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Portable Pedal Powered Washing Machine

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Abstract

Access to affordable and sustainable laundry solutions remains a significant challenge in off-grid regions and resource-constrained environments. Conventional washing machines are energy-intensive and expensive, while traditional manual washing is physically taxing and time-consuming. This study details the design and development of a portable pedal-powered washing machine, utilizing recyclable materials and an ergonomic structure to enhance user accessibility. The methodology involved mechanical design optimization followed by a comparative performance analysis against manual washing methods. Results indicate that the prototype effectively reduces physical strain and operational costs while maintaining cleaning efficiency without electrical dependency. Ultimately, this machine serves as a viable, eco-friendly alternative that promotes sustainable living and improved user well-being in diverse populations.

1. Introduction

Laundry is a daily necessity, yet access to electric washing machines remains limited in rural areas and among low-income communities, such as students. Conventional machines are expensive, require electricity, and consume large amounts of water, making them impractical for many users. Manual handwashing, on the other hand, is time-consuming, physically exhausting, and may cause skin irritation due to prolonged exposure to detergent. Extended periods of manual washing are associated with musculoskeletal disorders and ergonomic inefficiencies [1].

To address these issues, a pedal-powered washing machine was developed to provide a sustainable, electricity-free alternative for everyday laundry needs. The machine is designed to operate entirely through human pedalling power, making it suitable for areas without stable electricity and ideal for those seeking to reduce energy usage. It is compact, portable, and constructed from recyclable materials, including rubber wood, stainless steel, and High-Density Polyethylene (HDPE) plastic.

Many people, especially students and rural residents, still rely on handwashing due to high laundry costs or a lack of machines. This method requires significant effort, often leads to discomfort or injury, and is inefficient for larger loads. Inconsistent washing results and long drying times also affect productivity and quality of life.

1.1 Project Background

Laundry is a routine necessity in daily life, yet many people, especially in rural areas or student housing, face challenges in accessing efficient washing facilities. While conventional electric washing machines are widely available, they are often costly, require electricity, and consume large amounts of water. These factors make them unsuitable for users with limited space, unstable power supply, or financial constraints.

The pedal-powered washing machine addresses these challenges with a manually driven crank and bar linkage system that rotates a 50-litre drum. It supports a load of up to 12 kg, and its wheeled frame adds portability for small living spaces. Through thoughtful design and user feedback, this innovation offers an efficient, cost-effective, and eco-friendly alternative to conventional laundry solutions.

As a result, many individuals continue to rely on manual handwashing methods. Although simple and accessible, this method is physically demanding and time-consuming. Extended periods of handwashing can lead to health issues such as back pain, wrist fatigue, and skin irritation due to prolonged contact with detergent and water. In addition, handwashing is inefficient for larger laundry loads, reducing productivity and increasing user discomfort.

To address these issues, a pedal-powered washing machine was developed as a sustainable alternative that requires no electricity. The machine operates using a manual crank and bar linkage mechanism, allowing users to rotate a 50-liter drum by pedaling. It supports up to 12 kg of laundry and is built with recyclable and durable materials such as stainless steel and rubber wood. The design emphasizes portability, ergonomics, and ease of use, making it ideal for small living spaces and off-grid communities.

2. This innovation aims to reduce physical strain, lower dependence on electrical infrastructure, and promote environmental sustainability by offering a cost-effective and practical laundry solution.Literature Review

Research on pedal-powered washing machines highlights their practicality and sustainability, particularly in regions where electricity is scarce or unavailable. Traditional laundry methods, such as handwashing, are labor-intensive, time-consuming, and often inefficient. Mechanized alternatives, while effective, are unsuitable for off-grid communities due to their dependency on power and high costs.

Previous studies and prototypes reveal various mechanical systems that transform human energy into efficient washing mechanisms. Pedal-powered systems have been recognized as effective low-cost solutions for rural areas, converting human kinetic energy into rotational motion for laundry tasks [2]. For instance, crank and bevel gear systems provide smooth power transfer, while fixed gear and chain setups offer robust, low-maintenance solutions. Bar linkage mechanisms simplify the conversion of linear pedal motion into rotational drum movement, making them a popular choice for cost-sensitive designs.

