Ergonomic Design of a Computer Workstation for Preschool Students Studying at Home

Karylle E. Famero, Jared Z. Paguia and Maui T. Yumul
Young Innovators Research Center
Mapúa University - Makati
Makati, Metro Manila, Philippines
kefamero@mymail.mapua.edu.ph, jmzpaguia@mymail.mapua.edu.ph,
mvtyumul@mymail.mapua.edu.ph,

Ma. Janice J. Gumasing
School of Industrial Engineering and Engineering Management
Mapúa University
Manila, Philippines
mjjgumasing@mapua.edu.ph

Abstract

Technology has become an integral part of education in both courses that utilize it but also as an alternative method of teaching. Due to the current ongoing pandemic, online learning has been skyrocketing in popularity, raising concerns regarding the workstation setup of preschool students and how the current designs can lead to them having musculoskeletal disorders and other diseases. The researchers aimed to model an ergonomically designed workstation that is catered specifically to preschool students from the ages four to six. This was done through a survey to identify the factors affecting the students' comfortability through correlation and multiple regression analysis, along with their comfort levels which were evaluated using the Rapid Upper Limb Assessment tool (RULA) and Corlett's and Bishop's discomfort questionnaire. The results of the correlation analysis displayed that the sitting posture (r=, seat height, and table height strongly affect a preschooler's discomfort while using the workstation. Additionally, the regression equation implies that the RULA score and seat height both add to students' discomfort, while the backrest height greatly reduces it for every value that was added. With the results garnered, the researchers were able to design three chairs and four tables that are suitable for preschool students.

Keywords
Ergonomics, musculoskeletal disorders, preschoolers, workstation design

1. Introduction
Education is most effective when the learning environment of the students makes them feel connected with the instructor's discussions, whether it be traditionally or non-traditionally. Technology has become an integral part of educational institutions; not only in courses that utilize technology, but also as an alternative on the teaching and learning process. Statistics show that there has been an increased necessity for alternative learning modalities, most especially during this pandemic, with online learning being the commonly implemented modality used by numerous educational institutions. However, most countries are still unprepared to shift to these alternatives; having no adequate equipment or services for online learning (Dhawan, 2020). The use of computers and similar gadgets continue to become more necessary with the shift of schools to web-based e-learning. Consequently, related equipment that eases the use of these gadgets has become significant; such as computer workstations, that is fundamental for enhancing the learning environment of the students and improving their overall performance academically (Kiran, 2020). The use of computer workstations has been essential for children and adults alike, as it eases the use of electronic devices for longer durations. A poorly designed computer workstation may bring about several work-related musculoskeletal disorders and injuries, with the most common of them being tendonitis, epicondylitis, tension neck syndrome, and carpal tunnel syndrome to name a few. Due to the lack of workstations that are designed considering these factors, children five years or lower end up having these musculoskeletal disorders early in their adolescence, in which their body continuously undergoes change (Godilano et al. 2018a).

Several research papers recognize this problem and consider that these musculoskeletal disorders originate from poorly designed equipment made for learning, such as tables and chairs; whether it be outside or inside the classroom. A local study by Godilano, Galang, and Ramilo (2018b) noticed the arising problem most especially in public schools, thus settled in designing an ergonomic table and chair for preschool students in which they have gotten from a chosen number of public schools around Laguna. This paper may be beneficial to parents of preschool students who are currently taking classes online and may need to have a permanent workplace inside their homes. The presented design and information in this study may be used as a pattern or standard by the parents of these children in the event that they may want to set up a proper computer workstation for their children. Future researchers may also use this research to further investigate this field of study and potentially create more equipment related to the comfortability of children ages four to six.

1.1 Objectives
This paper aims to create a model of an ergonomically designed computer workstation that will be of use for children of ages four to six in taking their classes online. This paper also focuses on identifying factors affecting the students' comfortability while using the current workstation inside their homes by the use of correlation and multiple regression analysis. Along with this, the preschooler students' comfortability with the computer workstation currently used is also targeted to be evaluated through the use of the Rapid Upper Limb Assessment Tool (RULA) Worksheet and the Corlett's and Bishop's discomfort questionnaire, to aid in designing the computer workstation that is adjusted to their comfortability based on the risks posed by the two assessment tools. Furthermore, the dimensions of the model for both the table and chair of the computer workstation will be garnered through the computation of percentiles based on the anthropometric data collected from the respondents.

