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Design, Simulation and Fabrication of an Ergonomic Handgrip for Public Transport in Bangladesh

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ABSTRACT

Many individuals in Bangladesh prefer using private vehicles to avoid the discomfort of public transportation, causing significant congestion during rush hours. To ensure a pleasant journey in public transit, including safe and comfortable handgrips becomes crucial. This study adopts a comprehensive approach to alleviate the discomfort and hand fatigue experienced by public transport commuters in Bangladesh. Our research methodology thoroughly analyses existing handgrips with a diverse age group (11-50) and varied occupational backgrounds, ensuring inclusivity. Meticulously collected anthropometric data from previously published works incorporates the 95th percentiles to account for diverse hand sizes. Leveraging computer-aided design tools, we optimize the hand grip design based on ergonomic principles and hand anatomy. Our study fills a crucial gap by integrating locally derived anthropometric data. The resulting ergonomic hand grip, designed for the specific needs of Bangladeshi commuters, is poised for seamless integration into the public transport system, promising a substantial improvement in comfort and a more positive commuting experience.

Keywords:
Ergonomic, Handgrip, Congestion, Transportation

1. Introduction

Congestion, an outcome of the oversupply of vehicles overwhelming the available road systems, is a pressing issue in Bangladesh, intensifying as the number of vehicles continues to rise. These results heightened vehicle competition for time, leading to mutual slowdowns, especially during peak hours, causing lengthy traffic queues and overcrowded buses with passengers struggling for secure holds. The surge in private car usage exacerbates congestion, necessitating reduced private vehicle reliance.

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To address this challenge, expanding public transportation options, evaluating the convenience of each mode, and increasing available seats during rush hours are proposed solutions. However, the limited space within public transport units poses challenges, making handgrips a practical solution for passengers unable to secure seats. Observations indicate that 66.7% of users occasionally use a handgrip, 23.3% never do, and only 10.7% consistently have access. Consequently, 52.4% of users stand near the door, 25.3% attempt to grip other passengers' handgrips, and 22.3% stand without support [1].

The handgrip, often a small and overlooked feature in public transportation, ensures a convenient and secure commuting experience. As an essential tool for passengers, especially during crowded periods or when standing near doors, handgrips provide individuals with a stable hold, contributing to both safety and comfort. The necessity of handgrips becomes evident as they offer a practical solution for those unable to secure seats. Observations reveal that 66.7% of users occasionally use a handgrip, emphasizing its relevance [1]. In situations where standing without support or gripping onto other passengers' handgrips is prevalent, having well-designed, ergonomic handgrips becomes crucial. The incorporation of effective handgrips enhances the overall commuting experience and addresses challenges associated with congestion and limited space within public transport units. Recognizing the importance of handgrips underscores their necessity in optimizing public transportation for the well-being and convenience of passengers.

Considering previous research on this topic, Table 1 summarizes relevant studies and their findings. This adds context to the current discussion and helps identify gaps and build upon existing knowledge.

In light of these findings, ergonomic handgrips emerge as a crucial remedy, contributing to the ongoing discourse on optimizing public transportation for enhanced efficiency and passenger experience.

1.1 Scope and Objectives

When a large number of people use the road during peak hours to move quickly from one location to another, the road's condition will deteriorate into congestion. Congestion can be remedied, however, if public vehicles are equipped with the facilities and amenities necessary for passengers' needs. The elimination of urban pollution and resolving the traffic problem that troubles the majority of cities are two benefits that will accumulate from improving the standard of service provided by public transportation. As a result, public transportation will make life more comfortable for the general public, particularly in urban areas, where it can help to reduce pollution. When going to their respective workplaces, schools, offices, etc., individuals are strongly encouraged to take the public bus instead of a private mode of transportation. Some steps were followed for the ergonomic handgrips in public transport in Bangladesh. The use case was first defined to ensure access, comfort, and safety within public transportation units. The information comes from various published sources. The data up to the 95th percentile was considered. The target users are both male and female, ranging in age from 15 to 60. The architecture of the grip will either be a spherical grip or a palm grip, with the fingers wrapping the handle and the forearm muscles providing the pulling force. Following a number of different simulations, the material will be chosen. To eliminate any potential discomforts and perfect the design, prototypes will be put through rigorous testing. After the product has been manufactured, user feedback will be gathered to assess how comfortable the new model is compared to previous iterations.