Existing products, such as the Yirego Drumi [3], Giradora [4] and SudsCycle [5] exemplify the successful implementation of pedal-powered designs. These machines not only address energy limitations but also incorporate user-centric features, such as portability, lightweight construction, and ergonomic designs. Comparative analyses of these products underscore their ability to reduce water and energy consumption while ensuring effective cleaning performance. By leveraging insights from these studies, this project refines the design to maximize efficiency and user satisfaction.

Table 1 *Comparative advantages and limitations of current manual washing technologies*

Product Name	Yirego Drumi Portable Washing Machine	Giradora Foot Powered Washing Machine	SudsCycle Bicycle Washing Machine
Advantages	- It can wash small loads of clothes in about 10 minutes [3]. - Compact and lightweight, making it easily accessible anywhere [3].	- Its ergonomic design can help reduce back pain. - Compact and lightweight, making it suitable for outdoor uses [4].	- It reduces carbon footprint by generating power from pedaling the bicycle. - Combines both laundry and physical activity at the same time for a healthier lifestyle [5].
Disadvantages	- It has a limited washing capacity, which is around five to seven clothes per wash [3]. - Consumes much more time	- It has a limited capacity of five to seven clothes per wash [4]. - May lead to wear and tear of components if used	- It requires some effort to assemble it initially. - It may be uncomfortable for users to become accustomed to how it works.

to wash a load of clothes.	frequently.

Table 1 illustrates the comparative advantages and limitations of current manual washing technologies, revealing a persistent trade-off between portability and operational capacity. While the Yirego Drumi and GiraDora offer ergonomic, foot-powered solutions that reduce physical strain, they are constrained by small load capacities and susceptibility to mechanical wear under frequent use. In contrast, the SudsCycle leverages bicycle-driven power for environmental and health benefits but necessitates complex assembly and a steeper user learning curve. Collectively, these existing products demonstrate the viability of human-powered systems but highlight critical gaps in durability and volume efficiency that necessitate further design optimization.

3. Methodology

The development of the pedal-powered washing machine follows a systematic, user-centred approach that aims to strike a balance between functionality, cost, and sustainability. The process begins by clearly identifying a problem that needs to be solved. Once the problem is defined, relevant data and information are collected to better understand the situation. Based on this understanding, possible solutions or concepts are developed and evaluated. After selecting the most suitable concept, appropriate materials are chosen to ensure the design is practical and effective. A prototype is then created to represent the proposed solution, which is tested and analyzed. Finally, the design is improved through evaluation and optimization until it meets the desired requirements, completing the development process. This methodology ensures the final product aligns with user expectations while achieving the project's sustainability objectives. A flowchart detailing the development process provides a visual roadmap, emphasizing the iterative and collaborative nature of the project.Material Selection

The selection of materials for the pedal-powered washing machine emphasizes durability, sustainability, and cost-effectiveness. High-Density Polyethylene (HDPE) was chosen for the water drum due to its lightweight and robust properties. At the same time, rubberwood was selected for the frame, combining renewable attributes with strength and water resistance. Pedals made from Polypropylene (PP) and Polyvinyl Chloride (PVC) ensure user comfort and efficient energy transfer. Stainless steel tubes provide high corrosion resistance and reduced weight for structural components, and castor wheels with integrated brakes enhance portability and stability during operation. These carefully selected materials strike a balance between functionality and environmental considerations, making the machine both effective and eco-friendly. The use of rubberwood is particularly sustainable within the Malaysian manufacturing context due to its abundance as an eco-friendly byproduct [6], while stainless steel and HDPE provide the necessary durability for mechanical laundry components [7]. Fig. 1(a) shows the final product drawing created in SolidWorks, and Fig. 1(b) shows the complete fabricated product.

(a) **(b)**

Fig. 1 *Final Product using SolidWorks and Fabricated Product (a) Drawing of final product using SolidWorks; (b) Complete Fabricated Product*

3.1 Costing

This section outlines the estimated material costs involved in the development of the Pedal-Powered Washing Machine for Final Year Project 2. The components listed in Table 2 were sourced from local and online hardware suppliers, with prices reflecting the current market rates. Each material was selected to ensure a good balance between affordability and functionality, and to meet the design requirements. The total cost provides a transparent overview of the project's expenses, supporting effective budgeting and planning.