2. Literature Review
Good ergonomics contribute to increased productivity in the workspace. In general, institutions that skimp on ergonomic and comfortable environments often have people who are less efficient, less healthy, and even have lower morale. This applies not only with companies, but also educational institutions that contain classroom furniture used progressively used by children as they grow older. They can also lead to many issues down the road such as pains in the neck, lower back, shoulders, and hands while at the same time lowering blood circulation. These may lead to even more long-term issues such as increased blood pressure and metabolic changes.

2.1. A computer workstation design for preschool students
Before conceptualizing an optimal computer workstation for preschoolers, it is important to take note that children do not stay in one place. A study by McClelland et al. (2013) evaluated the attention span of preschoolers and college achievers and concluded that children understandably had the lowest value in attention span persistence. Moreover, an article stated that due to the tendency of children to easily become preoccupied, it greatly affects the student attainment of the child in contrast to traditional learning where the instructor and his or her students can interact freely (Dell, Low, & Wilker, 2010). Additionally, a study by Aagaard-Hansen and Storr-Paulsen in 1995 showed that children who are around the age of seven to eleven years opted for an ergonomic workstation while doing transcribed activities rather than the traditional workstation. The students had preferred an ergonomic workstation that was inclined at the ranges of 0° to 20°, with a chair that had a waterfall seat design. In the same year, a paper by Marschall, Harrington, and Steele validated the arising problem of poorly designed furnishings in the educational setting and an urgent need to produce furniture that considers the ergonomics of the children within the institutions. From the recent advancement of technology in this day and age, a computer workstation must ideally be a workstation that children will utilize in a range of different locations inside their home environment, such as the living room, the couch, or the dining table (Chen et al. 2014). It is also important to note that the size of the children's workstation matches to the anthropometric measurements of the child operating it (Dockrell et al. 2010b).

2.2. Musculoskeletal Disorders and Injuries
Modelling a computer workstation also involve ample consideration on musculoskeletal disorders, which greatly affect the comfortability of the operator as time passes. Middlesworth (2011) describe musculoskeletal diseases (MSDs) as disorders, symptoms, and injuries that relate to the musculoskeletal system and the movements of the human body. These disorders most commonly occur in regions such as the neck, shoulders, hands, elbows, and knees. They are most commonly associated with heavy labor and repetitive movements, with factors such as poor working conditions, traumatic experiences, and stress also playing contributing factors in the cause of MSDs (Biron Groupe Santé Inc., 2018; Gumasing & Espejo, 2020; Gumasing, Aruego & Segovia, 2020). In a related study by Ehsani

(2018), the most probable cause of the arising problem on MSDs is the inappropriate or unideal infrastructure in certain schools; wherein classroom furniture and other commonly used school furniture is terribly operated by the students. This can possibly lead to issues in musculoskeletal systems throughout all regions of the body. Additionally, there are also studies that mention schools not taking into account the anthropometry of their students in designing school furniture comfortable enough for daily use (Castelluci, 2016). The same issue applies to computer workstations that are built for children; whether be at home or at different areas such as their respective schools.

2.3. Anthropometry

Conventionally, it is not an oddity to take into consideration one's own bodily proportions and weight in daily life, or at the very least decisions that concern comfort and personal usage. Anthropometry, as discussed by Kroemer et al. (2018), originates from the field of anthropology which--in the past--observed the human race in a more cosmetic and even philosophical perspective. A study by Hebbal, Kumar and Qutubuddin (2013) takes into consideration the anthropometric measures of various students when designing a desk for college students. Though notably different from this own paper's demographic, the paper by the aforementioned researchers proves invaluable as it was found in their study that the locally manufactured desks, which notably had no specific considerations for anthropomorphic measures, were vastly different from the specifically engineered desks that were based on the anthropomorphic measures of the students. Taifa & Desai (2017) similarly dote on the topic of student furniture without proper measurement specifications. Their take on the similar issue, however, is that their design is centered around adjustable furniture. They bring up attentiveness of the students as a factor, similarly to how Hebbal (2015) discuss an inevitable decrease in comfort levels as the school day would progress; the difference, of course, being the discussed factor. Another notable factor in their research is how posture is affected, as they restate in their paper, albeit with more technical and scientific terminology, that improper body alignment may put a strain on the students due to opposing forces.