Table 1
Previous studies on handgrips

Reference	Outcome/ Findings of the Study
Javid *et al*. [2]	Public transport system is struggling to cope with the current travel demand
Abidi and Sharma [3]	Due to poor travelling facilities 23 % people have to leave their job opportunities
Kett *et al*. [4]	Transport-related problems are among the most commonly faced issues by PWDs
Almada and Renner [5]	The main problems with public transport was the lack of trained employees to help PWDs with wheel chairs
Isa *et al*. [6]	Certain train stations were inaccessible to PWDs due to poor planning, design, and maintenance
Harbering and Schlüter [7]	Females use public transport more often than their counter parts
Indriyani and Sahroni [8]	Decrease of high-range of the handgrip in women carriage is needed
Obelenis [9]	Musculoskeletal disorders are closely related to poor transport ergonomic conditions
Escalona [10]	The presence of risk factors that could explain the skeletal muscle disorders in upper limbs, shoulders and neck was confirmed
Njoh [11]	Investment in transportation is capable of stimulating economic growth
Jurkauskas and Prunskienë [12]	The concept of sustainable growth in both economy and transport sector must be analyzed in terms of sustainability
Conto- Campis *et al*. [13]	Handgrips in public transport are not at an adequate height which cause hand stretch and risk of falling. Ulrich and Schnarch methodologies can be used to solve this
Grant *et al*. [14]	Different diameters have different manual efforts and there is relationship between handle size and anthropometric dimension. 3.8 cm diameter handle is the most efficient one
Park *et al*. [15]	There are differences in the passenger's posture, height, and weight, decrease in muscle strength, holding the Grips with the thumb and middle finger
Seo and Armstrong [16]	Normal force is 2.3 times greater than split cylinder grip strength and grip strength and force are 46% greater for men than for women
Mbada *et al*. [17]	Pregnant females have significantly lower HGS compared with non-pregnant females, Level of adiposity significantly influences the performance of HGS in females
Liao [18]	Inappropriate force application leads to musculoskeletal injuries, MVC is not linearly related to grip diameter
Seo *et al.* [19]	Fatigue caused in the forearm muscles which can be measured with Electromyography method. The 1.5 in. diameter handle is optimum for gripping
Conto-Campis *et al.* [20]	Development of a grip and support system for public transport
Grant *et al.* [21]	Analysis of handle designs for reducing manual effort: the influence of grip diameter
Ayoub *et al.* [22]	The determination of an optimum size cylindrical handle by use of electromyography
Uetake and Shimoda [23]	Study on the grip and hold strength for stanchions and handrails in buses
Uygur *et al.* [24]	The effects of materials and surface on the frictional behavior between hand and handle
Pronk and Niesing [25]	Measuring handgrip force, using a new application of strain gages. Medical and biological engineering and computing
Yulianti *et al.* [26]	Business feasibility analysis: multifunction bus hand grip
Liao [27]	Study on Gender Differences in Hands and Sequence of Force Application on Grip and Handgrip Control
Ngoc *et al.* [28]	A set of appropriate criteria is proposed and recommendations for the design of quality standards for public transport in developing countries are given
Lee and Sechachalam [29]	This study compares the effect of wrist position, in the flexion extension plane, on grip endurance and grip strength
Hung [30]	The validity study of measuring the falling rate of griping strength
Conto-Campis *et al.* [31]	Development of a grip and support system for public transport