Table 2 *Material cost*

No.	Components	Quantity	Cost (RM)
1.	50L HDPE Water	1	43.90
2.	Drum Screw	-	3.00
3.	Screw Hook	-	3.00
4.	Pedal with Strap	2	19.94
5.	Stainless Steel Tube	6 (2cm x 1.6cm x 5cm)	154.10
6.	Rubber Wood Pallet	5 (100cm x 100cm)	65.00
7.	Fixed Wheel Tire (3")	4	17.00
8.	Fixed Wheel Tire (4")	4	23.00
9.	Swivel Wheel Tire	2	6.00
10.	Rod Retainer	2	2.00
11.	Ball Bearing	4	18.00
12.	Rubber Cork	2	3.00
	Total		357.94

The total expenditure for the fabrication of the prototype is RM 357.94, as detailed in Table 2. All components and raw materials were procured from local hardware suppliers in Pagoh, Johor, to ensure regional availability and cost-effectiveness. The primary cost drivers were the structural elements, specifically the stainless-steel tubes (RM 154.10) and the rubber wood pallets (RM 65.00), which form the chassis and support frame of the machine. The remaining budget was allocated to essential mechanical and mobility components, including the 50L HDPE drum, pedal mechanisms, and a combination of fixed and swivel wheels to ensure the portability of the final design.

4. Result and Discussion

This section presents the findings from the fabrication process, performance testing, and user evaluation of the Pedal-Powered Washing Machine. The objective is to assess the effectiveness of the machine in comparison to traditional manual washing methods. The evaluation includes measurements of washing time, water usage, and user fatigue, along with survey data from potential users. By analyzing both experimental and feedback-based data, this section provides a comprehensive overview of the machine's practical performance, user satisfaction, and areas for future improvement.

4.1 Pedal-Powered Washing Machine Fabrication

The Pedal-Powered Washing Machine was built in multiple phases using essential components, including a 100 cm × 100 cm rubberwood pallet for the body, 2 cm × 1.6 cm × 5 cm stainless steel tube for the pedal and mechanism, fixed wheel tires, rod retainers, and ball bearings. The process began with finalising the design and cutting the rubberwood pallet according to the dimensions. The base was assembled using screws, and the mechanism and pedal were fabricated using MIG welding. The mechanism was attached to the water drum using wing nuts to facilitate drum setup.

4.2 Data Collection

4.2.1 The Pedal-Powered Washing Machine's functionality and practicality were assessed through structured surveys and technical testing. The objective was to assess spinning efficiency, overall effectiveness, and usability using experimental data and user feedback. These results are crucial in determining how the tool addresses the challenges students face. Data

collected from Google Forms surveys revealed student expectations, sources of spending, and challenges faced with traditional methods. Several significant design decisions were inspired by user feedback, including the incorporation of water drum positions and movement, as well as sources of efficient usage. Comparative tests were performed on the Pedal-Powered Washing Machine and manual tools, including a washing brush and basin. These were carried out by users with varying physical abilities and evaluated using measures of performance such as water usage, time taken, and rating of fatigue (ROF). The discussion combines qualitative and quantitative findings to assess the tool's practical utility and identify areas for improvement.Methods of Washing

Fig. 2 illustrates the distribution of laundry methods among the 33 respondents. The data shows that the majority of participants n=21, 63.6% utilize laundromats or commercial laundry services as their primary method. Manual handwashing is the second most common approach, practiced by seven respondents 21.2%. A smaller portion of the group n=3, 9.1% utilizes washing machines belonging to neighbors or relatives, while the least common method involves seeking assistance from others, such as family members or friends n=2, 6.1%. From these results, it can be inferred that most individuals prefer commercial laundry services because they are energy-efficient, despite the associated costs.

