Anthropometric Chair Design for People with Down Syndrome

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Abstract

Down syndrome is a genetic disorder caused by the extra copy of 21st chromosome in human beings. People affected by Down syndrome have different anthropometric traits compared to rest of the population. They are shorter in height, have broader neck circumference, larger hip breadth and short hands. Many of the people affected with Down syndrome have desk jobs which require continuous sitting in the chair for a long period of time and causes musculoskeletal disorders among them. The office chair used currently is designed based on normal population. Musculoskeletal disorders (MSDs) maybe due to mismatch of their body anthropometry with normal chair. An ergonomic chair for people with Down syndrome was designed by considering their body anthropometric characteristics. The body measures of people with Down syndrome are collected and compared with the rest of the population. For designing the chair, 5th, 50th and 95th percentile of the anthropometric data was considered. It is found that people with Down syndrome needs chair with lower seat height, larger seat width and larger backrest width. The specific design of chair for people with Down syndrome will reduce their MSDs to a greater extent.

Keywords
Down syndrome, Anthropometric traits, Ergonomic chair, Musculoskeletal Disorders and Percentile.

1. Introduction
Down syndrome is a medical condition when the individual possesses an extra chromosome. Chromosomal disorder is due to cell division error (Temporal et al. 2017). According to a survey conducted by Centre for Disease Control and Prevention in 2021, 1 in 700 babies are affected with Down syndrome. The number of individuals with Down syndrome has increased in the 21st century (Krasniqi et al. 2022). People affected by Down syndrome have different body anthropometric traits while compared to rest of the normal population (Hassan et al. 2021). Studies conducted in the United States reveals that these people are employed in various fields like desk jobs, data entry, hospitality etc (Kumin and Schoenbrodt 2016). The quality of life these people should be increased as no cure can be done completely for this medical condition. Proper facilities should be provided to improve quality of work life providing ergonomic facilities. As most of the people prefer desk jobs, they use office chairs. They are engaged in jobs which need less physical effort. The office chairs in which they work now are designed based on anthropometry of the normal population. It may be difficult for them to use these chairs for long working hours as they have different body anthropometry. Anthropometry is the method in which human body dimensions are taken and studied. It is widely used in the field of ergonomics, automobile design, industrial engineering, clothing apparels design etc. Anthropometry is used in order to understand the body dimensions, design products etc (Dianat et al.2016). Using chair which have mismatch with ones body anthropometry can cause MSDs. The dimensions of chair like seat height, seat depth, seat width etc. are designed based on anthropometry. The dimensions of chair depends upon ones standing height, shoulder height, sitting height etc. (Santamaría et al. 2018). Usually for designing a workstation, anthropometric dimensions of people using the workstations are collected and designing is done based on suitable percentile (Kibria and Rafiquzzaman 2019). In the present study a anthropometric chair is designed for people with Down syndrome.

The conventional office chair that has been used by people affected with Down syndrome are designed based on the anthropometry of the normal population. Most of the people affected with Down syndrome are generally shorter in height. As height is an important parameter for designing a chair the existing design can cause discomfort for them. Similarly each parameter of chair is designed using suitable percentile of normal population. It is difficult for people

with Down syndrome to use those chairs for longer time period. The objective of present study is to design an anthropometric chair for people with Down syndrome. By collecting the anthropometry of them and normal population we can find out the significant differences. Designing a chair based on their anthropometry will motivate them to do for longer hours without any discomfort.

2. Literature Review

Most of the studies conducted on people with Down syndrome are based on cognitive thinking. Lukowski et al. 2018 in study stated that there are about 2 lakh individuals affected with Down syndrome are living in US. There is a linear decline in IQ starting from first year of life. Brains of infants have less dendritic branching. Young adults and older one have low brain volume relative to age and sex-matched controls.

Hassan et al. (2021) conducted study among children with Down Syndrome and normal children to find differences in their foot dimensions. The study revealed that children with Down Syndrome have wider and shorter width. According to Bertapelli et al. (2017), the growth rate of Down syndrome affected people at infant, childhood and puberty period are less compared to normal population when compared with the WHO standards. Their mean height is 20cm lesser than that of the normal population at the age group of 17-19 years old. Barboza et al. (2017),found that the body shapes of people affected with Down syndrome were classified into categories like hourglass shape, oval shape and triangular shape based on their bust size and hip size. Among female, oval body shape is predominant with larger neck width, shorter neck length.