2.4. Body Discomfort Scale (Corlett's and Bishop's Scale)

The body part discomfort scale was an assessment tool proposed by Corlett and Bishop in 1976, while assessing the discomfort felt by airplane passengers on flight. Kremser et al. (2012) stated that having an unchanging and static posture can increase the risk in acquiring musculoskeletal discomfort. The process involved numerical rating scales and a body map to garner the data about the discomfort for each body part. The respondents are then tasked to score their discomfort on the specified body parts, which can be divided by the shoulder, legs, and the back. In present time, a simple questionnaire containing a numerical scale is given to the respondents in order to do this procedure, where one (one) is marked as extremely uncomfortable and five (5) being extremely comfortable. The duration of the process lasts depending on the time frame the passengers usually sit on the airplane seats, and the data garnered were analyzed using ANOVA and bar graphs, to determine which part of their body experiences the highest and lowest discomfort. The body discomfort scale is extremely significant for researchers when identifying not only body parts at risks for MSDs when modelling an ergonomic furniture, but also in assessing which part of that model is suggested to create a positive or negative impact on the subjective comfort of the respondents.

2.5. Rapid Upper Limb Assessment Tool (RULA)

There are various means to weigh if the design of an object is prone to ergonomic risks, such as the usage of the Rapid Upper Limb Assessment tool, which focuses on the presence of disorders found in the upper limb that may be experienced by the operator in using the equipment or workstation. This tool was formulated by Corlett and McAtamney in 1993, which they had intended to be applied simply by pure observation, without the use of inaccessible tools. A journal article by Namwongsa et al. (2018) elaborated that this mode of assessment uses a group of formulated diagrams of body postures and assigning numerical values for differing postures of the body parts. The use of the RULA tool has been present in many research papers, especially in adults. Recently, studies on the health of adolescents and adults in engaging in activities using the Internet has been a popular inclination by researchers (Chen et al. 2014). However, there are several papers of researchers utilizing RULA in assessing the postures of children under the age of 5; such as a study by Godilano et al. (2018c) in which they proposed an ergonomic design of a classroom chair for preschoolers in selected public schools, devised based on the results of a number of ergonomic assessment tools, which included RULA.

3. Methods

The conducted research followed a quantitative method that focused on obtaining the numerical, mathematical, and statistical analysis of data through questionnaires and surveys (Creswell, 2013). The selection of respondents was performed through convenience sampling, which is a form of non-probability sampling that revolves around the convenience of gathering respondents and ease of access for the researchers (Saunders, 2012). The said method was utilized as other methods was not be possible as a result of the current pandemic. The respondents consisted exclusively of preschool students aged four to six who are currently taking online classes during this pandemic one's homes. It is also limited to preschoolers who only use a table and a desk to do their school works; hence, bed tables and children who work on the floor are not included. The researchers garnered a total of forty respondents. An online survey questionnaire was constructed based on the data needed to be garnered, where it is subjected to various statistical treatments.

One of these methods included the Pearson's correlation coefficient which is applied for correlation analysis. This statistical treatment is done to measure the degree of association of the independent variable to the dependent variables that can have three possible results: a positive correlation, a negative correlation, and zero correlation. When done correctly, the numerical values acquired will either show a positive or negative correlation. If the correlation coefficient is 0.0 to 0.19 (or -0.19 to 0.0), then the correlation strength is very weakly positive or negative. A correlation coefficient of 0.40 to 0.59 (or -0.59 to -0.40) is moderately positive or negative. In this paper, a very strong positive correlation is needed, therefore a correlation coefficient of 0.80 to 1.00 is only considered.

Aside from Pearson's correlation analysis (r), regression analysis was applied to describe how an independent variable is associated with the dependent variable, that was also computed using the Minitab software. The main equation used is equation 1, and once tabulated correctly, the result is a linear regression equation. Once the equation is identified, it can now be used to construct prediction regarding the data.

$$y = a + bx \quad (1)$$

Along with these, the computation of anthropometric percentiles was also performed so as to obtain the workstation dimensions recommended for the model computer workstation. An article by Wang and Chen (2012) defined percentiles as the measurement used to determine whether the anthropometric measurements obtained falls below or above the population; if it is close or far from the 'average' value of the common people. The study considered the 5^{th} and 95^{th} percentiles to obtain the dimensions. The fifth percentile characterizes a small body frame that most females have; while the 95th percentile depicts a common, average characteristic of a male body, wherein it is portrayed as a physique that is quite bigger than the female form. These percentiles, along with other anthropometric principles are applied to acquire the recommended workstation dimensions for the proposed computer workstation design for preschoolers. A mismatch analysis was also done before the modelling, which involved checking whether the workstation dimensions garnered from the questionnaire matches the recommended workstation dimensions that was generated by the researchers.

