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MAGIE BROOM: REVOLUTIONIZING CLEANING WITH USER-CENTERED ERGONOMIC DESIGN

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ABSTRACT
Magie Broom is an innovative cleaning tool designed by considering several principles such as ergonomics and anthropometry. This study aims to determine the optimal ergonomics design that can minimize the risk of musculoskeletal disorders (MSDs) that often arise from the use of traditional cleaning tools. The development of this tool involves several stages: literature review, field observations, and detailed design using the Quality Function Deployment (QFD) method, followed by testing. Anthropometric principles, especially for determining the optimal length and grip, are carefully considered to ensure the design meets user needs for ease of use, comfort, and cleaning effectiveness. The design The Magie Broom prototype was tested by various user groups such as housewives and students to obtain input used in refining the design. The test results showed that this tool was able to increase cleaning efficiency by provide 3in1 function and modularity. Its also provide comfort for users and reduce the potential for MSDs by decrease REBA score from 11 to 3. The design is very easy to carry, modular, and equipped with a rechargeable battery. The Magie Broom serves as a promising model for ergonomic product development especially in houshold tools, illustrating how thoughtful design can minimize physical strain and injury risk. Magie Broom offers a practical solution for everyday cleaning needs and has great potential to be further developed and marketed widely.
Keywords: *Ergonomics, Anthropometry, Musculoskeletal Disorders, Product Design, Quality Function Deployment.*

1. Introduction

Human-based design is an approach that aims to ensure that products or systems that are being and have been developed not only focus on technical or ergonomic performance but also consider the welfare aspects of workers or consumers as their main users (Hasanain, 2024; Kadir & Broberg, 2021; Nguyen Ngoc et al., 2022). Such an approach will encourage many designers to pay attention to the interactions that occur between users and certain artifacts such as goods, tools (Dudley & Kristensson, 2018; Haines-Gadd et al., 2018), or work equipment, this is done in order to create a more comfortable experience and can support work efficiency (Andreani et al., 2019; Bouncken et al., 2021) that is being and has been done. In this design process, involving primary users, such as employees or clients, is a very important step. This is done to ensure that the final result of the design process is able to optimally meet their needs and provide a positive impact in the long term (Al-saqqa et al., 2020). The subjective experience felt by users, whether in the form of comfort or discomfort during the use of a product or carrying out an activity, is often used as a primary indicator of their well-being (Alessandro Naddeo & Cappetti, 2020).

In the professional world, one form of work that is commonly done by many workers is cleaning activities, both at home and in the work environment. This cleaning is often a routine part of daily activities to maintain cleanliness and hygiene, both in and around the work area (Assadian et al., 2021; Peters et al., 2018). A clean work environment not only provides aesthetic benefits, but also has a significant impact on employee productivity, work quality, and the general well-being of all parties involved (Barton & Le, 2023; Marzban et al., 2023). However, this

cleaning activity is often not free from various challenges, such as repetitive workloads, physical fatigue, and discomfort that arise due to non-ergonomic body postures for a long period of time. These challenges, if not handled properly, can increase the risk of musculoskeletal disorders (MSDs) which are often experienced by workers in the administrative services and waste management sectors (A. Naddeo et al., 2018). Accroding to previouse research, MSDs become the second most common cause of disability in the world (Melese et al., 2020). Specifically in the cleaning workers, he percentage of MSDs cases in previous research samples showed a fairly high rate world wide. 74% in the UK (Woods & Buckle, 2005) , 90% in Taiwan (Chang et al., 2012), and 56% in Norway hospital cleaner (Lasrado et al., 2017).

Musculoskeletal disorders (MSDs) can cause serious problems, not only affecting workers' health but also leading to significant economic impacts. A recent study in Washington State found that MSDs ranked second (after falls from elevation) in terms of lost workdays among male cleaners and were third in median claim costs, amounting to $9,602 (ranging from $2,607 to $49,353) (Lin et al., 2022). The most preferred and effective way to reduce the risk of MSDs is by implementing engineering controls (Lin et al., 2022). This includes redesigning cleaning tools to provide mechanical benefits (Harris-Adamson et al., 2019) or choosing and adopting appropriate technologies (Carrivick et al., 2005; Jensen et al., 2011).

Although comfort and discomfort are subjective concepts that vary between individuals, research developments in recent decades have shown serious efforts to develop methods that can objectively evaluate comfort levels (Castaldo et al., 2018; Kim et al., 2018). This evaluation involves various factors, such as body posture, physiological conditions, cognitive capacity, and environmental influences on user activities (Bayot et al., 2018; Fan Zhang et al., 2019). This approach aims not only to better understand the user experience, but also to design more effective solutions to address ergonomic challenges. This effort is driven by two main needs: a comfort-oriented design method, which allows products to be continuously refined and optimized based on ergonomic and comfort principles (Liu et al., 2023; Palomares et al., 2022), and the ability to analyze human interactions with artifacts from the early stages of product development through data-driven analysis and virtual simulation(Tosi, 2020). In the context of ergonomics, applications can be divided into two main categories, namely corrective tasks and design tasks. When ergonomics is used to address problems that arise due to the use of a particular product or a particular work environment, it is called a corrective task (Dianat, I et al., 2018), while when ergonomics is applied to evaluate the overall quality of a system that is frequently used in everyday life, it is called a design task (Gallagher & Schall, 2017). This approach also involves disciplines such as anthropometry and biomechanics to understand and apply ergonomic principles comprehensively.