Our objective is to ensure safety and comfort and reduce congestion. The advent of an ergonomic handgrip can meet these objectives. To achieve these goals, we considered the wide range of ages, heights, mobility levels, and statures in Bangladesh. If these goals are not achieved, the passengers may become frustrated, particularly if the existing handgrips are uncomfortable enough to be held for an abnormally extended period. In addition to two people sharing a grip, touching someone else's hand can be stressful and unhealthy because it spreads germs. Handgrips that are hung at an inappropriately high height can contribute to various musculoskeletal problems. In addition to this, the risk of falling increases significantly if there is nothing to hold onto while standing. There is a greater possibility of falling when the public transport units suddenly stop or start moving. There is a significant possibility of experiencing health problems or numbness. Travellers frequently show physical signs of being stressed, the most noticeable of which is tension in their arms. Consequently, some individuals decide that the best option is to use their own personal transportation rather than the public one. The introduction of a handgrip designed with ergonomics in mind is a step toward achieving the goal of ensuring proper facilities in Bangladesh's public transportation systems.

2. Methodology

The design process began to create an ergonomic handgrip by considering fundamental principles outlined in previous works [33-38]. The initial steps involved defining the design case, which aimed to enhance the current gripping system in public transportation for comfort and ease of use, as shown in Figure 1. The user demographic encompassed all passengers of public transport, with a focus on those standing for extended periods, aged 14-60, taking a gender-neutral approach. Anthropometric data specific to Bangladesh, derived from published works [39-40], played a crucial role, and the 95th percentile values were chosen for design dimensions. The grip architecture was defined considering the trade-offs between power and precision, opting for a spherical grip suitable for curved fingers grabbing a circular object. Material selection depended on simulation data, with durometer (material hardness) determining grip security and reduced fatigue. Soft-touch materials were considered to decrease grip strength and contact pressure, providing cushioning and reducing vibrations. Prototypes were to be created through 3-D printing for realistic testing. The validation process involved user-centric sessions with realistic prototypes to identify errors or usability issues. The final step was validating the design by testing the fabricated model against existing ones and gathering user feedback for refinement. Ultimately, the goal is to ensure the finished product complies with design specifications, minimizing the risk of failures and faults.

3. Data Collection

In acquiring anthropometric data for this study, a comprehensive approach was undertaken by leveraging information from two previously published works: Talapatra and Mohsin [35] and Asadujjaman *et al*. [36]. The mean data for various anthropometric measurements was extracted from these reliable sources, forming a foundation for the study's design considerations [39-40].

Asadujjaman *et al*. [36] delved into hand anthropometry, capturing nine hand length, breadth, and thumb length measurements from 110 female workers aged 18 to 45 in Dhaka and Chittagong, Bangladesh. Both hands were measured, and stature was assessed utilizing digital slide callipers and a standard measuring tape.

A meticulous approach was taken to ensure accuracy—each subject underwent the measurement process twice, and the mean value was used to minimize potential errors. The sample size 110 was justified based on ISO 15535 standards, incorporating equations considering the coefficient of variation (CV). Protocols were in place to reject measurements not aligning within 0.4 cm, and a single observer conducted all measurements to eliminate inter-observer errors. This comprehensive approach aimed to provide reliable and standardized anthropometric data.

