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Design Proposal for a Rotating Children's House Using Anthropometric Approach and Hand Tools

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ABSTRACT

Early childhood, especially under the age of 5, is a critical period for the development of intelligence, with research showing that at the age of 4, a child's intelligence capacity has reached 50%, increasing to 80% at the age of 8. The focus of this study is the redesign of playground equipment, especially children's playhouses, using an anthropometric approach to ensure safety and comfort for children. This study involved 30 children aged 3-5 years with body dimension measurements that support ergonomic design. Normality tests showed the right distribution data using the 95th and 5th percentiles of body dimensions, ensuring a safe and comfortable design. The test results showed this design is more suitable for children living in the city because it showed a 15% increase in safety and 20% comfort.

Keywords: *Anthropometry, Ergonomic Design, Child growth pattern, Body dimension*

Introduction

The development of children's intelligence at the age of 5 years and under is the golden age. One of the research results states that at the age of 4 years, children's intelligence capacity has reached 50%, and 80% capacity is reached at the age of 8 years [1]. [1]This shows the importance of providing stimulation in early childhood before entering school. Even children aged 1 to 5 years are known to have photographic memory abilities, remembering like a camera eye [2] This age is the most appropriate time to start educating a child. By utilizing education at an early age, children are introduced to interesting and fun learning patterns [3] Creative learning patterns will make children more quickly grasp existing learning. They become happy to learn new things because the learning process feels like a play [4]. This happens because development itself is a complex process of change involving various elements that influence each other. In big cities, many children do not have a yard to play in, so city parks and playgrounds are significant and often the only place for children to play [5]. The high demand for play space along with adequate play facilities has become a must for the government to provide if it wants the next generation to have good physical and mental development [6]

Providing adequate facilities for children's playgrounds has become an awareness in many developed countries, but it has not been a major concern in Indonesia. [7]. However, Indonesians increasingly realize the importance of nearby playgrounds [8]. The introduction effectively highlights the significance of early childhood development. It would, however, benefit from a more lucid explanation of the research gap. Give a detailed description of the shortcomings in playground equipment designs and how this study uses an anthropometric method to fill these gaps. Furthermore, provide current research on playground ergonomics to support the rationale for your investigation. This can be seen in the increasing number of playgrounds in new residential areas and shopping centers in urban areas. If not well planned, providing playgrounds can pose a risk of accidents for children [9]. Therefore, the design of playgrounds should consider ergonomic principles to ensure the safety of children according to their stage of development. Along with the times, human creativity in creating products is increasing, with a focus on comfort and safety for consumers [10]. Applying ergonomic principles in product design plays a crucial role in minimizing the risk of injuries and ensuring users' comfort, particularly in the context of children's playground equipment. To achieve this, it is important to customize the product to the size of the human body, as each individual has different body characteristics[11]. In making games, children's comfort and safety must be prioritized, with designs that fit body dimensions and ensure sufficient movement to reduce the risk of obesity. Anthropometry, the study of the characteristics of the human body, is important to ensure products are comfortable and safe to use.[12].

Anthropometry is defined as the science of measurement and the art of applying human physical properties[13], one of the most important factors to consider in designing a product. Products that meet ergonomics rules are designed according to the dimensions of the user's body[14]. Thus, he can use the product effectively, safely, healthily, comfortably, and efficiently. In addition, products designed by human anthropometry can improve work performance and productivity and reduce the frequency of work accidents [15].

Therefore, this study was conducted to redesign playground equipment in kindergarten. The play facilities to be redesigned include a children's playhouse. A good play facility should be designed to be safe and comfortable so that it does not pose a potential hazard to children [16]. The ergonomic design will be recommended for all play facilities. The essence of ergonomics is the principle that work must be adapted to the abilities and limitations of humans (fitting the job to the man) [17], [18], [19]. This means that in designing a type of work, it is necessary to consider what factors are the advantages and limitations of humans as work actors. One of the human limitation factors that must be considered is the limitation in body dimensions [20]