In this context, the development of innovative tools for cleaning is crucial. Previouse research by Brazil et al., (2023) indicate that housekeepers are at risk of work-related upper-limb musculoskeletal injury when when doing cleaning task such as vacuming using traditional toools, with average Rula scores over 5. Research by Lin et al., (2024) also show a result that cleaning activity using traditional mop indicate high Composite Strain Index (COSI). Based on the problems associated with working postures when using traditional cleaning equipment, this research proposes the Magie Broom as an ergonomic solution to address these challenges. The Magie Broom is a multifunctional tool designed with ergonomics and user comfort in mind, while increasing work efficiency. This tool is equipped with various innovative features designed to meet the specific needs of users, such as a high broom or roof for cleaning high roof areas, a short roof broom for low areas, a glass cleaner for cleaning glass, a floor mop for mopping, and a broom for sweeping. Each feature of the Magie Broom is carefully designed to ensure that users can work in a more comfortable posture and reduce excess pressure on the body. For example, the high roof broom feature is equipped with an adjustable telescopic handle so that users can clean high areas without having to use a ladder, which also reduces the risk of accidents. Other features such as the floor mop and broom are designed with comfortable ergonomic handles, which can reduce tension on the wrist and arm during use. By combining multiple functions in one tool, Magie Broom not only helps to increase work productivity and time efficiency, but also creates a safer and more user-friendly design solution that supports the overall well-being of users. This

innovation is a clear demonstration of how a human-centered design approach can produce products that not only meet functional needs but also make a positive contribution to the health and comfort of users in the long term. This research try to answer the question about ergonomic design cleaning product abbility to reducce MSDs risk by a measurable percentage compared to traditional tools. This research proposes an ergonomic, user-centered cleaning tool as a practical solution to reduce MSD risk.

2. Literature Review

The product design and development process involve various interrelated activities, from understanding market needs, analyzing opportunities, to producing and distributing products to consumers. Ulrich & Eppinger (2011) explained that this stage includes analyzing market perceptions, identifying opportunities, manufacturing processes, sales, and product delivery. The main focus of this process is not only creating added value, but also ensuring that the products produced are in accordance with customer desires and needs. An important step in product development is formulating a problem statement that includes customer desires, expected value, and other relevant information. This statement is the basis for product development and can be adjusted to technological advances, changes in people's habits, or developments in market dynamics (Jamnia, 2018). Success in modern product development is highly dependent on the ability to adapt to these changes. The process of creating a new product generally goes through five main stages, namely: Idea collection is carried out by identifying customer input, market analysis, or technology research as the basis for initial ideas, Concept planning and development that evaluates the feasibility of ideas based on potential added value for customers and technical feasibility, Product development is the process of detailing the technical design of the selected idea, Prototyping and testing which aims to identify product deficiencies and ensure the design meets quality standards, and Production and market launch which is the final stage when the product is finally introduced and distributed to consumers (Lüthje & Herstatt, 2004).

In product development involving human interaction, anthropometric aspects play an important role. According to Wignjosoebroto (2008), anthropometry is a science that studies the measurement of human body dimensions that vary based on size, shape, and weight. In ergonomics, the use of anthropometric data aims to ensure that product or facility designs can support comfort, safety, and efficiency for users. The anthropometric-based design process is carried out through several stages, namely:

1. Determine the target user group, so that the design is made according to the specific needs of certain users.
2. Determine important body size tolerances, with a focus on body dimensions that are relevant to the design.
3. Choose the percentage of the population to be represented, so that the design covers most users.
4. Identify anthropometric principles, such as ranges, extreme values, or average body size.
5. Compile anthropometric data in the form of tables, as a guide during the design process.
6. Adjust the design to body posture, to ensure comfort of use.
7. Conduct design testing, to ensure the product meets user needs (Stack et al., 2016).

There are three main approaches to applying anthropometric data to design: Design for extremes, for example designing facilities to fit users with the largest or smallest body sizes. Adjustable design, which allows the product to be used by a range of users of different body sizes. Size range design, which is used when universal design does not apply.

The application of anthropometric principles in workplace design has resulted in significant improvements in user health, comfort, and efficiency. For example, research by Colim et al., (2019) showed that applying anthropometric data to the design of a furniture assembly workplace can reduce unergonomic postures, thereby reducing the risk of musculoskeletal disorders. Elsewhere, Kibria & Rafiquzzaman (2019) found that poor sitting posture in front of a computer caused discomfort for university lecturers, and this could be addressed with anthropometric-based workplace design. Lee & Cha (2019) also noted that the improper design of a human-computer interface on a nuclear power plant console caused serious ergonomic problems, but an improved design using anthropometric principles improved user interaction with the console. All these

examples demonstrate that applying proper anthropometric principles can improve user well-being, health, and safety (Hitka et al., 2018).