Krasniqi et al. (2022) found that the number of people with Down Syndrome has increased in the 21st century. The use of gadgets among them from a very young age nowadays. If these skills are improved it can lead to an independent living for them. Feng et al. (2008), there is an increase in usage of computers among people affected with Down syndrome. The usage time varies from 4 hours to 46 hours a week for various activities. They use computers for academic purposes, recreational activities and job purposes. Kumin et al. (2015), found that people with Down syndrome are employed in various sections of the society. They are getting educated and searching for jobs in their field of education. Hospitality, desk jobs like data entry, front desks jobs are some of the sectors they are employed.

Çetinet al. (2020) seat comfort affects performance of the employees. If the workplace is poorly designed and job posture is improper there will be a decrease in job satisfaction among employees. Dianat et al. (2018), found that objects can be designed on the classification of designing for working population, designing for children, designing for general population, designing for elderly and disabled ones. Based on anthropometry designing can be done in user centre approach and population centre approach based on their field of application. According Kibria et al. (2019), female workers using thefurniture have a mismatch to their human anthropometry experiences severe back pain and neck pain. For redesigning the chair they collected the anthropometric characteristics of the users and calculated the 5^{th}, 50^{th} and 95^{th} percentile values. After that they found the mismatch between the existing chair design and the new proposed chair design.

The literature survey summarizes that there is an increase in the number of people with Down Syndrome. As the quality of life increased, their lifestyle changed. They wish to lead an independent life and desire to earn money on their own. Work related musculoskeletal disorders can be reduced by designing the workplace based on ergonomics. When a workplace is designed based on worker's anthropometry the job satisfaction can be increased. Most of the time the designs are done by considering a suitable percentile range.

3. Methods

The methodology used for designing the chair is shown in Figure 1. As the first step of methodology, the different anthropometric dimensions were collected for designing an ergonomic office chair. Collecting the anthropometric dimensions of the normal population used for designing the chair based on the standards followed by the region.The anthropometric dimensions of the people with Down syndrome should be collected in order to design the chair based on their comfort. Both the data were collected from secondary sources. After the collection of data's we need to analyse and compare both the controlled group and normal group. Comparison can be done to identify the major differences in body anthropometry. We will be able to study how they differ from each other and in what proportion. After this step we have to refer the Business and Institutional Furniture Manufacturer's Association guidelines to understand how to design the chair. After referring the guidelines we have identify the postures used during work.

Based on the guidelines we have to choose an appropriate percentile value for designing chair. The percentile values vary in different cases. The commonly used percentile values are 5th , 50th and 95th (Dianat et al. 2018).

Based on the collected data of the controlled population we can now design chair for them based on the standard guidelines and suitable percentiles. For each chair parameter we will be choosing specific percentile value. Provide room for adjustment if possible. Now we can compare dimensions of newly designed chair with the existing chair used by them. This will help us to find out the mismatch that existed. Through this comparison we will be getting better idea about how to design the chair .The collected data can be compared with the Indian normal population and Down syndrome affected population in Indian so that we are able to find how they are varying relatively with one another. From this we are able to design a comfortable chair for Indian population.