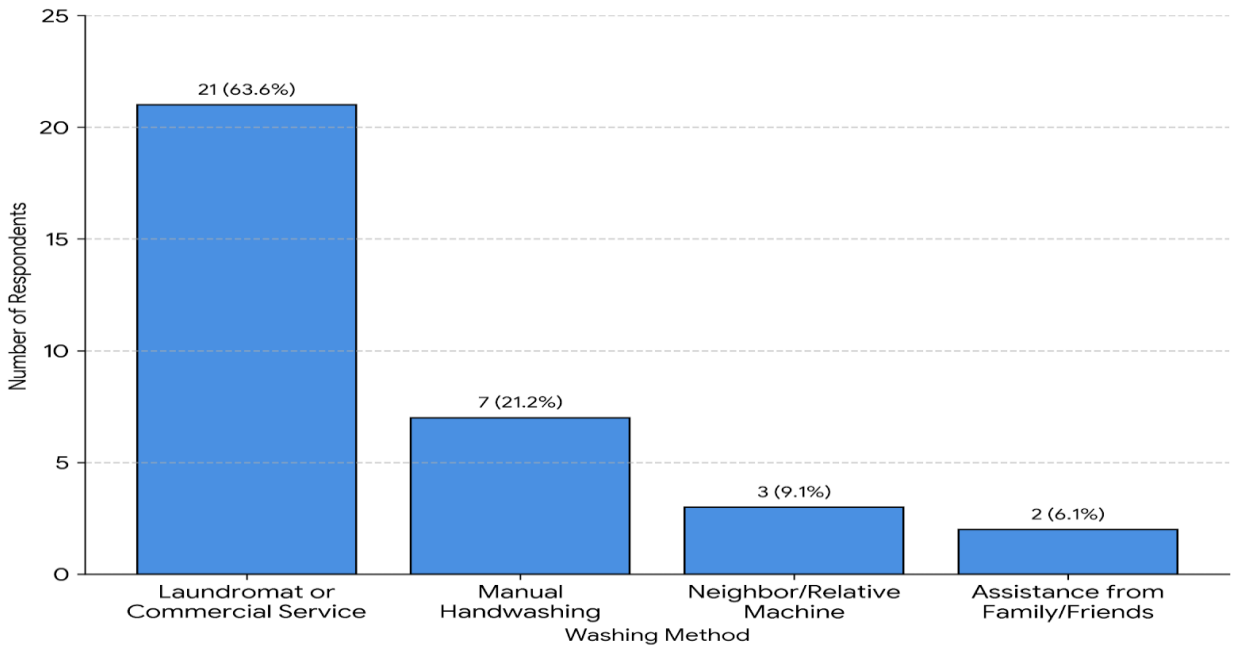

Fig. 2 *Methods of washing*

4.2.2 Challenges Faced Without Using a Washing Machine

Fig. 3 shows that 14 respondents identified time required as the biggest challenge when washing without a washing machine. Next, 11 respondents chose physical effort as their biggest challenge. Some cited the high cost and lack of cleanliness, with values of four people and three people, respectively. Only one respondent chose laziness. Based on the data obtained, various challenges can be encountered when washing clothes without a washing machine.

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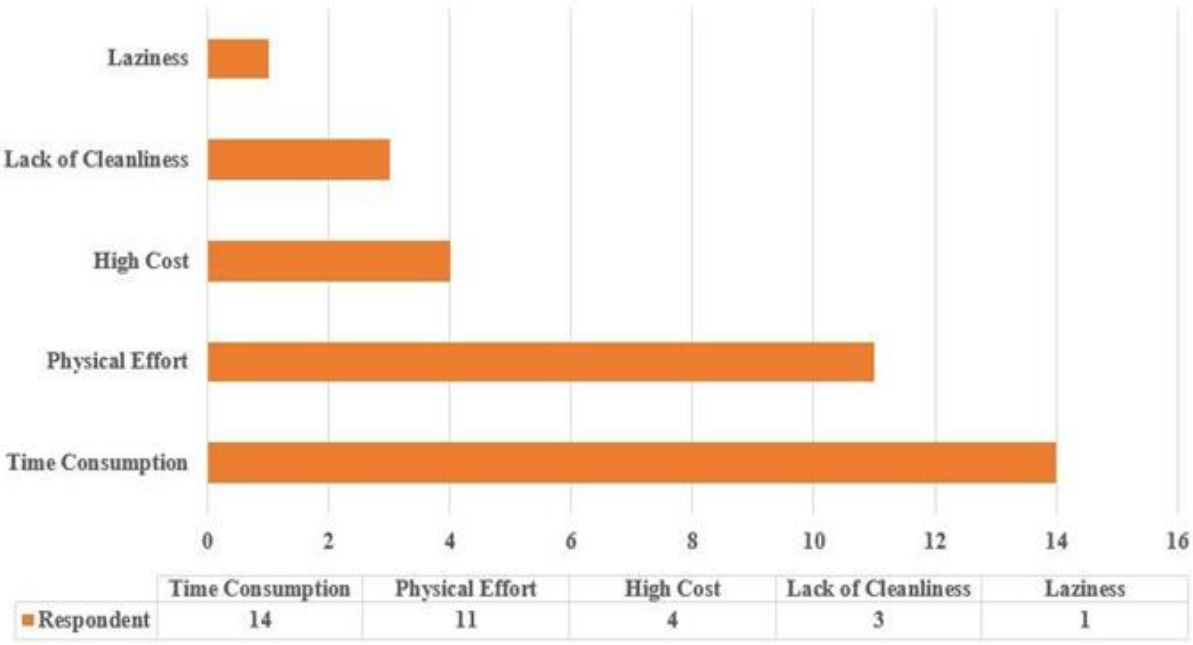

