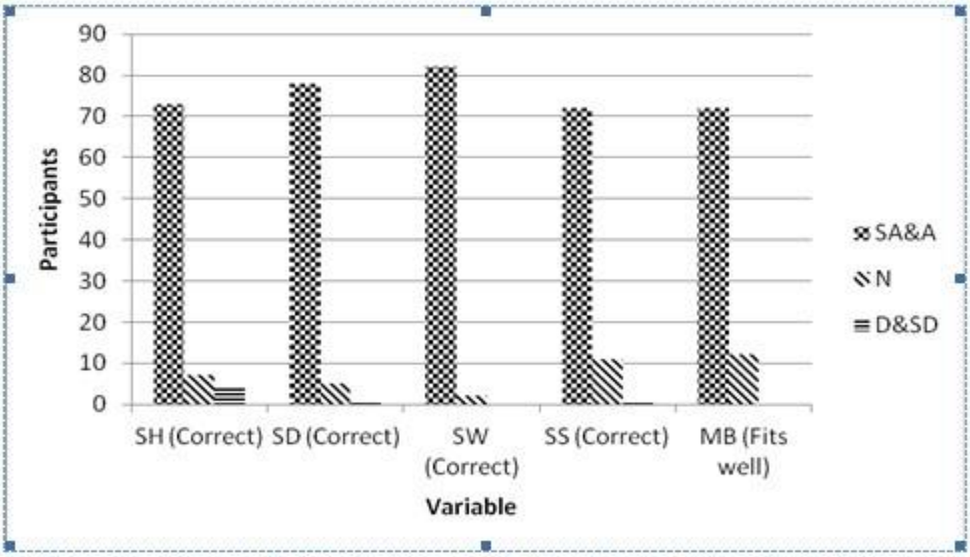


Figure 7: Response from administrative staff about new office chair feature evaluation

Good seat points

Majority of the participants (94.05%) who used new office chair reported that there was no difficulty in entering and leaving the chair, when they sat in to do office work. None of the participants experienced pain at the back of their knees while using the chair. Further, 82.14% felt comfortable in using the new office chair to do office work (Table 5).

Table 5: Participants responses from good seat points to assess the comfortability of the new office chair

Response	Comfortable number of participants	Number of percentage
Easy entry into chair		
Yes	79	94.05
No	5	5.95
Easy egress from chair		
Yes	79	94.05
No	5	5.95
Pain at the back of the knee		
Yes	0	0.0
No	84	100.0
Chair comfortability		
Uncomfortable	8	9.52
Average	7	8.33
Comfortable	69	82.14

DISCUSSION

Ergonomics also has the potential to eliminate injuries and disorders associated with the overuse of muscles, bad posture, and repeated tasks. To avoid developing or compounding back problems, it is important to have an office chair that is ergonomic designed, supports the lower back and promotes good posture.

Sitting becomes tiring and painful if one sits in a poorly designed seat. A good seat should allow for movement or a change in the sitting posture and space for easement to enhance best sitting posture for a lengthy period. Working in an office typically involves spending a great deal of time sitting in an office chair – a position that adds stress to the structures in the spine. The correct application of ergonomic principles reduces discomfort, fatigue and stress significantly. A seat should also be able to support the thorax, pelvis and to maintain the angle of the spine between them. Providing both a seat back that inclines backwards and has a lumbar support is critical to prevent excessive low back pressures. Another key to reducing lumbar disc pressure is the use of armrests. Armrests help by putting the force of the body not entirely on the seat and back rest, but putting some of this pressure on the armrests. Seat angle is the angle the seat makes with the horizontal. The seat slopes slightly backward to stop the user slipping out of the chair. The seat slope of 20° was recommended for the chair's construction. A recommended seat slope of 14^{o} – 24^{o} is good medically and ergonomically, which prevents buttocks from sliding forward (Abeysekera, 1985).

In order to properly design equipment and furniture, we should know the anthropometric characteristics of the target population. Thus, measurement of anthropometric dimensions is an important issue in different populations, age groups and genders. The key percentile values obtained from the anthropometric dimensions of administrative staff in this study (summarized in Table 1) which are of relevant dimensions in anthropometric design of the new office chair (summarized in Table 2) are presented in Table 3 as recommended sizes of the proposed chair.

Two questions need to be addressed: was the new office chair a good chair and is it possible the features of the chair construction appropriate for workers' anthropometry?

On the basis of the tests conducted, positive responses were recorded. The chair showed every indication of being designed according to ergonomic principles and performed very well when used in office environment.

CONCLUSION

In this study, the authors have tried to design a new office chair, which will give more advantages to the office workers at the administration block of Kumasi Technical University. This paper addresses a better approach to design and make of a new office chair, which will provide support to the body to eliminate musculoskeletal pain and discomforts. It is recommended to manufacturers to take proactive measures to apply ergonomics principles in their chair designs to arrive at dimensions that will fit the variations of anthropometric measurements of office workers in public institutions.

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