Ergonomic analysis on wheelchair redesign to improve user health and safety

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ABSTRACT

This research aims to redesign a wheelchair to enhance comfort and safety based on the ergonomic needs of users through a holistic ergonomic approach. The study employs the FMEA (Failure Mode and Effects Analysis) method to identify product failures in wheelchairs and determine preventive measures using the Risk Priority Number (RPN), calculated from Severity (S), Occurrence (O), and Detection (D). A biomechanical assessment using REBA (Rapid Entire Body Assessment) evaluates the posture and movements of wheelchair users and identifies factors contributing to ergonomic risks. The FMEA analysis revealed three failure modes with the highest RPN values: "head drooping" (192), "hands hitting the wheels" (120), and "feet drooping" (112). The REBA assessment indicated a final score of 9, signifying a high risk of injury, necessitating immediate corrective actions. In response to the findings from FMEA and REBA, a new wheelchair design is proposed, incorporating features such as neck support, a hydraulic system for the back, and calf supports. Additionally, the wheelchair dimensions will be adjusted based on the users' anthropometric measurements to ensure better ergonomics.

1. Introduction

A wheelchair is a crucial mobility aid for individuals with physical limitations (Akbar et al., 2021). However, the existing wheelchair designs on the market often do not fully meet the ergonomic needs of users. The mismatch between wheelchair design and the user's body dimensions can lead to discomfort, injury, and other health issues. One important aspect of ergonomic wheelchair design is considering the user's body dimensions through an anthropometric approach. Anthropometry is the science that studies human body dimensions, including size, shape, and body proportions. By using appropriate anthropometric data, wheelchair designs can be tailored to meet the specific needs of users, such as seat height, seat width, and hand position when operating the wheelchair (Barita & Nuryono, 2022; Uslianti et al., 2020). With the advancement of technology, products for people with disabilities and the elderly have emerged, including wheelchairs that can enhance human performance. These wheelchairs represent a tangible focus on technological development in the medical field as mobility aids for individuals who are unable to walk due to physical disabilities or health issues (Kholis et al., 2022).

Previous research was conducted through observations and interviews with manual wheelchair users while they performed various daily activities. Data was collected through direct observation and photography of several elderly users of manual wheelchairs. The observations focused on the GEA FS871 wheelchair model. The GEA FS871 wheelchair is a mobility aid for individuals with limited

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movement. It is a model produced by the GEA (General Equipment Apparatus) company. Below are the complete specifications for the GEA FS871 wheelchair at Fig. 1.

Fig. 1 Dimension of wheelchair GEA FS871.
Source : https://www.tokopedia.com/alkesda/kursi-roda-standart-gea-fs871-wheel-chair-gea?src=topads

The main issue that often occurs in wheelchair design is the mismatch between the dimensions of the wheelchair and the body dimensions of the user. This can lead to non-ergonomic body posture, pressure on certain body parts, and an increased risk of musculoskeletal injuries. Additionally, discomfort can reduce the mobility and productivity of wheelchair users (Yuslistyari & Shofa, 2021) Traditional wheelchairs still rely on finger-pushing movements. This is highly ineffective for individuals with disabilities to maneuver the wheelchair, as this hand movement requires significant effort to push the wheelchair, making users vulnerable to injuries (Nurmianto et al., 2021). Previous research indicates that wheelchair users are more likely to experience shoulder pain in their daily lives, as well as other physical issues such as balance problems, limited muscle strength, and mobility restrictions. A common occurrence among wheelchair users, which is a significant risk factor, is falling, which can lead to serious consequences.

Non-ergonomic wheelchair designs can cause biomechanical problems and inefficiencies in movement for users (Nie et al., 2023). However, there remains a gap in our comprehensive understanding of the relationship between the biomechanics of wheelchair users, movement efficiency, performance, and health status. Other studies have noted that non-ergonomic wheelchairs can lead to health issues such as back pain, pressure sores, and circulatory problems. Furthermore, "poor design can also limit user mobility and increase the risk of injury from falls or tipping over (Andrijanto & Hutapea, 2019)." Therefore, efforts must be made to improve wheelchair design by considering ergonomic and anthropometric factors. Thus, adjusting wheelchair design to meet users' ergonomic needs through anthropometric and biomechanical approaches is crucial. By considering the user's body dimensions and posture, wheelchair design can be optimized to provide comfort, reduce injury risk, and enhance user mobility and productivity.