In addition to applying ergonomic and human-centered design approaches, product design development must also consider sustainability. This is because the growing of environmental awareness, that leading to an increasing demand for sustainable products (Ricardo P et al., 2023). The demand for sustainable products is a crucial consideration in product design to ensure products have added value and able to compete in the market. To understand the application of ergonomics and sustainability concepts in product design, a literature review was conducted on various indexed journals available on the internet using keywords such as 'ergonomic design', 'household tools design', and 'ergonomic product design'. The search was also focused on English-language journals published between 2019 and 2025. Several relevant journals were found from the search results. The results show that application of ergonomic and sustainable product concepts is quite common in product development, particularly in industrial equipment (Chen et al., 2023; García-Chica et al., 2025; Grandi et al., 2022; Zhang et al., 2024). However, the application of these concepts is still not common in household appliances. Most ergonomic research on household appliances focuses on assessing the potential for MSDs (Brazil et al., 2023; Lin et al., 2024; Naik & Khan, 2020; Yang et al., 2022). In the past five years, only a few studies have focused on developing household appliance designs that consider both ergonomic and sustainability factors. These include the study by Zhao et al. (2022), which discusses the development of a modular cleaning set design considering user anthropometric dimension adjustments, and the study by Ricardo P et al. (2023), which develops environmentally friendly broomstick material selection. Additionally, the study by Zhao et al. (2022) has not yet considered various needs in cleaning activities and is only focused on one specific function, namely sweeping. Both studies not fully integrate ergonomic aspects with sustainability aspects.

Some cleaning products on the market do offer modular features, such as broomsticks that can be adjusted in length or have several types of heads (e.g., brushes or mops) that can be attached. However, these products are generally limited to basic modularity features (adjustable length, replaceable heads) without considering ergonomic principles or the specific needs of cleaning activities in high areas. Additionally, products on the market usually use plastic materials that are not environmentally friendly. To accommodate needs that were not considered in previous studies and available products on market, it is necessary to develop cleaning tools design that involve ergonomics and sustainability into consideration.

Magie Broom is designed to overcome the ergonomic challenges that workers often face when cleaning. This tool not only prioritizes user comfort, but also considers health, such as reducing the potential for musculoskeletal disorders that often arise from using traditional cleaning tools for a long time. Magie Broom is equipped with various multifunctional features designed with anthropometric data in mind, such as a handle that can be adjusted in length to ensure that the user's posture remains good when cleaning high areas (high roof broom), low areas (short roof broom), and floors (floor mop and broom). This design approach allows the tool to be used more efficiently, reducing pressure on the user's body, especially on the wrists, arms, and lower back. Features that consider various body sizes allow this tool to be used by various types of users, both tall, short, and those with certain physical limitations. Thus, Magie Broom is expected to increase productivity and comfort in daily cleaning activities, both at home and in public places.

To enhance the need of sustainable product, Magie Broom also consider material elements. First, Recycled Plastic Components for the broom handle and head (Bharadwaaj et al., 2024; Ramachandran et al., 2021; Ricardo P et al., 2023). This would reduce the product's environmental impact while maintaining durability and flexibility (Hahladakis & Iacovidou, 2018; Horodytska et al., 2018). Second, Bamboo or Natural Fiber Reinforcement to Replace synthetic for the broom bristles (Azam et al., 2023; E. Njoku et al., 2019; Kozlowski, 2020). These materials are not only renewable but also provide excellent strength and resilience, making them ideal for cleaning applications (Kamarudin et al., 2022; Keya et al., 2019; Suriani et al., 2021). Last is the use of Water-Based Paint and Coatings to Ensure that any coatings or finishes used on the Magie Broom are water-based and free from harmful volatile organic compounds (VOCs) (Enfield, 2020).

These eco-friendly coatings would make the product safer for both users and the environment (Akhter et al., 2025; Sfameni et al., 2023). Magie Broom also consider the energy need issue by using Solar Rechargeable Battery (Gurung & Qiao, 2018; Hudy et al., 2021). This would reduce reliance on conventional electricity, making the product eco-friendlier (Khan et al., 2021; Mariotti et al., 2020). Magie Broom also consider the product live cycle by considering Modular Design for Easy Recycling that allows to recycle individual components at the end of the product's lifecycle (Cong et al., 2019; Favi et al., 2019; Shahhoseini et al., 2023; Sonego et al., 2018).

By considering both ergonomics and sustainability, Magie Broom is expected to be an innovative solution that provides ease of use, multifunctionality, and sustainability to address the challenges of MSDs and support broader market potential.

3. Research Methods

The Magie Broom tool was successfully developed through the application of an organized and systematic product design and development method. This development process includes six main stages that collectively cover all the important aspects of creating an innovative product. Each stage has been carried out carefully, and the results obtained from each stage have met the targeted standards, as seen in Figure 1 below.