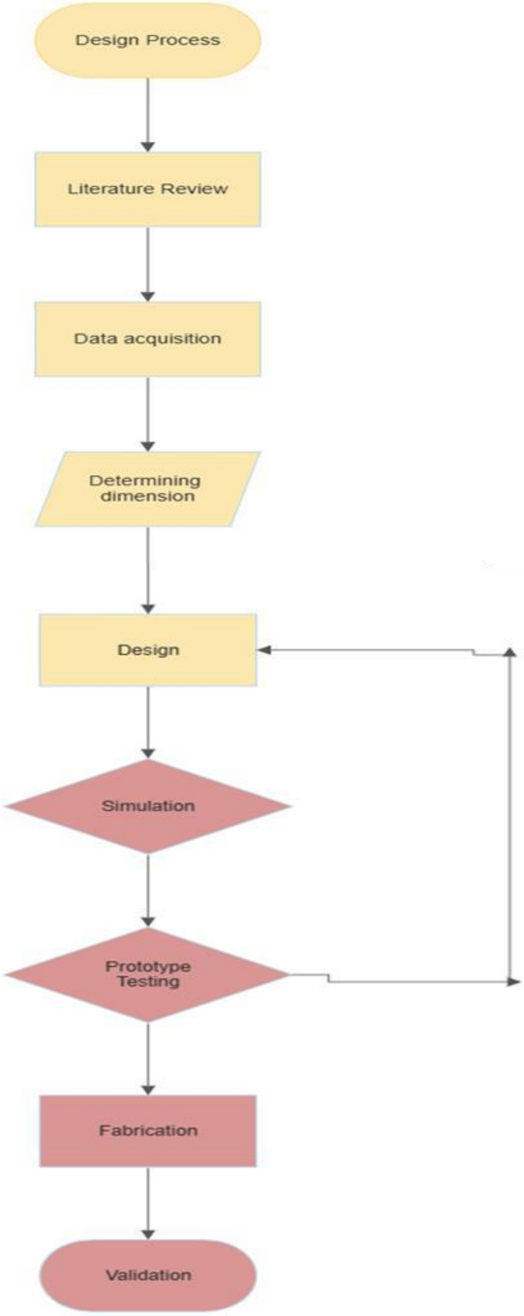

Fig. 1. Methodology of research

Talapatra and Mohsin [35] focused on obtaining hand anthropometric measurements from 110 female workers aged between 18 to 45 years in the Dhaka and Chittagong divisions of Bangladesh. A survey form comprising 15 hand anthropometric measurements was used to collect data. Measurements were conducted meticulously using a meter scale, tape, and sliding caliper, ensuring accuracy and reliability. The sample size justification followed ISO 15535 standards, incorporating equations from Aghazadeh and Mital [37]:

$$n \geq (3{:}006 * CV/a)^2 \quad (1)$$
$$CV = 100 * SD/x(2) \quad (2)$$

where CV represented the coefficient of variation, calculated as the ratio of the mean to the standard deviation (SD) multiplied by 100. The parameter 'a' denoted the percent value of estimated accuracy, ‘x’ represents the mean value of the data and 'n' represented the sample population size. For a precision of five percent, the study referred to similar research on Nigerian farm workers by Okunribido [38].

Moreover, a meticulous selection process was implemented to ensure precision in the study. Only the 95th percentile data from the published works were considered, aligning to design for a broad range of users. This percentile selection aimed to accommodate the diverse hand sizes and shapes within the Bangladeshi demographic, ensuring the resulting ergonomic hand grip would cater to most of the population. By incorporating mean and percentile data from reputable sources, this study aimed to establish a robust foundation for designing and implementing an inclusive and effective ergonomic solution for public transportation in Bangladesh.

Figure 2 shows the main considerations: palm length to middle finger length, hand breadth, finger lengths, and hand length. The dimensions were considered to determine the dimension of the length, width, and diameter of the grip. The Bangladeshi population are the main focus of the study. Thus, only recently published works of this geography were taken into consideration. As mentioned earlier, the anthropometric data taken into consideration was among the 95th percentile of the collected data of the works.

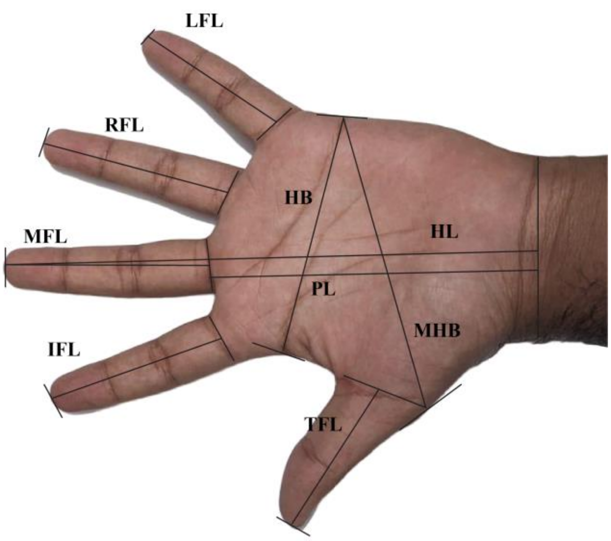

Fig. 2. Hand anthropometric measurements. HL: Hand Length, HB: Hand Breadth, MHB: Maximum Hand Breadth, PL: Palm Length, TFL: Thumb Length, IFL: Index Finger Length, MFL: Middle Finger Length, RFL: Ring Finger Length and LFL: Little Finger Length

4. Results and Discussion

4.1 Design

Figures 3 and 4 illustrate the proposed design based on the anthropometric data. *SolidWorks* was used to model the grip. The dimensions are set to have a comfortable and firm grip. 3D modeling was done after experimenting with the comfort factor of the design.