This research aims to redesign a wheelchair that is comfortable and safe according to the ergonomic needs of wheelchair users by using a holistic ergonomic approach. Holistic here means comprehensive. In this study, the researchers used the FMEA (Failure Mode and Effects Analysis) method to identify product failures in wheelchairs and to determine preventive measures through the calculation of the Risk Priority Number (RPN), which multiplies the results of the analysis from Severity (S), Occurrence (O), and Detection (D). A biomechanical assessment was then conducted using REBA (Rapid Entire Body Assessment) to evaluate the posture and movements of wheelchair users, as well as the factors contributing to ergonomic risks. Finally, an analysis of wheelchair dimensions was performed using anthropometric measurements of the users.

Several previous studies that support this research, both in the same area and using the same methods, can be seen below : A study by Batan IML (Batan, 2007) titled "Development of Wheelchairs as an Effort to Improve the Mobility of Individuals with Leg Disabilities" developed a method to accurately measure and analyze the body dimensions of wheelchair users. This method can be used as a basis for designing wheelchairs tailored to individual needs. Research by Pradita (Pradita et al., 2018) examined the impact of wheelchair dimensions on comfort and the risk of musculoskeletal injuries among wheelchair users. This study found that the mismatch between wheelchair design and the body dimensions of users can lead to non-ergonomic body posture and increase the risk of injury..

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Setianto et al. (2020) conducted an anthropometric analysis of wheelchair users. Their research highlights the importance of considering variations in body dimensions of users in wheelchair design to enhance comfort and mobility. Arnet et al. (2024) found that wheelchair users experience significant pressure on their shoulders and upper arms when pushing their wheelchairs. There is a clear interaction between shoulder pain and the biomechanics of propulsion in individuals with disabilities, which may be useful for further analyzing risk factors for shoulder pain in wheelchair users or applying literature findings to different patient groups.

The purpose of this research with title Analysis of the workload of Dock 16 Ilir workers Using Rapid Upper Lim b Assessment, Ovako Working Analysis System, and Nordic Body Map Methods: A quantitative case study is to measure the body posture of workers using REBA and OWAS and to design an assistive device that can reduce musculoskeletal disorders (Kusmindari et al., 2022). The novelty of this research is to provide recommendations for a more ergonomic wheelchair design that meets the specific needs of users, thereby improving the quality of life and well-being of wheelchair users (Yudiantyo, 2020).

2. Methods

This research is an application study aimed at producing an ergonomic redesign of wheelchairs that meets user needs through a holistic ergonomic approach. A quantitative approach will be used in the collection and analysis of data such as musculoskeletal disorders using the Nordic Body Map questionnaire, body posture, and anthropometry of wheelchair users. Anthropometric data such as height, shoulder width, arm length, and other body dimensions will be measured directly using appropriate measuring tools. This quantitative data will be statistically analyzed to obtain a general overview of the body dimensions of wheelchair users.

Data Collection Methods, Sampling, and Research Variables

Data collection in this study involves primary data collection conducted through:

1. Anthropometric Data Measurement
2. Body Posture Analysis using the REBA Method
3. Wheelchair Dimension Data
4. Nordic Body Map Questionnaire for initial observation

The research sample consists of elderly individuals using wheelchairs at the RSRK Charitas KM7 Nursing Home. Based on initial observations, there are 10 elderly individuals, 4 of whom use wheelchairs permanently, so the sampling method used is purposive sampling, meaning samples are taken according to the needs of the research.

The research variables studied include anthropometric data dimensions, body posture of wheelchair users, and complaints of musculoskeletal disorders.

Data Analysis Methods

The data analysis method used in this research is:

1. The FMEA method, which aims to identify potential injury risks. The assessment of the injury risk level for wheelchair users is conducted by calculating the Risk Priority Number (RPN). (McDermott et al., 2008)
2. Analyze the dimensions of the wheelchair compared to the anthropometric data of the users. (Lawi et al., 2023)
3. Conduct a posture analysis of the users using the Rapid Entire Body Assessment (REBA).(Gómez-Galán et al., 2020)
4. Provide recommendations for ergonomic wheelchair design sizes according to user needs.