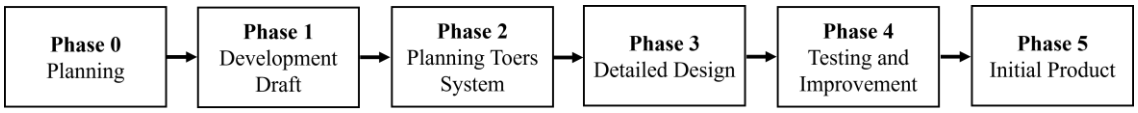


Fig. 1. Product Design Stage

During the product design process, the Quality Function Deployment (QFD) method is optimally applied to ensure that the resulting design not only meets technical requirements but also considers aspects of user comfort and satisfaction. QFD is closely related to human-centered design because it emphasizes analysis of human needs, in this case, the customer's needs. By using QFD, the product design process will obtain measurable design parameters to enhance the expected project quality through correlation with user needs (Giacobone & Mincolelli, 2020). Therefore, this methodology is based on the idea that the success of a product or service depends heavily on its ability to meet customer needs (Kulcsár et al., 2022). Its main benefits include reduced product development time, improved interdepartmental communication, identification of key features important to customers, and prioritization of areas requiring improvement (Y. Zhang et al., 2022). For these reasons, the QFD method was selected as the primary method used in the design of the Magie Broom.

In addition, a testing program has also been carried out by directly involving users at various stages of product development, to obtain constructive feedback. Based on the input obtained from the testing, improvements and refinements are made at the relevant stages, to ensure that the tool developed truly meets the practical and ergonomic needs of users who are the focus in designing this product. The overall flow of the program implementation process, starting from the initial stage to the finalization of the product, has been completed and can be clearly described through the figure 2.

1. Initial Identification Stage

The first stage in the development process of this tool begins with conducting an in-depth literature review on product design and the application of ergonomic principles in the design of cleaning tools. This literature includes various relevant references, both in terms of product design theory and ergonomic applications that can be applied to household cleaning tools. Literature review is highly relevant to the application of human-centered design because through literature review, designers can understand the gap of users needs and preferences in the previous study. In addition, the literature review method was chosen because it allows for rapid and comprehensive data collection and analysis from various previous studies that already have concrete results.

In addition to the literature review, at this stage a field study was also conducted involving the collection of primary data from relevant respondents. Field studies are necessary because this

method able to give information how products are used by users in real-world environments. This method is important because it provides a realistic condition of user behavior, habits, and challenges in daily interactions with products. Field studies are in line with the principles of human-centered design, which places user needs, preferences, and comfort at the forefront of product design.

Data collection was carried out by distributing questionnaires aimed at housewives and students, who carry out their own room cleaning activities on a daily basis. From this activity, there are 40 respondents consist of 20 female and 20 male, aged between 19 and 25 years. 64% reported engaging in cleaning activities for approximately 1 hour per day, while the remaining participants reported spending more than 1 hour per day. From the results of the questionnaire, the attributes that need to be prioritized in the manufacture of this cleaning tool have been identified, namely ergonomic product design, ease of use, and comfort felt by the user. This identification is very important to ensure that the tool developed can meet the practical needs of users in cleaning activities.