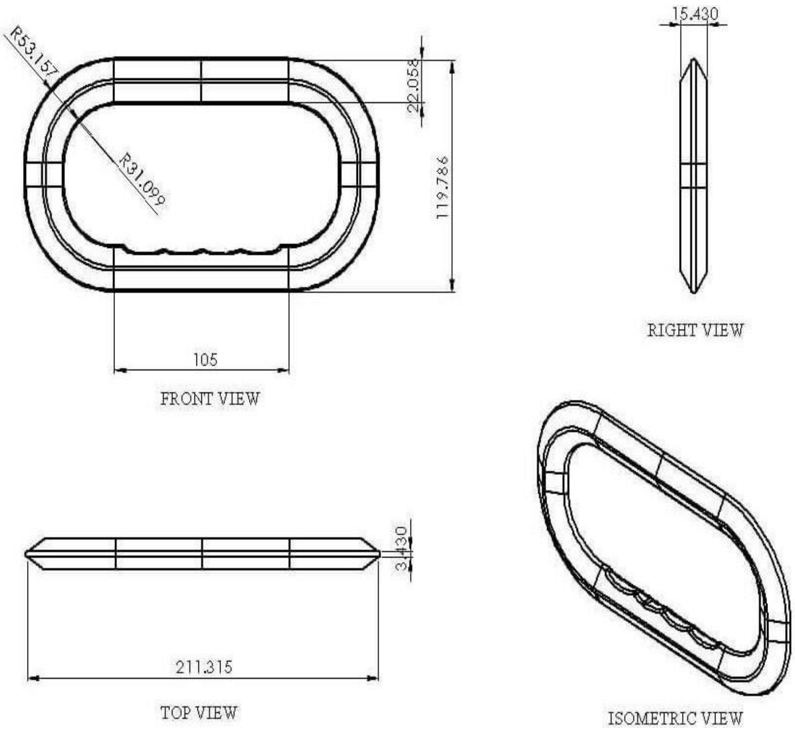

Fig. 3. Design of ergonomically optimized hand grip

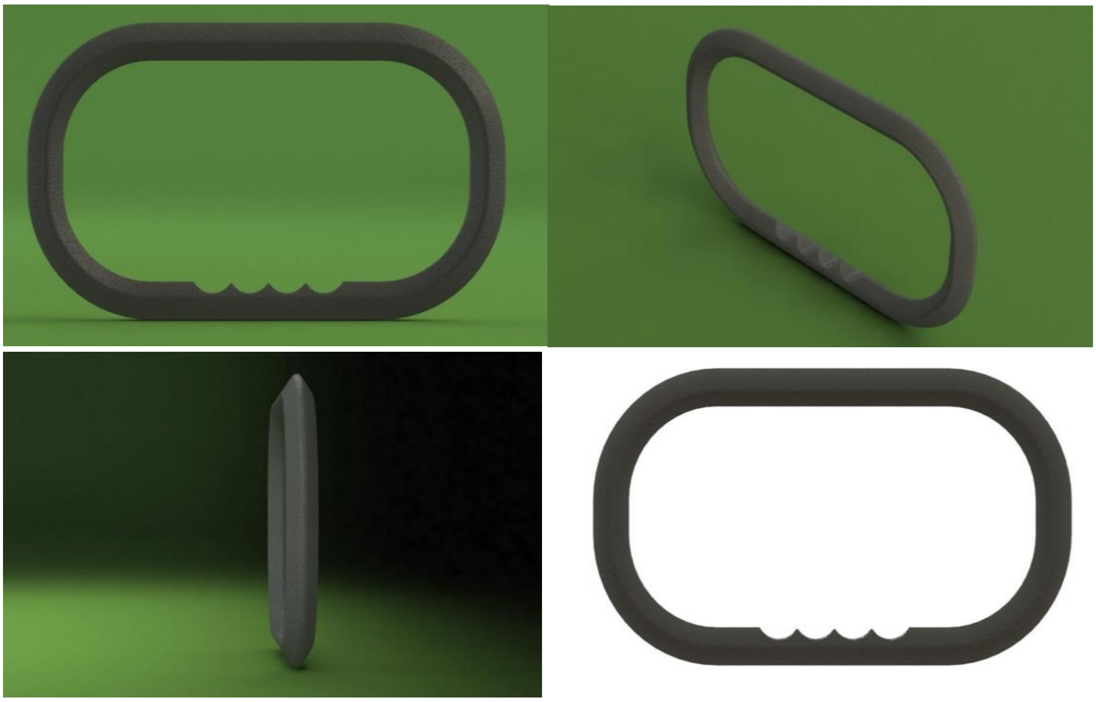

Fig. 4. Different views of the 3D model of the grip

The design process of the ergonomic hand grip involved a systematic experiment, considering key parameters to optimize the final design for the specific needs of commuters in Bangladesh. Utilizing Keyshot and *SolidWorks*, multiple 3D models were generated and tested to identify the most effective design. The grip length was experimentally determined to accommodate gripping opportunities for two individuals during rush hours.

A series of experiments were conducted to quantify the impact of design choices, assessing the contact area between the hand and the handle. Various handle shapes, including the curved design, were tested to measure the resultant contact areas. The experiments incorporated insights from Aldien *et al*. [39], where handle size, grip, and push forces were shown to influence the maximum pressure amplitudes on the contact area.

The iterative design process involved creating prototypes with different handle forms and lengths. These prototypes were evaluated based on numerical metrics, such as grip comfort scores and pressure distribution measurements. Iterative adjustments were made to enhance user-friendliness and ergonomic efficiency.

The final design, selected through this experimental process, exhibited superior performance regarding increased contact area and minimized pressure amplitudes. The chosen design represents an optimized solution supported by numerical data and empirical evidence gathered through systematic experimentation, ensuring an enhanced commuting experience for individuals in Bangladesh's public transportation system.

4.2 Simulation Results

This project centred on the ergonomic design of handgrips for public transport in Bangladesh. Comprehensive simulations were executed using SolidWorks and ANSYS software to assess the feasibility and performance of the design. The simulations specifically evaluated the deformation and strength characteristics of various materials commonly employed in handgrip manufacturing. The outcomes derived from these simulations offer valuable insights crucial for informed decisions in material selection and design refinement. These findings contribute significantly to achieving optimal performance and ensuring user comfort in the final handgrip design. Figure 5 provides a visual representation of the buckling and deformation experienced under external loads, simulating the weight of passengers on the handgrip.