Fig. 3 *Challenges faced without using a washing machine*

4.3 Performance Evaluation of the Pedal-Powered Washing Machine through Model Testing

A series of experiments was conducted to systematically evaluate the performance of the Pedal-Powered Washing Machine compared to manual washing, which involved using a washing brush and basin. The experiments utilised 10 pieces of clothing as the basis of the test. The evaluation focused on critical performance metrics, including water usage, washing duration, and the rating of fatigue across each session. All experiments were performed at Kolej Kediaman Kampus Pagoh, Johor, under normal conditions that simulate real-world applications. The tests were carried out by individuals of varying physical abilities to assess the tool's adaptability and overall effectiveness. The following subsections represent results from seven controlled experiments, and each intended to assess particular functional features of the Pedal-Powered Washing Machine.

4.3.1 Total Time Taken and Total Water Usage Between Using the Manual Method and the Proposed Washing Machine

The time used by the proposed washing machine was up to 21 minutes for both washing and rinsing sessions, while the manual method used up to 34 minutes. This shows a significant speed improvement, validating the tool's efficiency for both sessions.

Fig. 4 illustrates the comparison of water consumption between the manual handwashing method and the proposed pedal-powered washing machine across seven experimental trials. Based on the data collected, the manual method required an average of approximately 53.7 liters of water per session. These findings aligned with previous research show that manual washing methods often consume significantly more water than optimized labor-saving devices [8]. In contrast, the proposed washing machine consumed an average of approximately 39.9 liters. These results indicate a significant reduction in water usage, confirming that the prototype is a more resource-efficient and sustainable alternative to traditional manual washing methods.