Children's playground equipment in urban areas often does not consider ergonomics, leading to discomfort and injury [21]. In this study, an anthropometric approach is used in playground design in Indonesia to fill this gap by emphasizing the potential of measuring children's body dimensions to improve the safety and comfort of playground equipment. This study aims to fill the gap in playground equipment design by applying an anthropometric approach to redesigning a children's playhouse. In addition, this study will also review relevant ergonomic principles and how international safety standards such as ISO 8124 and ASTM F1487 are applied in the design of children's play equipment [22]. The reliability of anthropometric data is essential to improving the safety, comfort, and suitability of products for children. Recent research has shown the importance of using up-to-date anthropometric data in designing children's products to prevent discomfort and injury and meet international safety standards [23], [24], [25]. By understanding the concept of anthropometry and hand tool design, this study is expected to provide benefits for researchers in understanding the details of the interaction between humans, machines, equipment, and work environments and the importance of design to prevent injuries. This study can produce designs for playhouse makers that follow needs and improve children's comfort and safety while playing.

Research Methods

Research Subjects

Thirty male and female children aged 3 to 5 were the subjects in this anthropometric and hand tools research.

Object of Research

This research aims to measure the human body to design rotary house products. The size of this rotary house is also flexible and can be used by boys or girls.

Research Tools and Materials

The tools and materials used in this research are operator demographics, anthropometric data of operators, measuring meter, observation sheet, and cell phone camera. The collection of anthropometric data is carried out using tools such as digital stadiometers and scales to measure body mass and density, as well as flexible scales and meters to measure specific body dimensions. Children must be positioned honestly during the measurement process, and each measurement is double-checked twice to ensure accuracy. In gathering data, a tendency that frequently makes it difficult to remain focused and attentive arises from the limited intention of children aged three to five. A variety of low birth weights, such as tremors or incapacity to participate, might also affect the outcome. Maag berpartisipasi dengan orang tua, karena mereka membantu anak-anak berpose dalam pengukuran. Because of this, it is necessary to use engaging and interactive research methods to obtain accurate and representative data [26].

Research Flow

The research procedure begins with preparation, which includes preparing everything needed. The first step is to identify the problem and research objectives based on the background so that the goals to be achieved from this research can be determined. Furthermore, the researcher conducted a literature study by reading deductive and inductive studies from previous studies and relevant journals. Data was then collected through observation and measurement of the operator's body dimensions, which were recorded and analyzed. After collecting the data, a normality test was conducted using SPSS software to ensure data distribution. Data adjustments are needed if the data is not normally distributed (sig. <0.05). Then, the researcher determined the right percentile for product redesign, using the 95th percentile for maximum design, the 50th percentile for average, and the 5th percentile for minimum design. The researcher also applied a repeated measurement procedure to reduce measurement errors. The anthropometric data obtained included sitting height, hip width, and popliteal height. The 95th and 5th percentiles were used to ensure that all sizes, from the smallest to the largest children, could be accommodated in the playhouse design [27]. After that, the researcher redesigned the product based on anthropometric calculations and ergonomic guidelines. The conclusion of this study was made based on data analysis and overall discussion. It provided recommendations for product improvement so that users feel comfortable and safe from the risk of injury. This study ended with the completion of all planned stages.

Results and Discussion

Operator Data

The following is a table of operator body dimension data used as a sample to represent the population at **Table 1:**

Table 1. Body Dimensions

Body Dimensions	Explanation	Usability of the Re-Design to be Performed
Sitting Upright Height (TDT)	Measure the vertical distance from the seat's base to the top of the head. The operator sits upright with eyes looking straight ahead and forming an angle	Calculating the distance from the stand to the roof
Hip Width (LP)	The operator sits upright measure the horizontal distance from the right and left side hips.	Measuring the width of the stand
Popliteal Buttocks (PPO)	Measure the horizontal distance from the buttocks' outer part to the knee's inner curve. Thigh and lower leg form a 90° angle	Measuring the length of the stand
Popliteal Height (TPO)	Measures the vertical distance from the floor to the inner knee	Measuring the height of the stand from the footing
Palm Length (PTT)	Measuring the vertical distance (height) of the hand from the tip of the middle finger to the wrist and the hand is extended	Measuring the thickness of the steering wheel
Maximum Width (LBMAX)	Measuring the farthest horizontal distance from the thumb to the little finger	Measuring the bulkhead distance on the steering wheel