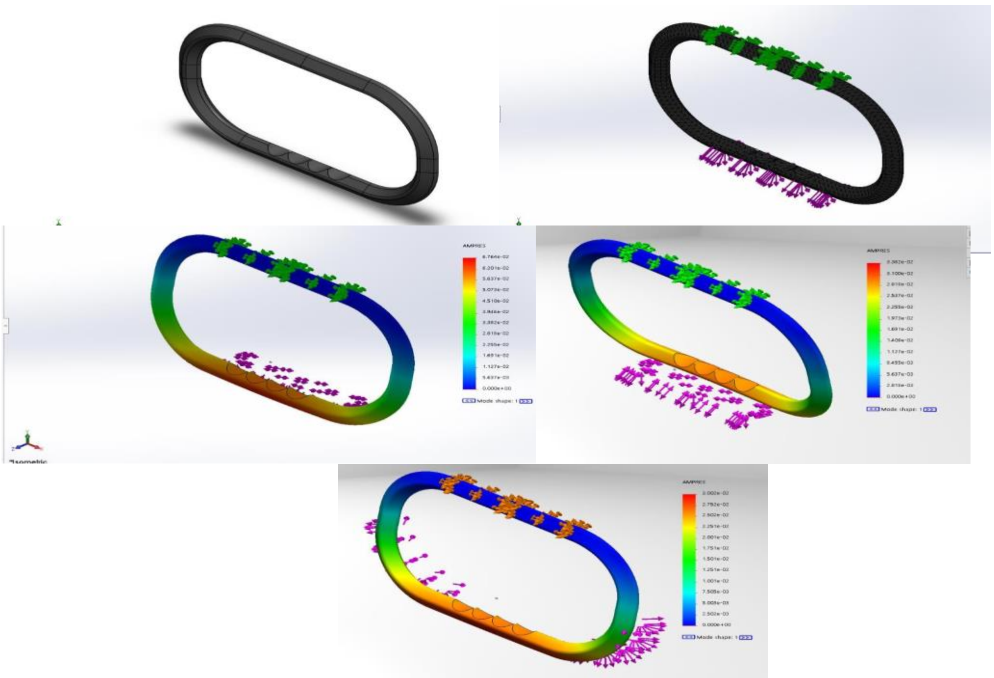

Fig. 5. Simulation results

The experimentation involved three distinct materials: PVC, silicon, and rubber. While conclusive remarks are yet to be drawn, preliminary results indicate that PVC exhibits superior performance. Choosing the most suitable material for handgrip manufacturing is a critical decision, influenced by factors including user comfort, grip specifications, durability, and adaptability to environmental conditions. Despite the ongoing analysis, the current findings suggest PVC as a promising material based on its performance in the simulated conditions. By incorporating these insights, manufacturers can prioritize user comfort and safety, ensuring a reliable and durable commuter solution.

4.3 Model Validations

To rigorously validate the efficacy of our ergonomic handgrip design for public transport in Bangladesh, we conducted a meticulous comparative study against three established hand grip designs. The objective was to gauge user preferences, comfort levels, and safety perceptions by engaging a diverse group of 46 participants spanning a wide age range from 11 to 50, as shown in Table 2. The survey was conducted anonymously to encourage candid responses, ensuring unbiased feedback.

Table 2
Number of participants

Age number	Number of participants
11-20	6
21-30	22
31-40	14
41-50	4
Total Participants	**46**

The realization of our final handgrip design culminated in using 3D printing technology, marking a crucial transition from theoretical simulations to tangible prototypes. Employing materials such as PVC, the 3D printing process facilitated the creation of physical samples, enabling a hands-on evaluation of the design's feasibility and user-friendliness.

Participants were presented with our handgrip design alongside three alternative options (Figure 6), and their feedback was solicited on aspects of comfort, safety, and ease of grip. A noteworthy trend emerged as 27 out of the 46 participants unequivocally favoured our design, as shown in Figure 7. These participants consistently highlighted the superior comfort, enhanced safety features, and ease of gripping provided by our design.

The anonymized survey facilitated honest opinions, and the consistency of the preference for our design across diverse age groups is a testament to its universal appeal. Comments from participants in different age brackets further enriched the feedback. A participant from the younger age group (11-20) highlighted, "This design looks modern and feels like it's designed for the younger generation. It's not just about aesthetics; it genuinely provided better support." Conversely, a participant from the older age group (41-50) mentioned, "The design appeared to offer better support, particularly during sudden movements, making it a preferable choice for a commuter like me who values stability." Comments from the participants offered valuable insights, with one individual (21-30) expressing, "The ergonomic contours of this design provided a more natural and comfortable grip compared to the others, making it easier to hold during the entire journey. It felt like a thoughtful design considering the commuter's experience." Another respondent (31-40) emphasized safety, stating, "I felt more secure using this handgrip; it felt like it was designed with consideration for my comfort and safety, which wasn't as pronounced in the other options."