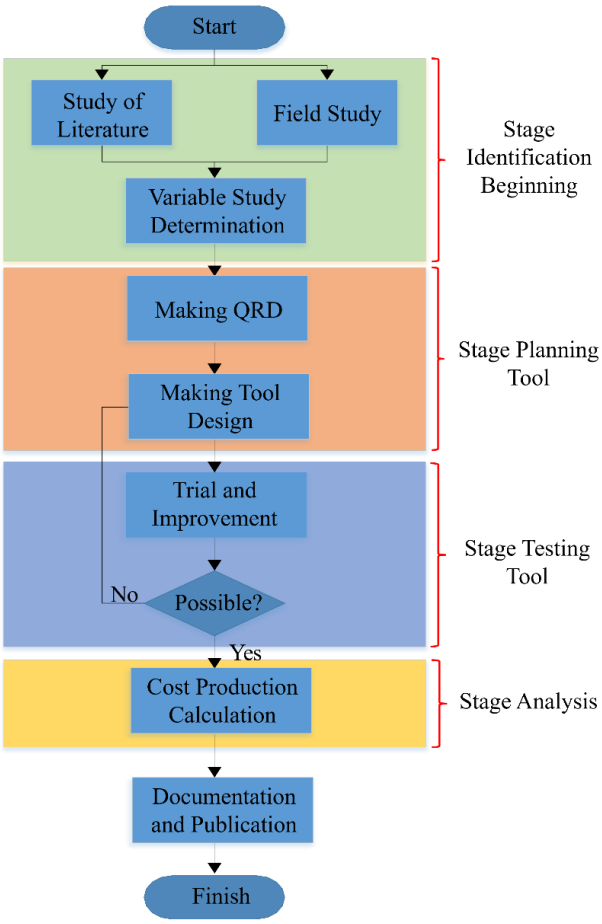
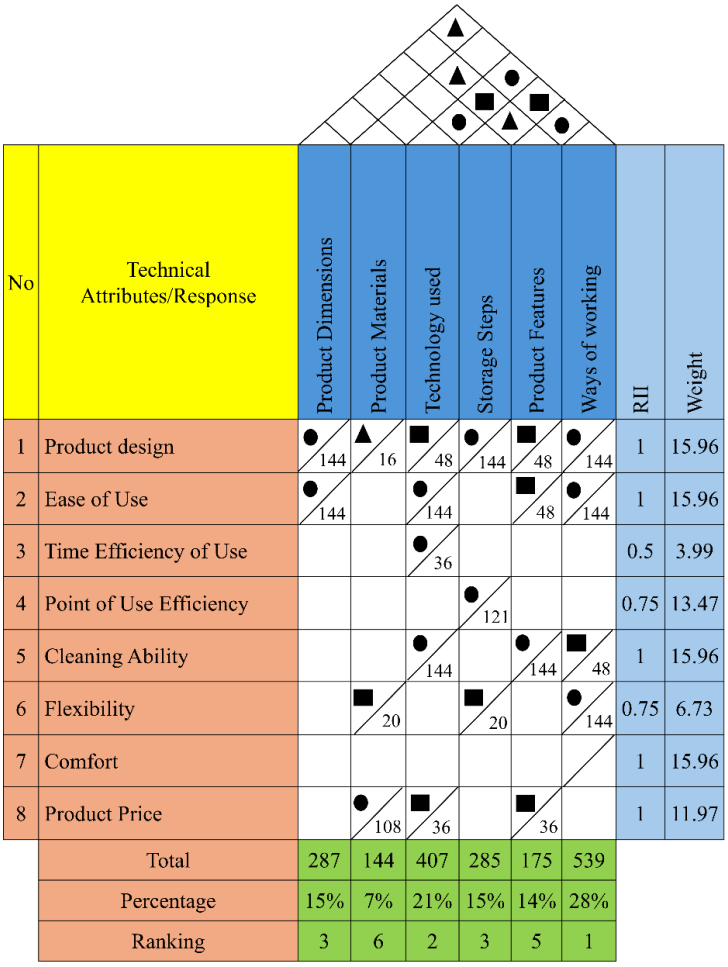


Fig. 2. Implementation Method

2. Tool Design Stage

This stage is the core of the entire tool development program. At this stage, the entire planning and concept development process is carried out in detail, starting from system-level design to detailed design of the tool in question. At this stage, ergonomic principles are applied optimally to create a design that is not only efficient in its function, but also comfortable to use in the long term. The Quality Function Deployment (QFD) method is applied in a structured manner in designing the prototype of this tool, with the aim of maximizing important attributes in the previously determined product design, such as product design, ease of use, comfort, and effectiveness of the tool in cleaning. Based on the QFD analysis, these attributes become the main

focus that must be met in the final product design. In addition, a more detailed tool design plan is prepared, covering technical aspects such as the materials used, the working mechanism of the tool, and the overall design appearance. The tool prototype produced at this stage undergoes several revisions to correct deficiencies found during the evaluation, with the hope that the final product can meet all established ergonomic and functional standards.



No	Technical Attributes/Response	Product Dimensions	Product Materials	Technology used	Storage Steps	Product Features	Ways of working	RII	Weight
1	Product design	● 144	▲ 16	■ 48	● 144	■ 48	● 144	1	15.96
2	Ease of Use	● 144		● 144		■ 48	● 144	1	15.96
3	Time Efficiency of Use			● 36				0.5	3.99
4	Point of Use Efficiency				● 121			0.75	13.47
5	Cleaning Ability			● 144		● 144	■ 48	1	15.96
6	Flexibility		■ 20		■ 20		● 144	0.75	6.73
7	Comfort							1	15.96
8	Product Price		● 108	■ 36		■ 36		1	11.97
	Total	287	144	407	285	175	539		
	Percentage	15%	7%	21%	15%	14%	28%		
	Ranking	3	6	2	3	5	1		

Fig. 3. Quality Function Development

According to Figure 3, important technical attributes obtained from customer needs are product design, ease of use, cleaning ability, and comfort. Meanwhile, important technical responses required to meet customer need are how products work, the technology used, storage steps, and product dimensions.

Fig. 4. Tool Design Plan

In developing Magie Broom, beside the implementation of ergonomics concept, the selection of sustainable materials also become a key focus, such as the use of recycled plastic components for the handle and head of the broom, bamboo or natural fibers for the bristles, and water-based paint that is free of VOCs. However, the challenge faced during the design development was how to ensure that the recycled and natural materials selected had strength and durability that was equivalent to or better than conventional synthetic materials. Additionally, there were difficulties in designing a product that remains ergonomic and aesthetically appealing while meeting sustainability standards.