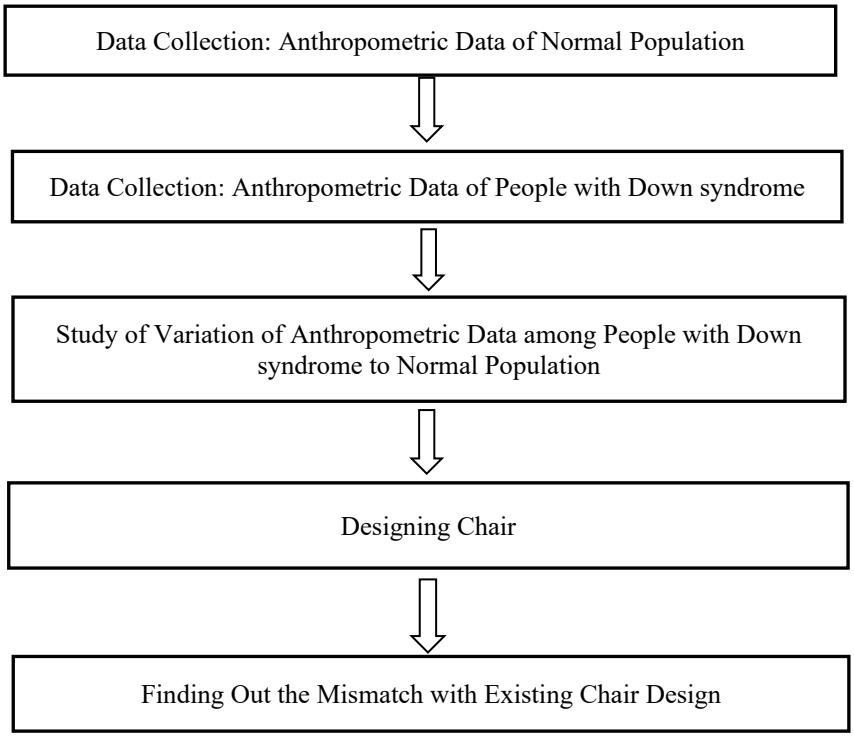


Figure 1. Methodology of the Proposed Model

4. Data Collection

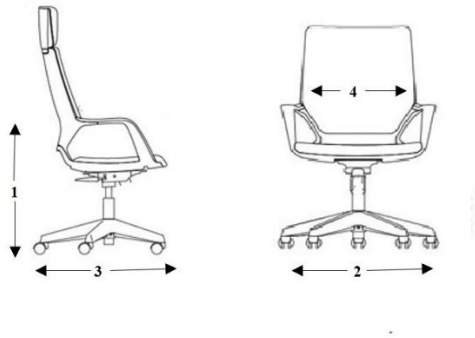
The anthropometric data of people affected with Down syndrome and normal population were obtained from a secondary sources based on a study conducted in the Portugal region. The various dimensions listed in the study are weight, height, crotch height, neck circumference, knee length, shoulder width, popliteal height, hip breadth etc. Out of these the required data for designing chairs were filtered out. These includes popliteal height, shoulder width, height etc. The anthropometric data of people with Down syndrome were measured using Kinect sensors in the following table (Barboza et al. 2017). The measurements were taken three time for accuracy. After collection of data the 5th, 50th and 95th percentile of collected samples are calculated (Table 1).

Table 1. Variation of Anthropometric Measurements (Barboza et al. (2017) and Barroso et al.(2005))

Measurement		Normal Population 5th Percentile	Normal Population 95th Percentile	Population with Down syndrome 5th Percentile	Population with Down syndrome 95th Percentile
Weight (kg)		48	80	44.76kg	84.06
Height (cm)		145.6	167.4	132	150
Hip Breadth (cm)		35.5	44.5	38.9	48.7
Popliteal Length (cm)		32.7	40.3	31.9	37.1
Waist Circumference (cm)		68.5	92.3	71.6	100.3
Sitting Elbow Height (cm)		20.4	31.5	19.3	27.3

5. Results and Discussion

In this section the chair dimensions are calculated using suitable percentile ranges for the collected anthropometric characteristics. The results obtained is discussed and compared with literatures. Figure 2 shows the dimensions of chair calculated.The chair dimensions are shown in Figure 2 given below. Each dimensions of chair are calculated using suitable percentile values.



1.Seat Height
2.Seat Width
3.Seat Depth
4.Backrest Width

Figure 2. Chair Dimensions

5.1 Seat Height

Seat height is designed by considering popliteal height and shoe allowance. While designing the seat height, the user must be able to place his feet comfortably. For a short person 5th percentile of popliteal height is used for design. A shoe allowance of 2.5 to 5cm can be provided. Adjusting knob can be provided to adjust the height of chair.
Seat height = 5th Percentile of Popliteal height + Shoe allowance
Here the seat height obtained is 35cm. According to Business and Institutional Furniture Manufacturer's Association (BIFMA) guidelines, seat height for office chair must be between 38cm-48.6cm.

5.2 Seat Width

95th percentile of female hip breadth is considered for designing the seat width. We should provide allowance for clothing. People with Down syndrome normally have higher hip breadth.
Seat width= 95th percentile of hip breadth of female+ clothing allowance

Seat width = 1.15*Biacromial Breadth
Seat width= 48.86cm
By BIFMA Guidelines seat width must not be less than 45.78cm.