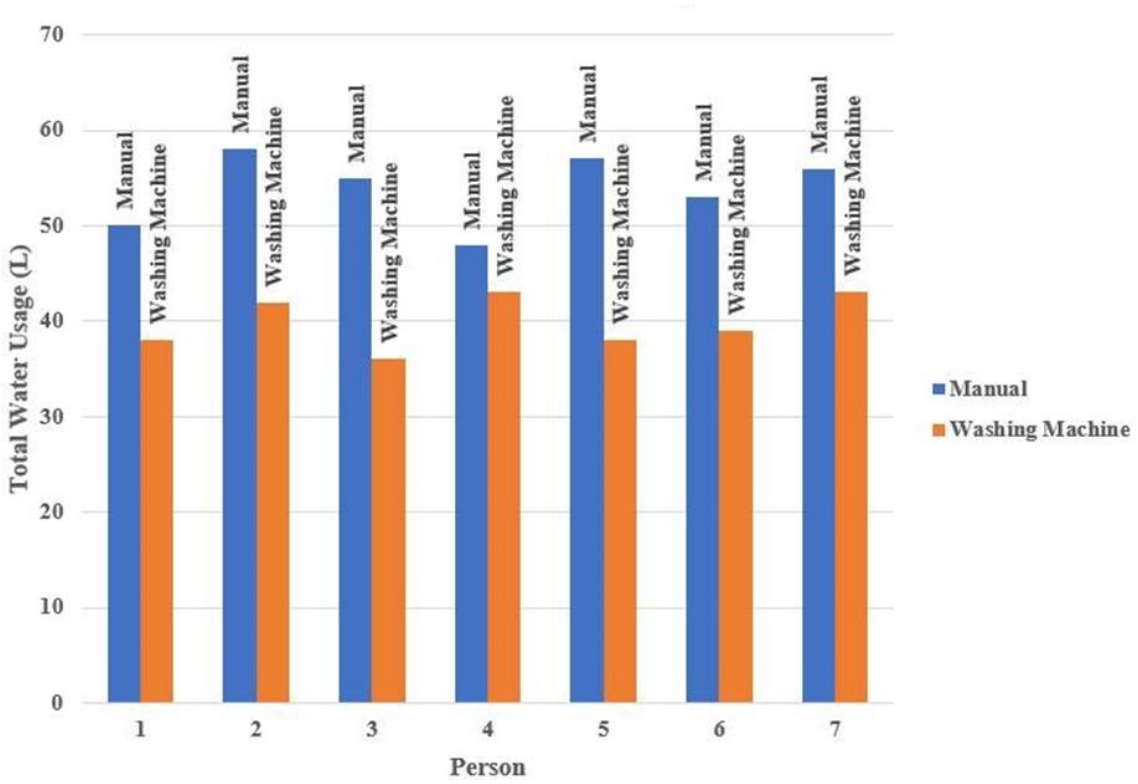

Fig. 4 *Total water usage*

4.3.2 Average Rating of Fatigue Between the Manual Method and the Proposed Washing Machine

Fig. 5 illustrates the comparison of the average Rating of Fatigue (ROF) between traditional manual washing and the proposed pedal-powered washing machine. The ROF scale, which ranges from 0 (no fatigue) to 10 (total exhaustion), provides a subjective measure of the physical exertion required during the laundry process. Manual handwashing typically induces significant wrist fatigue and lower back strain due to repetitive scrubbing and a bent posture. In contrast, the pedal-powered prototype significantly reduces these issues by shifting the physical load from the upper body to the more powerful muscle groups of the legs. This ergonomic shift resulted in a substantial improvement in user comfort, with the prototype consistently achieving a lower average fatigue score across all sessions compared to the manual method.