The steps of the research can be seen in the flowchart in Fig. 2.

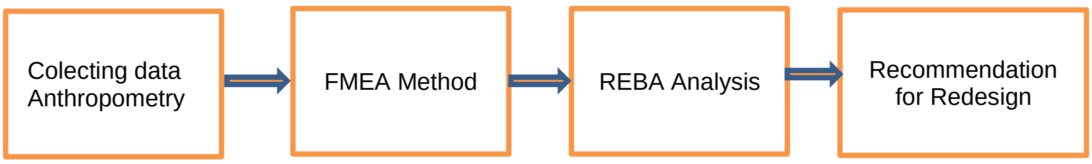

Fig. 2 Step of the research.

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Collecting Data Anthropometry

The process of collecting anthropometric data was conducted at the Werdha Dharma Bhakti orphanage located at Jl. Kolonel H. Berlian, Sukarami District. Measurements were taken on a total of 10 participants with disabilities who use wheelchairs. The participants consisted of 5 men and 5 women, with an age range of 60 to 90 years. The measurement of anthropometric dimensions refers to the dimensions of the sitting position as shown in Fig. 3.

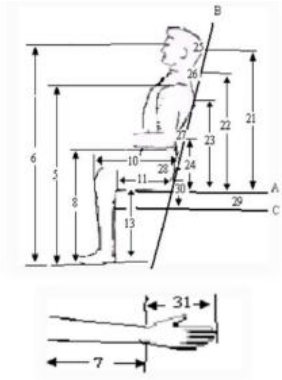

Fig. 3 Anthropometry dimension at the sitting position.

In this measurement, the body dimensions used are:

1. Sitting Shoulder Height (SSH – No. 23)
2. Sitting Elbow Height (SEH – No. 24)
3. Hip width (HW – No. 27)
4. Popliteal Height (PH – No. 22)
5. Popliteal Buttock (PB – No. 30)

Based on the data collection conducted on 10 individuals with different body sizes, the data is presented in Table 1.

Table 1 Results of anthropometric measurements of the elderly

No	HW (cm)	PH (cm)	PB (cm)	SSH (cm)	SEH (cm)
1	36	46	28	31	56
2	43	47	31	31	57
3	49.5	48	32	32	66
4	41	49	39	26	50
5	44	48	36	29	58
6	49	49	34	32	57
7	42	48	36	31	58
8	47	48	39	30	53
9	49	48	31	32	52
10	51	50	31	33	51

In order for the anthropometric data to be used for further analysis, the data must be tested for normality, homogeneity, and adequacy. The results of the normality test, homogeneity test, and adequacy test can be seen in Table 2.

Table 2 The results of the normality test, homogeneity test, and adequacy test

Normality Test				Homogenity test					Adequacy test		
Anthropometric	Sig.	α	Result	$\bar{X}$	σ	BKA	BKB	Result	N	N’	Result
HW	0,2	0.05	normal	45.96	4.14	57.8	34.1	Homogen	14	3.6	Adequate
PH	0.12	0.05	normal	50.67	1.05	48.42	46.17	Homogen	14	0,86	Adequate
PB	0.2	0.05	normal	34	3.093773	41.15	26.8	Homogen	14	3,6	Adequate
SSH	0.12	0.05	normal	30.35	2.056597	37.3	23.4	Homogen	14	2,7	Adequate
SHE	0.2	0.05	normal	55.14	4.033027	66.8	43.48	Homogen	14	2,9	Adequate

FMEA Method

The research was conducted in June 2024 at the Dharma Bakti Elderly Care Center, which is an elderly home located at Jl. Kolonel H. Berlian No.228, Sukarami, Kec. Sukarami, Kota Palembang,

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South Sumatra. The primary data collection included interviews, types of data, and photographic documentation of the research. Below is the table of questions asked to the elderly wheelchair users. The question for interview can be seen in Table 3.

Table 3 Question for interview

No	Questions
1	Are you satisfied with the wheelchair you are using?
2	Are you satisfied with the comfort level of the wheelchair?
3	Do incidents often occur while using the wheelchair?
4	Have you ever experienced an injury while using the wheelchair?
5	Which part of the wheelchair causes discomfort?
6	What activities do you often do while using the wheelchair?
7	How do you move the wheelchair?
8	What is the reason you need to use a wheelchair?
9	What caused you to use a wheelchair?
10	How long have you been using a wheelchair?