5.3 Seat Depth

Seat Depth is measured based on the shortest height. 5th percentile of buttock-popliteal length is used for design. Excess seat depth can lead to comfortless. Seat depth here is 33cm. According to BIFMA Guideline it should not be deeper than 42.3cm

5.4 Backrest Width

50th percentile of hip breadth is considered for designing backrest width. Here the backrest width is 41.41 cm. According to BIFMA Guidelines backrest width must not be less than 36.06cm.

5.5 Armrest

Armrest are connected to seat surface. While designing chair for people with Down syndrome we must design armrest -in such a way to accommodate their shorter and broader hand. Pivoted Arm rest can be provided

5.6 Discussion

High prevalence of musculoskeletal disorders were found in users when products are not designed considering anthropometric characteristics. Users reported pain body parts including neck, shoulder, arms etc. (Kibria and Rafiquzzaman 2019, Taifa et.al 2016,Ansari et.al).Present study utilizes this concept. Designing chair based on anthropometry of people with Down syndrome can reduce the MSDs to greater extent. Barboza et.al (2018) found that the dominant shape among females affected with Down syndrome were oval. Other shapes found were hourglass, triangle, bottom hourglass, spoon, diamond etc.Among oval body shape bust size is higher than that of abdomen size. Waist circumference is higher compared to normality. In the present study female body of oval shape is considered to do the chair design. The 95th percentile of heightin Portugal region among normal population was found to be 167.4cm(Barroso et.al 2005). The 95th percentile value of people with Down syndrome was found to be 150cm. This value itself indicates the difference between normal group and subject group. Ansari et.al (2018) designed chair with adjustable armrest so that users can adjust height of elbow level to avoid the pressure.Designing workstation based on principle of adjustability accommodates wide range of users. This can also reduce the risk musculoskeletal disorder (Taifa etal. 2016).A height adjusting knob is provided in chair so that users can use them comfortably. Kibria and Rafiquzzaman designed chair for teachers in university considering their body anthropometry. They used 95th percentile of female hip breadth to design the chair's seat width. In this study also we considered the 95th percentile of female to design the seat width. The work stations are generally designed using 5th percentile and 95th percentile value considering suitability and to accommodate large number of users (Kushwaha et al. 2016). The chair's seat height was designed based on the 5th percentile value of popliteal height and seat width based on 95th percentile of female hip breadth to accommodate large number of users.

6. Conclusion

Ergonomic fundamentals were considered to design the workstation and provide comfort. The 5th , 50th and 95th percentile were used to calculate the suitable results. Suitable allowances were also provided. By designing the workstation following guidelines user's discomfort can be reduced which enhances their performance and productivity. While designing the workstation, safety guidelines should also be considered. The designing should follow the design for adjustability principle. The anthropometric dimensions play a vital role in the designing of a workstation. By using the collected data from different participants and based on the posture and nature of work the designing of workstation is done. When a workstation is designed based on anthropometric traits the MSDs were reduced to greater extent.The body anthropometry of people with Down syndrome are very different compared to the normal population. They are shorter in length compared to the normal population which make their seat height and seat depth shorter in length compared to existing chairs. Hip breadth and waist circumference are larger for them when compared to the normal population which results in increased dimension of seat width compared to existing design. Most office furniture are designed based on BIFMA Guidelines were not suitable for the subject group use for a long period of time. While calculating seat parameters it is evident that most of the dimensions calculated have high variation from the conventional design of chair. Since more people of the controlled group are getting educated and prefer to go to a job for a daily living we should design workstations comfortable to them considering their anthropometric traits.

The limitation of this research work is that the anthropometric characters collected are from secondary sources. All the calculations and comparisons were done for population in Portugal Region. Further research can be done by collecting the anthropometric traits of Indian population. Variations among subject group and normal group can be found and a new chair for Indian population can be done.

References

Annerén, G., Growth charts for Down's syndrome from birth to 18 years of age. *Archives of disease in childhood*, *87*(2), 97-103, 2002.

Barboza R., Carvalho, M., Ferreira, F., & Xu, B., Main Characteristics and Anthropometrics of People with Down syndrome–Impact in Garment Design. In *International Conference on Applied Human Factors and Ergonomics* (pp. 417-427) , 2017.