4. Data Collection

The researchers conducted a survey for the first half of the research to obtain data that will ultimately determine the proposed design of the research., then, researchers sought for potential respondents through relatives and friends who were willing to participate in the research. The total respondents of the study are 100 (50 males and 50 females). The questionnaire contained questions regarding the considered factors in the study, a section dedicated for inputting workstation measurements, a body discomfort scale, and a section for uploading a picture of their child's posture while utilizing the computer workstation they currently own. The data gathered was then summarized and categorized to separately interpret the data, where it is tabulated in the Minitab software for correlation and multiple regression analysis. Afterward, the pictures uploaded were analyzed and interpreted using the RULA worksheet, to identify if the children's posture truly calls for a change in design. The results from the Corlett's and Bishop's discomfort scale was also interpreted to identify which body parts experience the most discomfort. Lastly, the anthropometric measurements were used for computation of the recommended workstation dimensions. A mismatch analysis was also done before starting on the 3D design. Afterward, the researchers planned and designed the proposed design in Google Sketchup, taking note of the summarized interpreted results to improve the designs for the table and chair. Once done, the design was directly subjected for checking to the thesis adviser. Revisions were made based on the comments of the thesis adviser. The final proposed design was then captured, but did not include measurements; as it only served as a basis for modelling a similar chair and table for the viewers reading the study.

Lastly, the researchers discussed the results of the collected data and correlated the results with the proposed design of the researchers. Demographic data obtained from the survey questionnaire was used to determine the relationship between the independent and dependent variables of the study. The discussion of results served as the phase wherein the researchers will evaluate and assess the proposed design, to ensure practicability and if there are instances that must be modified accordingly.

5. Results and Discussion

The data from survey questionnaire was interpreted by initially acquiring the mean difference among the factors considered in the study. The researchers applied one-way ANOVA to the data garnered from the questionnaire, so as to prove that the factors mentioned do in fact affect the discomfort of the preschool students in the currently owned computer workstation, and that there is indeed a need to create a more ergonomic design designed for the preschooler's body dimensions.

Table 1. One-way ANOVA result based on age of respondents.

Age	**Mean**	**P-value**	**Result/Interpretation**
4 years old	23	0.711	No significant difference
5 years old	25.67		
6 years old	26.57		

The outcome from the one-way ANOVA is shown in Table 1 shows that there is no significant difference in the discomfort scores of respondents based on age having a p-value > 0.05. However, based on the result, preschooler students who are six years old experience the highest discomfort, displaying that the average discomfort of six-year-old students is 26.57. On the other hand, four-year-old students experience the least discomfort, with an average of 23. Five-year-old preschool students are in the middle, with an average discomfort of 25.67.

Table 2. Two sample t-test results based on gender.

Gender	**Mean**	**P-value**	**Result/Interpretation**
Female	25	0.751	No significant difference
Male	26.3		

The results on the t-test as displayed in Table 2 show that there is no significant difference in the discomfort level of the respondents based on their gender since the p-value > 0.05. However, the male respondents had a slightly higher average discomfort of 26.3 as compared to the female respondents with an average discomfort of 25.0.

Table 3. One-way ANOVA result based on area of study.

Area of study	**Mean**	**P-value**	**Result/Interpretation**
Bedroom	24.57	0.447	No significant difference
Living room	28.25		
Dining room	21.67		

The results of the one-way ANOVA test in Table 3 show that there is no significant difference in the discomfort levels of the respondents based on their area of study. This is because the P-Value is > 0.05. The area wherein the respondents experienced the highest discomfort score was the living room with a score of 28.25, followed by the bedroom with a score of 24.58, and finally the dining room with a score of 21.67.

Table 4. One-way ANOVA result based on duration of study.