Based on the questions above, a number of observational data were collected from elderly individuals using manual wheelchairs in the form of descriptions as follows:

1. Acin (Female, 72 years old)
   Observation Description: Mrs. Acin uses a manual wheelchair due to an injury to her leg from a fall. Although the injury has healed, she still has difficulty walking long distances. When operating the wheelchair, she requires full assistance from family members or caregivers for mobility and daily activities. She appears quite skilled and confident. She seems independent in performing daily activities and only needs minimal assistance from others.
2. Sahartini (Female, 70 years old)
   Observation Description: Mrs. Sahartini experienced a mild stroke that caused partial paralysis in her arms and legs. She uses a manual wheelchair and appears quite skilled in operating it. However, she often needs partial assistance when navigating narrow or uneven areas.
3. Sulinda (Female, 58 years old)
   Observation Description: Mrs. Sulinda uses a manual wheelchair due to an injury to her leg from a fall. She appears to struggle when pushing the wheelchair. She requires full assistance from a caregiver for mobility and daily activities.
4. Leni (Female, 80 years old)
   Observation Description: Mrs. Leni uses a manual wheelchair due to an injury to her leg from a fall. Although the injury has healed, she uses a manual wheelchair and appears quite skilled in operating it. However, she often needs partial assistance when navigating narrow or uneven areas.

After collecting data from the four respondents along with the staff present at the data collection site as companions for the respondents, seven potential risks and hazards were identified that may be experienced by elderly users of manual wheelchairs. Below is a list of potential risks and hazards associated with wheelchair use among the elderly. The potential risks and hazard can be seen Table 4

Table 4 Potential risks and hazards

Potential	Hazard
Head drooping	Pinched neck nerve
Hands caught in wheel spokes	Hand injury
Back bent	Pinched nerve
Hands	Scratched/abraded hands
Legs drooping	Scratched/pinched legs
Hands hit by wheels	Scratched/injured hands

After determining the assessment of potential risks and hazards through brainstorming with the team and staff at the care facility where the data was collected, the results for S, O, and D were obtained as follows:

Table 5 Risk assessment

Potential	Hazard	Risk Assessment		
		S	O	D
Head drooping	Pinched neck nerve	8	4	4
Hands caught in spokes	Hand injury	5	2	5
Back bent	Pinched nerve	7	4	2
Hands	Scratched/abraded hands	4	2	2
Legs drooping	Scratched/pinched legs	6	4	3
Hands hit by wheels	Scratched/injured hands	8	2	5
Legs hit by wheels	Scratched/pinched legs	5	4	1

Potential refers to the ability or capacity of something to develop, produce, grow, or provide benefits. It includes the positive possibilities that can be achieved or utilized. In contrast, hazard refers to the likelihood or risk of loss, injury, or other negative impacts, encompassing threats that may arise from an action or situation.

REBA Analysis

The body posture data obtained from the initial observation is then analyzed using the Rapid Entire Body Assessment (REBA) method to evaluate the risk of non-ergonomic body postures. REBA analyzes the upper body posture (neck, back, arms, wrists) and lower body (legs and body position) and is supplemented with load and activity factors.

1. Data collection of the worker's posture is conducted by photographing the body position of manual wheelchair users in detail to obtain valid and accurate data as a basis for subsequent calculations and analyses.
2. The next step is to calculate the angle of each segment of the manual wheelchair user's body, such as the back, neck, upper arms, lower arms, wrists, and legs. These segments are divided into two groups: group A (back, neck, and legs) and group B (upper arms, lower arms, and wrists). Scores are calculated from the angles of each segment in groups A and B using tables A and B. Subsequently, the scores from tables A and B are used to determine values in table C, which is the REBA score table used to assess the risk level of the activities performed by the worker. The score in table C can increase if the worker's activities meet the activity score criteria. After obtaining the score from table C, the final step is to determine the risk level category of the worker's activities based on the summary of risk levels in the REBA table body posture can be seen in the Table 6.