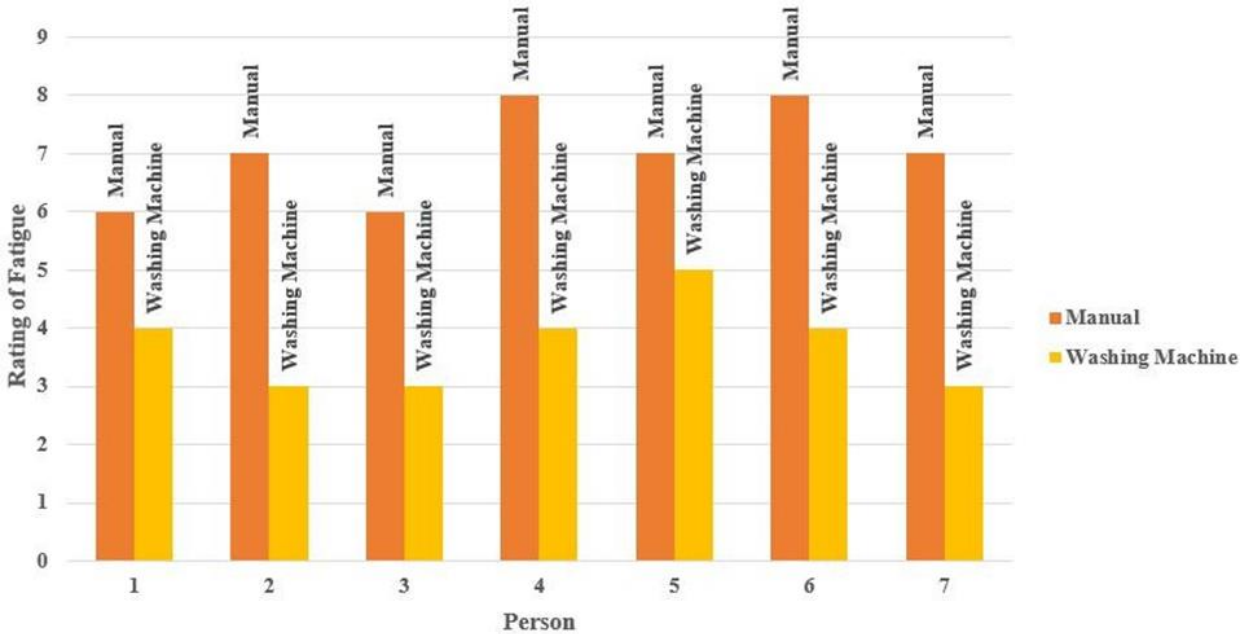

Fig. 5 *Rating of Fatigue (ROF)*

4.4 Discussion

The Pedal-Powered Washing Machine presents a significant improvement over traditional manual laundry methods, particularly in terms of time efficiency, water usage, and user fatigue. The performance tests demonstrated the clear advantages of this pedal-powered design compared to manual washing

In terms of time, the pedal-powered machine completed the washing process in just 21 minutes, a substantial improvement over the 34 minutes required for manual washing. This product reduces the time used by 38% compared to traditional methods. This reduction makes the machine an attractive solution for individuals seeking efficiency without relying on electricity. These results align with previous research on human-powered appliances, which suggests that utilizing lower-body mechanics significantly optimizes task duration compared to manual labour.

Water usage also saw a marked improvement. The pedal-powered washing machine used only 43 liters for both washing and rinsing, while the manual method required 58 liters. This reduces water consumption by 26%, making the machine a more sustainable option for water-scarce areas.

Regarding user fatigue, the pedal-powered machine outperformed manual methods. The fatigue rating (ROF) was significantly lower, reflecting the reduced physical effort required compared to hand scrubbing. This improvement in comfort is particularly beneficial for users with limited physical strength, such as the elderly. This shift from upper-body strain to the more powerful muscle groups of the legs is a well-documented ergonomic advantage in pedal-driven technology literature

Survey data confirmed that the primary issues with manual washing are time and physical effort. Users expressed a clear preference for solutions that mitigate these factors. Furthermore, the machine's independence from the electrical grid makes it ideal for off-grid communities. While the design provides significant advantages, there remains room for improvement. Enhancements in mechanical efficiency, further refinement of the pedal mechanism, and increased portability would make the machine even more user-friendly. Additionally, incorporating further ergonomic features would help improve comfort for users who operate the machine for extended periods

5. Thus, the Pedal-Powered Washing Machine provides an innovative, sustainable alternative to traditional laundry methods. The machine's sustainability is further reinforced by the selection of durable, recyclable materials, such as HDPE, rubberwood, and stainless steel. These materials ensure the unit is robust enough for long-term use in demanding environments while remaining an eco-friendly solution for environmental conservation. Its ability to reduce washing time, water consumption, and physical strain offers real benefits to users in communities where electricity is limited. Moving forward, prioritizing refinements in portability and ergonomic design will be essential to maximizing its potential as a versatile and user-friendly solution.Conclusion

The development of the Pedal-Powered Washing Machine offers a sustainable and practical alternative to conventional laundry methods, providing significant benefits in reduced washing time, lower water consumption, and minimized user fatigue. By utilizing durable and eco-friendly materials, the design effectively addresses the challenges of manual washing for users in off-grid communities or regions with unreliable electricity. The project demonstrates the potential of human-powered technology to improve the quality of life while promoting environmental conservation. Moving forward, research should focus on specific technical refinements to enhance usability, including the optimization of pedalling resistance, improvements in mechanical efficiency, and rigorous structural durability testing. These iterations will ensure the machine meets a wider range of user needs and successfully promotes a more sustainable, health-conscious lifestyle.

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Conflict of Interest

The authors declare that there is no conflict of interest regarding the publication of the paper.

Author Contribution

The authors confirm contribution to the paper as follows: ***study conception and design:*** *Muhammad Hamdi Khairul Anwar;* ***data collection:*** *Muhammad Zul`Akmal Mohd Khairy and Muhammad Zulfadhli Roslan;* ***analysis***

and interpretation of results: *Muhammad Hamdi Khairul Anwar, Muhammad Zul`Akmal Mohd Khairy and Muhammad Zulfadhli Roslan;* ***draft manuscript preparation:*** *Mahmod Abd Hakim Mohamad, Muhammad Hamdi Khairul Anwar, Zul`Akmal Mohd Khairy and Muhammad Zulfadhli Roslan. All authors reviewed the results and approved the final version of the manuscript.*

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