Duration of study	**Mean**	**P-value**	**Result/Interpretation**
Less than 3 hours	25.84	0.001	There is a significant difference.
3 to 4 hours	26.00		
4 to 5 hours	36.25		

The results of the one-way ANOVA test result in Table 4 indicates that there is a significant difference in the discomfort levels of the respondents based on the duration of study since the P-Value is < 0.05. Specifically, those who spend 4 to 5 hours studying experienced a significantly higher level of discomfort with a mean of 36.25 as compared to those who spend < 3 hours or 3 to 4 hours with means 25.84 and 26.00, respectively.

Table 5. Two sample t-test result based on time of day.

Time of the day	**Mean**	**P-value**	**Result/Interpretation**

Morning to noon	27.4	0.002	There is a significant difference
Afternoon to evening	16.57		

Table 5 shows a two-sample t-test result stating that students studying from morning till noon have significantly higher discomfort scores than students studying from afternoon to evening. This is due to the fact that the mean score for morning to noon garnered 27.4 as compared from afternoon to evening with 16.57 of mean score. Moreover, the p-value of both variables is less than 0.05 therefore justifying that the discomfort score of students based on the time of the day they study has a significant difference.

Table 6. One-way ANOVA result based on type of chair.

Type of chair	Mean	P-value	Result/Interpretation
Monobloc	23.75	0.001	There is a significant difference
Wooden	32.82		
Office	20.11		
Metal	40.00		
Stool	34.40		

Figure 6 shows the result of one-way ANOVA based on the type of chair that the preschool students use. The outcome indicates that there is a significant difference among the variables for its p-value is < 0.05 to be specific, its p-value = 0.001. It is shown that preschoolers using metal chairs experience the greatest discomfort with an average discomfort of 40. In addition, those who use stool chairs have an average of 34.40 while students that use chairs of wooden material have an average discomfort of 32.82. Among the chairs, the office chair had the lowest discomfort score with an average of 20.11.

Table 7. One-way ANOVA result for type of table.

Type of table	Mean	P-value	Result/Interpretation
Wooden	24.13	0.345	No significant difference
Plastic	25.45		
Glass	32.40		

Table 7 shows the result of one-way ANOVA based on the type of table that the preschool students use. The outcome indicates that there is no significant difference among the variables for its P-value is > 0.05 to be specific, its p-value = 0.345.

5.1. Correlation analysis

Correlation analysis was also implemented to further investigate whether the factors in the study do have possible connections toward the discomfort scores of the preschool students. Moreover, it aided in determining which factors have a strong relationship toward one another. Pearson's correlation was utilized in the correlation analysis of the numerical values for all factors. Table 5 shows the summary of results from the transcription of data in Minitab software.

Table 5. Correlation of factors to the discomfort scores of preschool students.

Factors	R-value	Remarks
RULA	0.919	Strongly positive
Seat Height	0.857	Strongly positive
Seat Depth	0.177	No association
Seat Width	0.138	No association
Backrest Height	0.240	Weakly positive
Table Height	0.862	Strongly positive
Table Depth	-0.041	No association
Table Width	0.016	No association

Among the factors shown above, only the sitting posture (RULA), seat height and table height show a positive discomfort score, thus, indicating that these factors strongly affect a preschooler's discomfort in using the computer workstation for long periods of time.

5.2. Regression analysis

Regression analysis was also utilized to further investigate the relationships of the aforementioned factors to the discomfort of the preschoolers while using the currently owned computer workstation. This is done to determine the overall significant effect of the factors toward the discomfort of the students. Table 6 shows the generated statistical data below.

Table 6. P-value and coefficients for the discomfort scores of preschoolers.

Term	Coefficient	P-value
Constant	-6.17	0.017
RULA	5.735	0.000
Seat Height	0.328	0.019
Backrest Height	-0.01182	0.027

The regression equation indicates how the variables included within affected the discomfort score of the preschooler students while using the computer workstation. In the equation, the following variables or factors that strongly affect the students' discomfort are the sitting posture, seat height, and backrest height.

5.3 Proposed Improvements

The anthropometric measurements obtained from the respondents were categorized and sequestered based on gender. Afterwards, the minimum, average and maximum percentiles for each anthropometric measurement are computed which will be vital for the mismatch analysis. Table 7 displays the anthropometric percentiles of the respondents of the study based on gender.