3. Testing Stage

After the prototype of the tool is designed, the next step is to test the tool to ensure that the product developed meets the established standards and can be used safely and comfortably by its users. Testing is carried out in several stages designed to test various aspects of the product. In the first stage, testing is carried out to determine the feasibility of the tool prototype, which includes testing the functionality and safety of the tool. In the second stage, the tool prototype, which includes testing the functionality and safety of the tool. In the second stage, the prototype is tested directly by the cleaning service team from the Industrial Engineering Department to test its performance in a daily use contest. Data collection from respondents at this stage was conducted through interviews with a sample of users who had participated in product testing. In the third stage, testing is carried out by an ergonomics expert. The data in this third stage was also collected through in-depth interviews with respondents to gather perspectives from experts. An ergonomic expert, Mr. Sritomo Wignjosoebroto, provides an evaluation from an ergonomic perspective, ensuring that the tool developed is truly comfortable to use and in accordance with applicable ergonomic principles. The testing process also applied ergonomic testing by measuring REBA scores in cleaning activities using Magie Broom and traditional tools to determine the potential reduction in MSDs among users.

4. Analysis Stage

In this final stage, an in-depth analysis is carried out on the product prototype that has been tested and is ready for further production. This analysis includes calculating the cost of

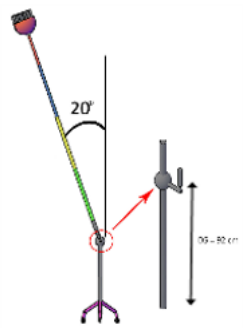
manufacturing the product, which is carried out by following the principle of "A good ergonomics is a good economics", which emphasizes that ergonomic design not only supports user comfort, but also provides cost efficiency in the production process. With this cost analysis, it is expected that the resulting product can be mass-produced and marketed at a competitive price. In addition, at this stage, documentation is also carried out regarding the entire process of program implementation, as well as efforts to socialize the product to the community to increase awareness and market acceptance of this product.

4. Results and Discussions

Magie Broom is an innovation designed based on user needs analysis to create a cleaning tool that can provide convenience, efficiency, and comfort in cleaning various areas in the house. This tool is designed by considering the results of a user needs survey involving various groups, such as housewives and students, who routinely clean rooms. From the results of the questionnaire distributed to potential users, it was found that the main attributes considered most important include ergonomic and aesthetic product design, ease of use that can save time and energy, and comfort in the cleaning process. In addition, the tool's ability to clean thoroughly, including hard-to-reach areas such as roofs, corners of rooms, and windows, is also a major concern in designing this product. Identification of these needs is in line with the principles of ergonomics and anthropometry that have been explained previously, where the design of the tool must adjust to the dimensions of the human body to minimize the risk of injury and increase work efficiency.

Based on data obtained from the survey and analysis results using the Quality Function Deployment (QFD) method, the technical attributes that are the main priority in designing Magie Broom include the effective way the tool works, the technology used, efficient storage steps, ideal product dimensions, additional features that support the tool's function, and high-quality product materials. This technique ensures that every element of the tool's design is directly related to the user's needs. For example, the way the tool works is designed to support important attributes such as ease of use, flexibility, comfort, and the ability to clean a variety of surfaces. This results in line with research by Merino et al., (2012) that highlight the importance of product usability in product design. In addition, the results showing the importance of product flexibility in this study are also in line with the results by Schneider et al., (2020). The technology used, such as the use of rechargeable batteries, not only makes it easier to use, but also increases time efficiency and reduces dependence on direct electricity sources. This statement is consistent with research by Kang et al., (2012). The storage process is also designed so that it does not take up much space, supporting the principle of modularity that is a priority in product design. The modularitu feature also use to consider product live cycle for Easy Recycling that allows to recycle individual components at the end of the product's lifecycle (Cong et al., 2019; Favi et al., 2019; Shahhoseini et al., 2023; Sonego et al., 2018). The dimensions of the product are made according to the proportions of the user's body, while additional features such as a combination of broom, mop and ceiling cleaner provide more benefits than ordinary cleaning tools. The materials used in the Magie broom are also selected to ensure durability, production cost efficiency, and an aesthetic appearance that suits consumer tastes.

Table 1 – Comparation with Competitor

	Magie Broom	Competitor
Picture		
Design	Modular Design & Portable	Modular Design
Electricity	Rechargeable battery	Only Electricity (plug-in)
Function	3 functions (mop, broom, ceiling broom)	Only 2 functions (mop, broom)
Price	IDR 550.000	IDR 959.900

This comparison shows that the magie broom is not only superior in terms of more affordable price, but also has significant advantages in various aspects of its design and function. Its modular and portable design makes it easy to store and flexible to use, while its more environmentally friendly power source with a rechargeable battery makes it more economical than other more diverse cleaning tools, including brooms, mops, and ceiling cleaners, providing a more complete solution for home cleaning needs. These advantages are in line with the product design principles discussed earlier, where flexibility, efficiency, and innovation are key elements in developing optimal tools.

As part of the product validation process, the magie broom has gone through a user phase to ensure effectiveness, comfort, and ease of use. The test results show that this tool has a significant impact on facilitating cleaning activities, both on floors, roofs, and windows. Feedback from users, including suggestions and criticisms, is an important input in the evaluation and improvement process of this tool, so that detected weaknesses can be minimized. This process emphasizes the importance of an iterative approach in product development, as discussed earlier, where prototype analysis and interactive evaluation play a major role in improving the quality and functionality of the final product.