Table 6 Posture position for table A REBA

Documentation	Part of Body	Angle
	Neck	0^0
	Trunk	108^0
	Leg	70^0

The following are the scores obtained from Table A through the REBA calculation:

a) Neck: Upright (score 1) + rotation to the right (+1) = 2
b) Back: Angle 108° (0°-20° extension, score 2)
c) Legs: Not supported/unstable (score 2) + bending 70° (+2) = 4

Additional REBA scores in Table A (Table 7) if there is a load received by the manual wheelchair user: Load < 5kg: +0, Sudden force: +0 and Total final score for Table A:

Table 7 Table A of REBA

Table A		*Neck*											
		1				2				3			
	Legs	1	2	3	4	1	2	3	4	1	2	3	4
Trunk Posture Score	1	1	2	3	4	1	2	3	4	1	2	3	4
	2	2	3	4	5	3	4	5	6	4	5	6	7
	3	2	4	5	6	4	5	6	7	5	6	7	8
	4	3	5	6	7	5	6	7	8	6	7	8	9
	5	4	6	7	8	6	7	8	9	7	8	9	9
Load													
0 <5 Kg				1 5-10 Kg			2 >10 Kg			+1 The addition of sudden load/shock load occurring during work			

Parts of body	Angle
Upper Arm	73^0
Lower Arm	50^0
Wrist	38^0

Table B REBA

Score tabel B:

1. Upper Arm 73° (>45°) = 3 + bersandar (+1) = 4
2. Lower Arm: 50°
3. Wrist: 38° fleksi = 2
4. Coupling = Good +0

Score Table B = 6

Table 8 Table B of REBA

Tabel B		*Lower Arm*					
		1			2		
	Wrist	1	2	3	1	2	3
Upper Arm Score	1	1	2	2	1	2	3
	2	1	2	3	2	3	4
	3	3	4	5	4	5	5
	4	3	5	5	5	6	7
	5	6	7	8	7	8	8
	6	7	8	8	8	9	9
Coupling							
Good +0		*Fair +1*		*Poor +2*		*Unceprable +3*	

The total score obtained from Table A is 6, and the total score from Table B is also 6. When these two values are entered into Table C, the result shows a score of 8. This score is then added to the activity score. The score in Table C can be seen in Table 9.

Table 9 Table C of REBA

Score A (Score fro table A +load force score)	Tabel C *Score B (Table B Value + Coupling score)*											
	1	2	3	4	5	6	7	8	9	10	11	12
1	1	1	1	2	3	3	4	5	6	7	7	7
2	1	2	2	3	4	4	5	6	6	7	7	8
3	2	3	3	3	4	5	6	7	7	8	8	8
4	3	4	4	4	5	6	7	8	8	9	9	9
5	4	4	4	5	6	7	8	8	9	9	9	9
6	6	6	6	7	8	8	9	9	10	10	10	10
7	7	7	7	8	9	9	9	10	10	11	11	11
……	8	8	8	9	10	10	10	10	10	11	11	11

Final REBA Score:

1. Table A (6) + Table B (6) = Table C (8)
2. Addition of repetitive activity: +1
   Total: 9
   Risk Level: High (8-10)
   Action: Immediate improvement is needed

3. Results and Discussion

Table 10 below explain the RPN assessment table, obtained by multiplying the values of Severity (S), Occurrence (O), and Detection (D) of potential risks using the FMEA method.

Table 10 Risk potential number

Activity	Potential	Hazard	Risk Assessment			RPN	Mitigation
			S	D	O		
Sitting	Head drooping	Pinched neck nerve	8	6	4	192	Raise the backrest and padding at the neck area.
	Unbalanced shoulders and hands hit by wheels	Strain and scratches from armrests	5	2	5	50	Make the backrest slightly firmer or use thicker padding.
	Back bent	Pinched nerve	7	4	2	56	Use appropriate padding for the back.
	Hands	Scratched/abraded hands	4	2	3	24	Expand padding on the armrests.
	Legs drooping	Scratched/pinched legs	7	4	4	112	Place footrests that fit the feet.
Wheelchair walking	Hands hit by wheels	Scratched/injured hands	8	3	5	120	Cover the armrest walls.
	Legs hit by wheels	Scratched/pinched legs	7	4	1	28	Install wheel guards.