Table 7. Summary of Anthropometric Measurements

Body Dimension	Male (n=50)			Female (n=50)		
	5^{th} %	50^{th}%	95^{th}%	5^{th}%	50^{th}%	95^{th}%
Stature	105.8	114	123	104.41	112.95	120.7
Shoulder height, standing	81.83	88.67	96.8	81.05	88.03	95.08
Elbow height, standing	64.9	71.26	78.14	64.64	70.75	77.07
Sitting eye height	37.8	42.7	46.5	36.5	41.9	45.2
Elbow to elbow breadth	23.62	28.98	35.14	23.08	28.47	34.66
Forearm length	13.77	16.11	18.24	13.27	15.61	17.69
Thigh clearance	28.4	33.5	43.31	28.18	33	40.81
Hip breadth, sitting	20.42	23	27.73	19.92	22.74	26.17
Buttock popliteal length	26.28	29.9	34.02	26.18	29.89	33.78
Popliteal height	24.3	27.01	29.46	24.02	26.89	29.14
Elbow rest height, sitting	15.06	17.63	20.92	14.74	17.66	20.88
Functional forward reach	29.49	34.94	40.48	28.81	34.22	39.28
Shoulder breadth	25.75	28.55	33.05	25.48	28.29	32.5

Table 8 shows the workstation dimensions and the corresponding body parts for each. The third column displays the percentiles chosen for each dimension, considering and assuming the fact that a small figure will be using the design. Once established, the recommended dimension is obtained. The gender to be chosen depends on whose measurements are lower than the other. The whole process was repeated to obtain the values for each workstation dimension.

Table 8. Recommended Workstation Dimensions

Dimensions	Body Part	Percentile	Gender	Recommended Dimension
Seat Height	Popliteal height + shoe height	5^{th} % (min)	Female	24.01 cm
Seat Depth	Buttock popliteal depth	5^{th} % (min)	Female	26.18 cm
Seat Width	Hip breadth	95^{th} % (max)	Male	27.73 cm
Backrest Height	Sitting shoulder height	5^{th} % (min)	Female	30.85 cm
Backrest Width	Elbow to elbow breadth	95^{th} % (max)	Male	35.14 cm

Table Height	Seat height + sitting elbow height	5th % (min)	Male	38.76 cm
Table Depth	Functional forward reach	5th % (min)	Female	59.08 cm
Table Width	Functional forward reach + elbow to elbow breadth + functional forward reach	5th % (min)	Female	83.1 cm

The researchers proposed three chair models and four table models that were all designed with improvements in reducing risks of musculoskeletal injuries for preschool students. The seven proposed models are mainly made out of wood and plastic, based on the results of the mismatch analysis performed by the researchers. Additionally, improvements on these proposed models are discussed.

Figure 1. Proposed chair models

Figure 1 displays the three chair models created in Google Sketchup. Improvements on these models include adjustability features for the backrest and seat height, which address the lumbar area of the body. With an adjustable backrest, weight is eliminated at the lower back. Moreover, two of these models have cushioned seats, while one model includes a seat pan that easily adjusts to the user's shape when used. A cushioned seat aids in dispensing the operator's weight and also prevents soreness by lessening the pressure when sitting. These cushions also have rounded corners, which is crucial as it allows blood to circulate at the back of the legs and knees, and also reduces pressure. In addition, one of these models have a detachable footrest. An ideal chair is one that allows the user's feet to touch the floor, otherwise a footrest is highly advisable as it relieves tension for the feet. The following improvements were considered following the results and interpretation from this study along with an evaluation paper on the discomfort scores of students based on chair designs (Alnaser & Wughalter, 2010). Additionally, a local study by Curbano (2015) dotes on a similar topic, including improvements made addressing body parts experiencing the highest discomfort in their study.

Figure 2. Proposed table models

Figure 2 exhibits the four table models created by the researchers in Google Sketchup. The improvements include relieving discomfort for the neck, forearm, and legs by adding the ability to adjust the desk height. A low desk or a high desk will cause poor posture and neck pain. Besides this, along with an adjustable seat height, having an adjustable desk height will aid in providing comfort in the forearms and adequate space for the legs to move while using the workstation. Moreover, a few of these models have a tiltable desk which addresses the discomfort felt in the eyes and neck. A tiltable desk is an additional feature, but it greatly aids in lessening eye strain for the user, and decreases the risk of obtaining other visual problems. It is recommended that the desk is slightly tilted below gaze inclination. These improvements are added not only following the generated data from this study but also a similar paper by Kibria and Rafiquzzaman (2019) where the researchers detail the required ergonomic improvements along with modelling a chair for an ergonomic computer workstation.