The commercialization potential of the magie broom is also very promising. The cost analysis results show that this tool not only meets ergonomic standards but is also cost-efficient, making it an attractive choice for consumers. This approach supports the principle of "Good ergonomics is good economy," as explained in the previous analysis stage. In addition, compared with conventional cleaning tools, the magie broom offers a number of advantages, such as efficient use of storage space, significant energy savings, and higher effectiveness in completing various household cleaning activities. With these advantages, the magie broom is not only able to meet user needs, but also has the potential to become an innovation that can revolutionize cleaning tools in the market.

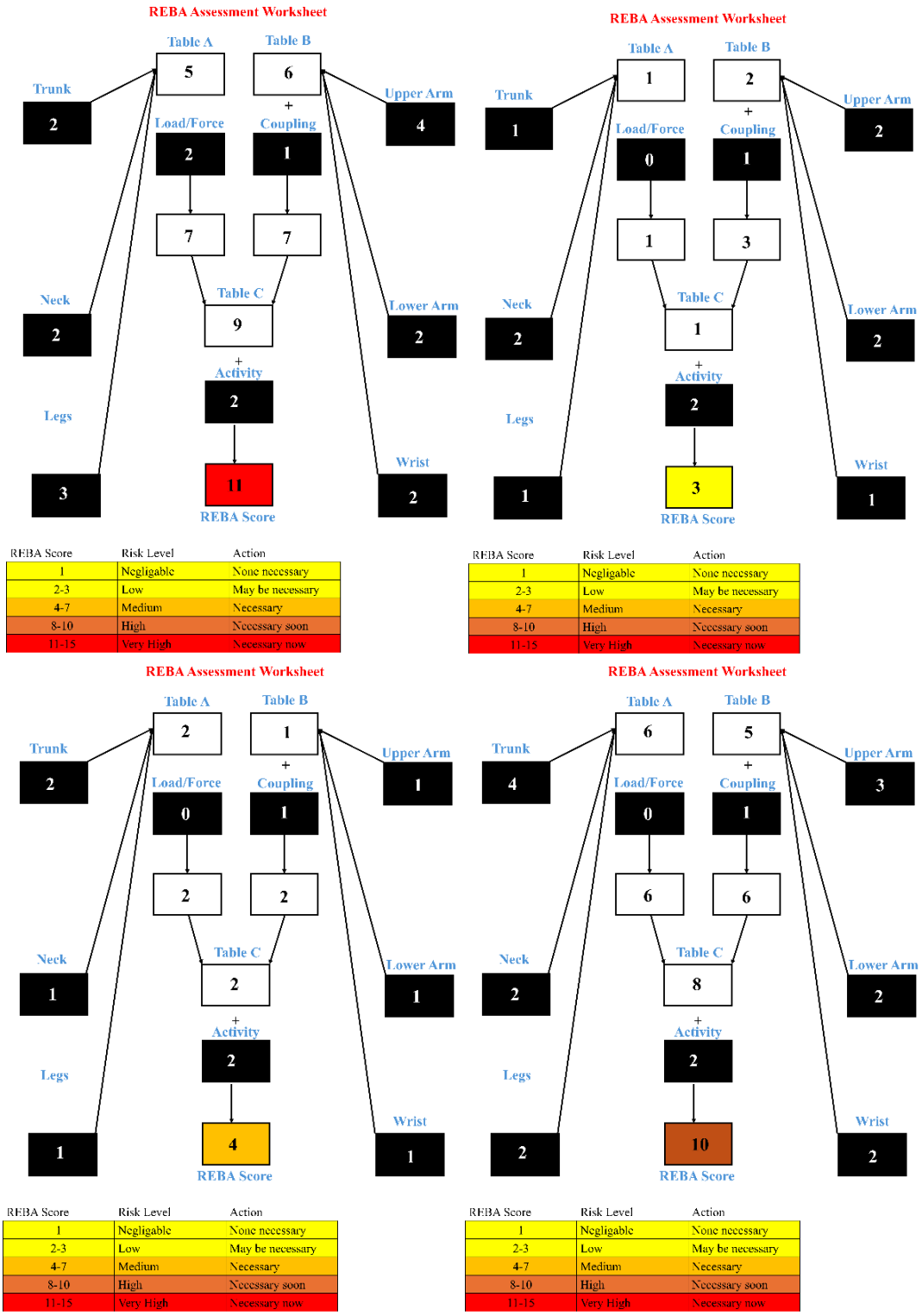


Fig. 5. REBA Assessment Worksheet

Base on previous study The most preferred and effective way to reduce the risk of MSDs is by implementing engineering controls that include redesigning cleaning tools to provide mechanical benefits and choosing and adopting appropriate technologies (Carrivick et al., 2005; Harris-Adamson et al., 2019; Jensen et al., 2011; Lin et al., 2022). The results of the Rapid Entry Body Assessment (REBA) for Magie Broom showed a significant improvement in terms of user comfort and safety in accordance with the application of ergonomic principles in the design of this product. The assessment was carried out by comparing the user's working posture before and

after using the Magie Broom. Before using this tool, the REBA score reached 11 which is included in the "very high" category and requires immediate action to prevent potential disorders of the muscles and joints. This score indicates that conventional cleaning tools put heavy pressure on the body, especially on the neck, back, and arms, due to non-ideal working postures. In some conditions, the REBA score also reached 10 which is included in the "High" category, this indicates that the risk is still quite high in certain body positions that put pressure on the back and arms. This is a warning that the use of traditional cleaning tools without proper ergonomic design can have a negative impact on body health in the long term.