The researcher established a cut-off point for categories > 200, a medium category ranging from 100 to 199, and a low category ranging from 1 to 99. RPN values exceeding 200 will be considered requiring further analysis and corrective action (Alijoyo et al., 2020). The cut-off point is implemented to facilitate the determination of handling priorities and controls for each potential failure. When the RPN results are relatively low, recommendations will still be made to further reduce the RPN value and even eliminate any impact. With the ranking of criticality or priority, the researcher can promptly determine that actions and controls must be taken for medium and high category rankings.

Referring to the RPN calculation results in Table 7, it can be determined that the potential risk of accidents with the highest RPN value is 'Head drooping,' which has the hazard of a pinched neck nerve with an RPN value of 192. The next highest is 'hands hit by wheels' while the wheelchair is in motion, posing a risk to the hands that could potentially come into contact with the wheel spokes or wheels if the wheelchair user misjudges the movement of their hands, with an RPN value of 120. The third is 'legs drooping,' which has the hazard of scratched or pinched legs when sitting still in the wheelchair and could be greater when the wheelchair is in motion, with an RPN value of 112. These three highest RPN values establish the priority for recommended actions to reduce the RPN values

Based on the REBA analysis, it was found that the REBA Score = 9, indicating a high-risk category. Immediate corrective actions are necessary to reduce the risk of musculoskeletal injuries. Overall, the observed posture shows several areas that require attention, particularly in the neck, back, and shoulders. Ergonomic adjustments and training on proper wheelchair usage techniques can help reduce the risk of injury and improve user comfort.

To make ergonomic adjustments, anthropometric data is needed to redesign the wheelchairs they use. The collected anthropometric data is then statistically processed to obtain percentile values (5th, 50th, and 95th percentiles) that will be used as a reference in determining ergonomic wheelchair design specifications that meet user needs. The calculation of percentile values is performed to determine sizes that are suitable for the majority of elderly wheelchair users. The calculated percentile values are the 5th, 50th, and 95th percentiles, as shown Table 11.

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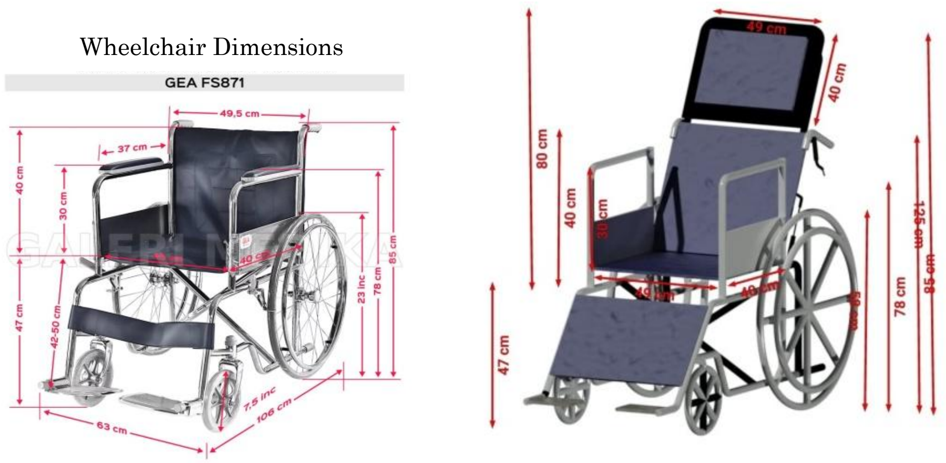
Table 11 Percentile values of elderly anthropometric data

Body Dimension	5th Percentile	50th Percentile	95th Percentile
Sitting Height (cm)	48.94	50.67	52.39
Hip Width (cm)	39.15	45.96	52.77
Popliteal Height (cm)	28.91	34.00	39.08
Sitting Shoulder Height (cm)	26.97	30.35	33.72
Sitting Elbow Height (cm)	48.51	55.14	61.76

Based on the anthropometric data of users, the ergonomic wheelchair size specifications are as follows:

a. Seat Width: Use the 95th percentile (52.77 cm) to accommodate the majority of users. Consider a design that can be adjusted for comfort for users with smaller hips.
b. Seat Height: Use the 5th percentile of popliteal height (48.94 cm) to ensure that users' feet can comfortably touch the floor or footrest.
c. Seat Depth: Use the 50th percentile of popliteal height (34.00 cm) as a reference, with adjustment options to accommodate variations in thigh length.
d. Backrest Height: Use the 95th percentile of sitting shoulder height (33.72 cm) as the minimum limit to provide adequate support for the majority of users.
e. Armrest Height: Use the 50th percentile of sitting elbow height (55.14 cm) as a reference, with possible adjustments to accommodate variations in users' elbow heights.