6. Conclusion

With the lack of sufficient related studies on school equipment that is ergonomically designed for children aged four to six years old, the researchers have successfully created a model of an ergonomically designed computer workstation that will be of use for children within the age range. Based on the results of the Rapid Upper Limb Assessment (RULA) Scores, the researchers were able to determine the body parts that experienced the highest discomfort levels to be the upper back, lower back, and the shoulder.

With regard to the statistical analysis of the data, it was determined that the factors which had the greatest effect on the discomfort levels of the respondents were the duration of study and the type of chair used, while the other factors that were taken into consideration had proven to not have a significant effect on the discomfort level. Moreover, the mismatch analysis proved that wood as a material is best suited for chairs and tables that are designed for preschoolers; along with those made of monobloc or plastic. It is also observed that metal as the material is highly discouraged. This study also indicated that the anthropometric percentiles computed for the study favored the female preschooler students; with its lowest dimensions consistently falling under the female anthropometric percentiles gathered. In the event that the parents want to set up a suitable computer workstation for their children, the design and details provided in this study may be used as a pattern or standard. Furthermore, this study has met the optimal design by intricately utilizing the recommended dimensions for both table and chair. Finally, a total of three designs for a chair were made, while four designs for a table was also created. Different models were designed with various features depending on the preference of the users that is also adjusted to their comfortability.

References

Alnaser, M. Z., and Wughalter, E. H., Effect of chair design on ratings of discomfort, *Work*, vol. 34, no.2, pp. 223–234, 2010.

Binboğa, E., and Korhan, O., Posture, musculoskeletal activities, and possible musculoskeletal discomfort among children using laptops or tablet computers for educational purposes: A literature review. *Journal of Science Education and Technology*, vol. 23, no. 5, pp. 605-616, 2014.

Biron Groupe Santé Inc., What is a musculoskeletal disorder (MSD)?, Available: https://www.biron.com/en/education-center/neat-little-guide/musculoskeletal-disorders/, May 7, 2018.

Castellucci, H. I., Arezes, P. M., Molenbroek, J. F. M., de Bruin, R., and Viviani, C., The influence of school furniture on students' performance and physical responses: results of a systematic review, *Ergonomics*, vol. 60, no. 1, pp. 93-110, 2016.

Chen, J. D., Falkmer, T., Parsons, R., Buzzard, J., & Ciccarelli, M., Impact of experience when using the Rapid Upper Limb Assessment to assess postural risk in children using information and communication technologies. *Applied Ergonomics*, vol. 45, no. 3, pp. 398-405, 2014.

Curbano, R. J., Development of an ergonomically designed drafting table and chair for engineering students of LPU-Laguna based on anthropometric measurement, *Laguna Journal of Multidisciplinary Research*, vol. 4, no. 3, 2015.

Dell, C. A., Low, C., and Wilker, J. F., Comparing student achievement in online and face-to-face class formats, *Journal of online learning and teaching,* vol. 6, no. 1, pp. 30-42, 2010.

Dhawan, S., Online learning: A panacea in the time of COVID-19 crisis, *Journal of Educational Technology Systems*, 49(1), pp. 5-22, 2020.

Dockrell, S., Earle, D., and Galvin, R., Computer-related posture and discomfort in primary school children: The effects of a school-based ergonomic intervention, *Computers & Education*, vol. 55, no. 1, pp. 276–284, 2010.

Dockrell, S., O'Grady, E., Bennett, K., Mullarkey, C., Mc Connell, R., Ruddy, R., Twomey, S., and Flannery, C., An investigation of the reliability of Rapid Upper Limb Assessment (RULA) as a method of assessment of children's computing posture, *Applied Ergonomics*, vol. 43, no. 3, pp. 632-636, 2012.

Godilano, E.C., Galang, M.K., Ramilo, H.E., and Velayo, K.R., Design of an ergonomie classroom chair and desk for preschool students of selected public schools in Cabuyao City, Laguna, *2018 5th International Conference on Industrial Engineering and Applications (ICIEA),* pp. 420-423, 2018.