However, after using the Magie Broom, the REBA score showed a significant decrease. For the neck, the score dropped to 3, indicating a very low risk of injury. Likewise, the back condition received a REBA score of 4, which is included in the "moderate" category. This decrease in score indicates that the magie broom design has succeeded in reducing the pressure on the body of use with better ergonomics. In addition, the REBA scores for other body parts, such as the feet and wrists, also showed significant improvements. This decrease in score reflects the efficiency of the magie broom design which prioritizes user comfort, helps maintain natural body posture, and reduces excessive physical burden when cleaning. This proves that the magie broom is comprehensively designed by considering the ergonomic and anthropometric aspects of the user. This tool is not only used, but also helps reduce the risk of musculoskeletal disorders that often occur due to the use of traditional cleaning tools. Thus, the magie broom is not only a practical solution for cleaning activities, but also supports the health and well-being of users in the long term. The results of the REBA ergonomic testing are consistent with previous studies, which also showed a reduction in the risk of MSDs in products with ergonomic designs (Brazil et al., 2023; Fathurohman et al., 2024; Lin et al., 2024; Naik & Khan, 2020; Yang et al., 2022).

According to Piedrahita 92006), the total cost caused by one case of MSDs can reach $489 per year, which includes various social losses experienced by workers such as medical expenses, transportation, equipment, child care, and housework. Assuming that 1 dollar is IDR 15,000, the total loss caused by one case of MSDs per year is IDR 7,335,000. If the Magie Broom can reduce the risk of MSDs from a REBA score of 11 to 3 (73%), it can be assumed that by using the Magie Broom, users can reduce lost costs by IDR 5,334,543 per year.

The results of the design and testing show that the Magie Broom, which integrates ergonomic and sustainability concepts into its design, has broad application potential across various user populations due to its adjustable feature that can adapt to the tool's height requirements. The Magie Broom can also be applied to various cleaning activities due to its multifunctional features. The ergonomic and flexible design of this tool makes it an adaptive solution in various cleaning contexts, enhancing productivity and reducing the potential risk of MSDs. However, some limitations of the product that were not analyzed in this study also need to be considered. First, the limited lifespan of the rechargeable battery can be a constraint for users requiring long operational time. Second, although the modular design offers significant flexibility, there is a risk of wear or damage to the joints and modular components with frequent use, requiring careful consideration of material selection and joint design.

5. Conclusion

Magie broom is an innovative cleaning tool that combines the concepts of anthropometry and ergonomics to overcome problems that often arise due to improper body position when using conventional cleaning tools. This tool is designed with a broom handle that can be adjusted in length, from 92 cm (50th percentile) to 400 cm (90th percentile), so it is comfortable for various body sizes. Rapid Entire Body Assessment (REBA) analysis showed a decreasing score when using Magie Broom compared to conventional tools from 11 (high risk) to 3 (low risk). This result indicates an improvement in ergonomic safety and user comfort. Because the design can adjust to the user's height, the user sample also reported positive feedback in reducing strain on the neck, shoulders, and arms, when performing tasks using Magie Broom. Sample users also highlighted the ease of use due to its multifunctional features. With a comprehensive ergonomic approach, the market potential for Magie Broom is very promising, especially in sectors that require repetitive cleaning such as hotels, offices, hospitals, and factories. Its multifunctionality and

ergonomic adjustability fill a gap in traditional cleaning tools. The lower price of the Magie Broom compared to similar products also enhances its market potential. Finally, this research provides cleaning tools innovation that can directly improve comfort and reduce the risk of work-related injuries for cleaning process. Also gives examples of the practical application of ergonomic principles in product design and emphasizes the importance of sustainable design to meet the needs of diverse users. Further research could focus on materials selection to maximize environmental sustainability, conducting larger-scale studies to validate its benefits, and exploring the integration of smart technology.

6. Author Contribution

Roikhanatun Nafi'ah: Conceptualization, Methodology, Software, Validation, Formal analysis, Investigation, Resources, Data Curation, Writing – Original Draft, Supervision, Project administration, Funding acquisition**. Adhe Lingga Dewi:** Methodology**,** Software, Validation, Formal analysis, Investigation, Writing – Original Draft**. Kamila Nur Rosya:** Formal analysis, Resources, Writing – Review & Editing, Visualization

7. Data Availibility

Data supporting this study are available from the authors upon reasonable request. Access to the data is subject to approval and a data sharing agreement due to the presence of personal information and respondents' opinions, and because the data is also intended for commercial development

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