Table 2. Data Operator

Name	Age	Gender	Body Dimension (cm)					
			TDT	LP	PPO	TPO	PTT	LBMAX
Respondents 1	4	P	53,2	18	23	30	17	29
Respondents 2	4	L	62	23	29	29	28	26
.								
.								
Responden 30	3	P	42	17	46,5	21	29	20,6

Data Processing

Normality Test

In the normality test that has been carried out, researchers use an accuracy or significance level of 95% with a hypothesis test:

Ho: the population is normally distributed
H1: the population is not normally distributed with the basis of decision making based on:
If the significance value (sig.) > 0.05 then Ho is accepted If the significance value (sig.) > 0.05 then H0 is rejected

Tests of Normality

	Kolmogorov-Smirnov[a]			Shapiro-Wilk		
	Statistic	df	Sig.	Statistic	df	Sig.
LP	.118	30	.200*	.930	30	.049
PPO	.094	30	.200*	.962	30	.343
TPO	.089	30	.200*	.960	30	.305
TDT	.107	30	.200*	.985	30	.929
PT	.134	30	.178	.957	30	.254
LBMAX	.126	30	.200*	.952	30	.191

*. This is a lower bound of the true significance.

a. Lilliefors Significance Correction

Figure 1. Test of Normality table

The normality test results in figure 1 shows that the significance value (Sig.) of all dimensions in the Kolmogrov-Smirnov column is>0.05, so Ho is accepted. The data above is normally distributed, so it can be used as a reference for anthropometric product innovations and hand tools.

Percentile Calculation

The following is a percentile calculation of the body dimensions that will be used in the product design made by the researcher:

Table 3. Result of Percentile Calculation

Average					
Hip width (LP)	**Buttock popliteal length (PPO)**	**Popliteal height (TPO)**	**Sitting upright height (TDT)**	**Hand length (PT)**	**Maximum width (LBMAx)**
22,43	28,67	24,73	55,13	20,53	18,59

Calculation of Standard Deviation:

Table 4. Result of Standard Deviation

Average					
Hip width (LP)	**Buttock popliteal length (PPO)**	**Popliteal height (TPO)**	**Sitting uprigt height (TDT)**	**Hand length (PT)**	**Maximum width (LBMAx)**
6,23	7,8	4,8	5,7	6,2	4,91

Table 5. Z Score

Z *Score*					
Percentil	0,5	1	2,5	5	10
	99,5	99	97,5	95	90
Zx	2,575	2,327	1,96	1,645	1,282

Calclation of Percentil

1. **Hip width (LP)**

$P_5 = X - (Z_x \cdot SB) = 12,485$

$P_{50} = X = 22,43$

P_{95} = X + (Z_x . SB) = 32, 98

2. **Buttock popliteal length (PPO**

P_5 = X – (Z_x . SB) = 12,485
P_{50} = X = 22,43
P_{95} = X + (Z_x . SB) = 32, 98

3. **Popliteal Height (TPO)**

P_5 = X – (Z_x . SB) = 16,834
P_{50} = X = 24,73
P_{95} = X + (Z_x . SB) = 32,626

4. **Sitting Up Right Height (TDT)**

$P5$ = X – (Zx . SB) = 45,753
$P50$ = X = 55,13
$P95$ = X + (Zx . SB) = 64,506

5. **Palm length (PTT)**

$P5$ = X – (Zx . SB) = 10,331
$P50$ = X = 20,53
$P95$ = X + (Zx . SB) = 30,729

6. **Maximum Width (LBMAX)**

$P5$ = X – (. SB) = 10,513
$P50$ = X = 18,59
$P95$ = X + (. SB) = 26,695

Based on the measurements conducted on 30 children aged 3-5, percentile calculations were performed for several body dimensions relevant to the playhouse's redesign. Graph 1 below illustrates the distribution of body dimensions based on the 5th, 50th, and 95th percentiles used in the design.