Based on the anthropometric data obtained, the results of the ergonomic wheelchair design measurements for the needs of elderly users have been achieved at Fig. 4.



(a) Before (b) After

Fig. 4 Redesign of ergonomic wheelchair

Improvement Recommendations

Based on the results of the REBA and FMEA calculations, elderly users of manual wheelchairs are still at risk of experiencing musculoskeletal disorders. To address this, modifications to the wheelchair are proposed, including the addition of a headrest, a hydraulic system for adjusting the tilt of the backrest, and enlarging the footrest. These changes aim to enhance safety, comfort, and reduce the risk of injury for elderly users.

Head or Neck Rest

The headrest of the manual wheelchair is an adjustable soft cushion mounted at the top of the chair. Made from foam covered with soft fabric, this device supports the head and neck, enhances comfort, and promotes good posture. It is attached with a clamp system and is essential for long-term comfort, especially for users with special needs.

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Hydraulic System on the Backrest

The hydraulic system on the wheelchair backrest allows for easy and precise adjustment of the backrest position. This system enables smooth adjustments of the backrest angle through a lever or button. Benefits include ease of operation, smooth movement, stable load-bearing capacity, and flexibility for various needs. This system enhances comfort, supports good posture, and helps prevent injuries and fatigue in the back, thereby improving the quality of life for wheelchair users.

Calf Support

The calf support of the wheelchair is a soft cushion on top of the footrest, made from foam covered with vinyl or fabric. It serves to support the calves, distribute the weight of the legs, and improve circulation. It is important for the comfort, stability, and health of wheelchair users. Redesign of ergonomic wheelchair can be seen in Fig. 5.

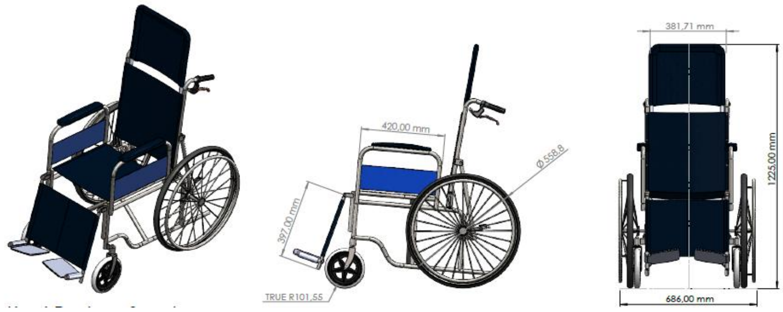

Fig. 5 Redesign of ergonomic wheelchair

The limitations of this study are that it only considers the needs of users by examining risk factors, body posture, and anthropometric measurements. In future research for redesigning wheelchairs, it is also necessary to consider the psychological factors of users. Future research will focus on fundamental research in product development, particularly in quality, musculoskeletal disorders, workload analysis, and ergonomics related to work and tools.There is an emphasis on the importance of anthropometric data in the design of wheelchairs to enhance user comfort and mobility.The application of ergonomic principles in redesigning wheelchairs to meet the specific needs of users is a key area of interest. Additionally, the integration of biomechanical assessments and failure mode analysis will be crucial for improving wheelchair design and user safety

4. Conclusion

Based on the data analysis results using the FMEA method, it can be determined that the three failure modes with the highest RPN values are 'head drooping' with a value of 192, 'hands hitting the wheels' with an RPN value of 120, and 'legs drooping' with a value of 112. Meanwhile, the REBA (Rapid Entire Body Assessment) method shows that the final REBA score is 9, indicating a high risk. Immediate corrective actions are needed to reduce the risk of injury. In line with the results of FMEA and REBA, a new design for the wheelchair is proposed, which includes adding a headrest, a hydraulic system for the backrest, and calf support. The dimensions of the wheelchair are also adjusted according to the users' anthropometry

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