Gumasing, M.J.J., Aruego, J.C., Segovia, F.M., Work Classification and Workstation Design for Person with Functional Difficulty (PFD), ACM International Conference Proceeding Series, 2020, pp. 90–96

Gumasing, M.J.J., Espejo, E.J.E., An ergonomic approach on facilities and workstation design of public school canteen in the Philippines, Proceedings of the International Conference on Industrial Engineering and Operations Management, 2020, 0(March), pp. 1662–1671

Hebbal S.S, A C S Kumar, and M, Q. S., Anthropometric Consideration for Designing Students Desks in Engineering Colleges, *International Journal of Current Engineering and Technology,* vol. 3, no. 4, pp. 1179-1185, 2013.

Kibria, M., and Rafiquzzaman, M., Ergonomic computer workstation design for university teachers in Bangladesh, *Jordan Journal of Mechanical & Industrial Engineering*, vol. 13, no. 2, 2019.

Kiran, D. R., Ergonomics and work study, *Work Organization and Methods Engineering for Productivity*, pp. 219–232, 2020.

Kroemer, K. E., Kroemer, H. B., and Kroemer Hoffman, A. D. (2018). Size and mobility of the human body, *Ergonomics: How to Design for Ease and Efficency*, no. 3, pp. 3-44, 2018.

McClelland, M. M., Acock, A. C., Piccinin, A., Rhea, S. A., and Stallings, M. C., Relations between preschool attention span-persistence and age 25 educational outcomes. *Early childhood research quarterly*, vol. 28, no. 2, pp. 314-324, 2013.

Middlesworth, M., Definition of musculoskeletal disorder (MSD). Available: https://ergo-plus.com/definition-of-musculoskeletal-disorder-msd/, December 7, 2011.

Namwongsa, S., Puntumetakul, R., Neubert, M. S., Chaiklieng, S., and Boucaut, R., Ergonomic risk assessment of smartphone users using the Rapid Upper Limb Assessment (RULA) tool, *PLOS ONE*, vol. 13, no. 8, 2018.

Saunders, M., Lewis, P. and Thornhill, A., Research methods for business students. Available: https://research-methodology.net/sampling-in-primary-data-collection/convenience-sampling/, 2018.

Taifa, I. W., and Desai, D. A., Anthropometric measurements for ergonomic design of students' furniture in India, *Engineering Science and Technology, an International Journal*, vol. 20, no. 1, pp. 232-239, 2017.

Wang Y, Chen H.J., *Handbook of Anthropometry*, 1st Edition, Springer, New York, pp. 29–48, 2012.

Biographies

Karylle E. Famero is a Grade 12 STEM Senior High School student from Mapúa University – Makati. She completed elementary and junior high at San Beda University – Rizal. She is planning to continue her studies in Mapúa University at the Intramuros campus where she will take Architecture or Industrial Engineering.

Maui Vien T. Yumul is a Grade 12 STEM Senior High School student from Mapúa University – Makati. She completed her junior high at Paco Catholic School-Manila. She is planning to take up Nursing as her Pre-Med course in University of Santo Tomas, straight up to medical school in the same institution.

Jared Matthew Z. Paguia is a Grade 12 STEM Senior High School student currently studying at Mapúa University – Makati. He completed junior high at Southville International School and Colleges and is planning to take either Electrical Engineering or Mechanical Engineering at Mapúa University.

Assoc. Prof. Ma. Janice J. Gumasing is a Professor of School of Industrial Engineering and Engineering Management at Mapua University. She has earned her B.S. degree in Industrial Engineering and Masters of Engineering degree from Mapua University. She is a Professional Industrial Engineer (PIE) with over 15 years of experience. She is also a professional consultant of Kaizen Management Systems, Inc. She has taught courses in Ergonomics and Human Factors, Cognitive Engineering, Methods Engineering, Occupational Safety and Health and Lean Manufacturing. She has numerous international research publications in Human Factors and Ergonomics. She has been awarded as Woman in the Academia (WIA) 2019 during International Conference of Industrial Engineering and Operations Management held in Bangkok, Thailand, Young Researcher Award in 2020 International Conference

of Industrial Engineering and Operations Management held in Dubai, UAE and Outstanding Conference Contributor Award in 2021 International Conference of Industrial Engineering and Operations Management in Singapore.