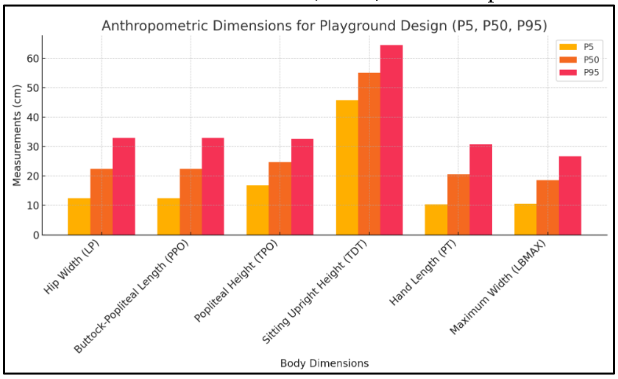


Figure 2. Body Dimension Distribution

Graph 1 shows that the body dimensions of children used in the calculation are fairly wide, especially in dimensions such as hip width (HW) and sitting height (SWH). The design based on the 95th percentile ensures that children with larger bodies can still use the equipment safely, while using the 5th percentile ensures comfort and ease of access for younger children. By implementing this percentile calculation, the redesigned playhouse can improve overall comfort and safety, as reflected by a 15% increase in safety and 20% in comfort compared to the previous design.

Data Analysis

Normality Test Analysis

The data normality test is carried out to test whether a data distribution follows or approaches a normal distribution and can be used for parametric statistics. From the normality test results in the previous section, it can be seen that the significance value (Sig.) in the Hip Width (LP) dimension is 0.2 where the value is> 0.05 so that Ho is accepted, so the dimension data is normally distributed. For the significance value (Sig.) in the Popliteal Buttocks (PPO) dimension of 0.2 where the value is> 0.05 so that Ho is accepted, the dimensional data is normally distributed. And for the significance value (Sig.) in the Popliteal Height (TPO) dimension of 0.2 where the value is > 0.05 so that Ho is accepted, the dimensional data is normally distributed. And for the significance value (Sig.) in the Upright Sitting Height (TDT) dimension of 0.2 where the value is> 0.05 so that Ho is accepted, the dimensional data is normally distributed. And for the significance value (Sig.) in the dimension of Palm Length (PTT) of 0.178 where the value is> 0.05 so that Ho is accepted, the dimensional data is normally distributed. And for the significance value (Sig.) in the dimension of the Maximum Width of the hand (LBMAX) of 0.2 where the value is> 0.05 so that Ho is accepted, the dimensional data is normally distributed.

1. **Body Dimension Analysis**

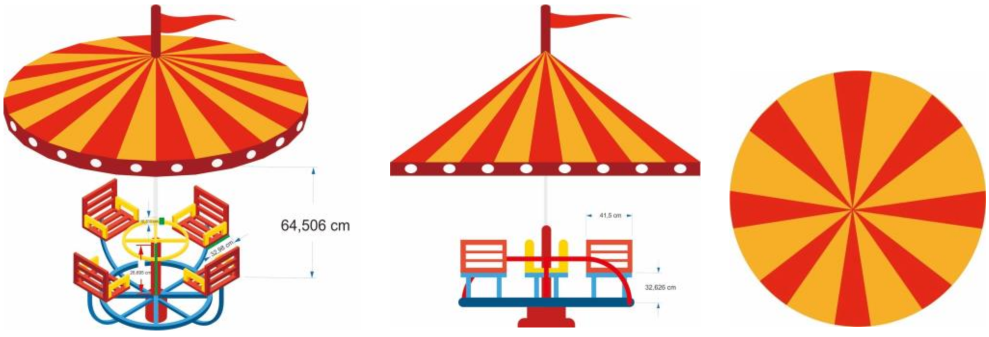
   The following are the anthropometric dimensions used:
   - Hip Width is calculated by the operator sitting upright and measuring the horizontal distance from the right and left hips. This size dimension uses the 95th percentile because it requires the maximum size result so that all children can occupy the seat in the rotary house.
   - Popliteal Buttocks measure the horizontal distance from the outer part of the buttocks to the inner knee curve and the thighs and legs form an angle of 90, this size dimension uses the 95th percentile because it requires maximum size results so that all children who have large or small bodies can all sit on this seat comfortably.
   - Popliteal height measures the vertical distance from the floor to the inner knee, this size dimension uses the 5th percentile because it requires the minimum size result so that children with a small height can easily sit on the seat.
   - Upright Sitting Height measures the vertical distance from the base of the seat to the tip of the head with the operator sitting upright and looking straight ahead, this size dimension uses the 95th percentile because the maximum size result is needed so that children who have a large height can sit on the seat without their head touching the roof.
   - Hand tools used to determine the size of the grip as follows:
     - Hand length measures the vertical distance (height) of the hand from the tip of the middle finger to the wrist, this size dimension uses the 5th percentile because the minimum size result is needed to obtain the smallest size so that all types of hands in children both small can comfortably hold the steering wheel that has been determined in thickness.
     - Maximum Width measures the farthest horizontal distance from the thumb to the little finger in this dimension using the 95th percentile. It takes the maximum measurement result so children with large hands can comfortably grip the steering wheel without being hit by the tip.