Barroso, M. P., Arezes, P. M., da Costa, L. G., & Miguel, A. S., Anthropometric study of Portuguese workers. *International Journal of Industrial Ergonomics*, *35*(5), 401-410, 2015.

Bieć, E., Zima, J., Wójtowicz, D., Wojciechowska-Maszkowska, B., Kręcisz, K., &Kuczyński, M., Postural stability in young adults with Down syndrome in challenging conditions. *PLoS One*, *9*(4), e94247, 2014.

Bertapelli, F., Agiovlasitis, S., Machado, M. R., do Val Roso, R., & Guerra-Junior, G., Growth charts for Brazilian children with Down syndrome: Birth to 20 years of age. *Journal of epidemiology*, *27*(6), 265-273, 2017.

Centres for Disease Control and Prevention, https://www.cdc.gov/ncbddd/birthdefects/downsyndrome.html, Accessed on October 2, 2021.

Çetin, M. S., Karabay, G., Öztürk, H., &Kurumer, G., Seating comfort satisfaction level of office workers and their expectations from an office chair. *Mugla Journal of Science and Technology*, *6*(1), 72-77, 2020.

Dianat I., Molenbroek, J., &Castellucci, H. I., A review of the methodology and applications of anthropometry in ergonomics and product design. Ergonomics, 61(12), 2018.

Dun, X., & Liu, Y., Study on design of female office chair based on ergonomics. In *E3S Web of Conferences* (Vol. 179, p. 02073). E3S Web of Conferences, 2020.

Gnanavel, R. C. P. C., Vishnu Bhat, B., Ramachandra Rao, K., & Rajesh, B., Anthropometric measurements in Down's syndrome children during pre-school period-Part I. *Current Pediatric Research*, *11*(1), 10-12, 2007.

Hassan, N. M., Buldt, A. K., Shields, N., Landorf, K. B., Menz, H. B., & Munteanu, S. E., Differences in foot dimensions between children and adolescents with and without Down syndrome. *Disability and Rehabilitation*, 1-8, 2021.

Ismaila, S. O., Akanbi, O. G., &Oriolowo, K. T., Relationship between standing height and popliteal height. In *Proceedings of the 2012 International Conference on Industrial Engineering and Operations Management Istanbul, Turkey, July* (pp. 3-6), 2012.

Krasniqi, V., Zdravkova, K., &Dalipi, F., Impact of Assistive Technologies to Inclusive Education and Independent Life of Down Syndrome Persons: A Systematic Literature Review and Research Agenda. *Sustainability*, *14*(8), 4630, 2022.

Kibria, M., &Rafiquzzaman, M., Ergonomic Computer Workstation Design for University Teachers in Bangladesh. *Jordan Journal of Mechanical & Industrial Engineering*, Jul 1;13(2), 2019.

Kumin L., &Schoenbrodt, L., Employment in adults with Down syndrome in the United States: results from a national survey. *Journal of Applied Research in Intellectual Disabilities*, *29*(4), 330-345, 2016.

Lukowski, A. F., Milojevich, H. M., & Eales, L., Cognitive functioning in children with Down syndrome: current knowledge and future directions. *Advances in child development and behavior*, *56*, 257-289, 2019.

Myrelid, Å., Gustafsson, J., Ollars, B., &Annerén, G., Growth charts for Down's syndrome from birth to 18 years of age. *Archives of disease in childhood*, *87*(2), 97-103, 2002.

Santamaría, A. M., Bonett, E. B., Rico, H. T., Vargas, S. A., &Mckinley, J. R., Anthropometrics General Sizing of a Didactic Instrumentation Workbench, 2018.

Sardinha, L. B., Santos, R., Vale, S., e Silva, M. J. C., Raimundo, A. M., Moreira, H., &Mota, J., Waist circumference percentiles for Portuguese children and adolescents aged 10 to 18 years. *European journal of pediatrics*, *171*(3), 499-505, 2012.

Taifa, I. W., & Desai, D. A., Anthropometric measurements for ergonomic design of students' furniture in India. *Engineering science and technology, an international journal*, *20*(1), 232-239, 2017.

Temporal, M. S., Catalá, A. Q., Salvador, J. O., &Cerdá, R. F. D., Anthropometric survey on children with Down syndrome. *International Medical Review on Down syndrome*, *21*(2), 27-32, 2017.

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