Table 6. Result Of Calculation Body Dimension

No	**Antropometri Dimension**	**Product Dimension**	**Calculation of Size**			**Result of Calculation**
			Percentile	Percentile Grade	*Allowance*	
1	LP	Holder Width	P_{95}	1,645	0	32,98
2	PPO	Holder Length	P_{95}	1,645	0	41,5
3	TPO	Stand Holder From Footing	P_5	1,645	0	32,626
4	TDT	Distance Holder from stand to the roof	P_{95}	1,645	0	64,506
5	PTT	Steering Wheel Thickness	P_5	1,645	0	10,331
6	LBMAX	Bulkhead distance on steering wheel	P_{95}	1,645	0	26,695

Product Analysis

A. Characteristic Of Product



A.Isometric View B. Side View C. Top View

Figure 2. Characteristic Of Product

The product above is a rotary house design measured based on anthropometric body dimensions and hand tools. Each product size is adjusted to a predetermined size to provide comfort when used by children. This design uses percentiles 5 and 95. The use of the 5th percentile is in the thick part of the steering wheel and the height of the seat from the footing, the use of the 95th percentile is for the width of the seat, the length of the seat, the distance of the seat to the roof, and the distance of the skat on the steering wheel. This playhouse is safe, and the steering wheel is smooth so that it cannot harm the child's body while in the playhouse or when the child puts his hand on the steering wheel and rotates the steering wheel because the playhouse uses strong and neat iron material so it is safe when the child is in it. The steering wheel is made of iron and then covered with a fluffy fabric that is smooth and non-conducting so that it cannot injure the child. Concerning the Guidelines for Ergonomics, the hand grip should not be rough, slippery, then the rotary house has met the Guidelines for Ergonomic standards because it is made of iron and the steering wheel is covered with a furry cloth that is not slippery and not a conductor.

B. Innovation Aspect

The rotary house is a children's play area often used by children aged 3-5 years because children very often use the rotary house to play. Without a rotary house, children may be unable to train their body's activeness during growth. In this study, the rotary house is newly designed by increasing the seat, roof and steering wheel distance so that children can be safe and comfortable while playing in it. And this rotary house is designed based on the calculation of anthropometric body dimensions and hand tools so that children feel comfortable, and of course it is safe not to cause bone disease, such as hunched spine and others or even accidents such as collapsed rotary houses. With the redesign of this rotary house, besides having advantages in function, this rotary house has good material quality and is made of strong, smooth, and not easily brittle materials.

Conclusion

The new design of this children's playhouse is made based on the measurements of the specified body dimensions. With these dimensions, it is expected that this children's rotating house can provide more comfort than before. The design of this rotating house uses dimensions that have been calculated based on their respective dimensions, namely hip width for seat width of 32.98 cm, popliteal buttocks length for seat length of 41.5 cm, popliteal height for seat height from footrest of 32.626 cm, upright sitting height for seat distance to roof of 64,506 cm, palm length for steering wheel thickness of 10,331, and maximum width for distance on steering wheel partition of 26,695 cm. Anthropometric data explains that the design of the new playhouse can improve safety and comfort. The design of this rotating house can be used with various body sizes of children because the 95th and 5th percentiles are applied to various dimensions of the child's body. Testing this playhouse in real environments such as city parks or schools is recommended for further research. In addition, it is recommended that the research be expanded to children using the techniques used in previous studies.

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