Fig. 6. Alternatives for the validation test (Sample A-Sample D) from left to right

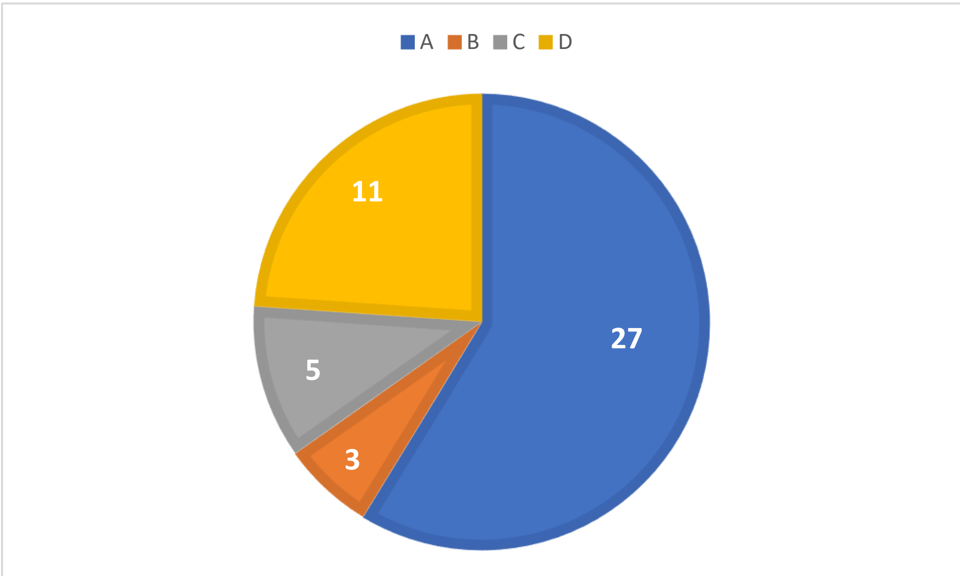

Fig. 7. Validation result

This comprehensive study validates the effectiveness of our ergonomic handgrip design and underscores its versatility in addressing the diverse needs of commuters using public transportation in Bangladesh. The detailed comments from participants serve as valuable qualitative feedback, affirming the positive impact of our design on user experience, safety, and overall satisfaction.

4.4 Discussion

Our study revolves around the efforts made to enhance the ergonomic design of handgrips for public transport in Bangladesh. The utilization of SolidWorks and ANSYS software enabled a thorough simulation of real-world conditions, providing insights into material performance and contributing to the optimization of the final handgrip design. The comparison study revealed our final handgrip design as the preferred choice among participants, consistently lauded for its enhanced comfort, safety features, and ease of grip.

Comparing our final design with previous iterations highlights significant improvements. Incorporating locally derived anthropometric data specific to Bangladesh ensures a design that caters to a broad spectrum of users. The strategic curvature of the grip, designed to increase the contact area between the hand and the handle, stands out as a crucial factor influencing comfort and safety. Simulations using SolidWorks and ANSYS aided in analyzing the deformation and strength of various materials, leading to the selection of PVC as the material of choice due to its superior performance.

The principles of ergonomic design have been paramount in shaping our final design. By tailoring the handgrip to accommodate the natural movements and dimensions of the human hand, our design prioritizes grip comfort, pressure distribution, and overall user experience. This emphasis on ergonomic principles aims to provide a handgrip that meets public transport's functional requirements and enhances commuters' overall well-being and satisfaction.

In conclusion, our study significantly advances Bangladesh's ergonomic handgrip design for public transport. The meticulous approach, including local anthropometric data, material analysis, and user feedback collectively contribute to developing a handgrip that excels in comfort, safety, and user-friendliness. This work sets a new standard for ergonomic design in the context of public transportation, emphasizing the importance of addressing user needs to create a more pleasant and efficient commuting experience.

5. Conclusions

This study shows that handgrip in mass transportation is one of the most necessary parts/tools. Here, we aimed to design and generate an ergonomically safe handgrip to ensure the comfort and safety of the passengers and avoid unwanted injuries. As we are still halfway through our project, we cannot comment on the outcome of the handgrip. Primarily, out of three materials (PVC, silicon, rubber), we have found that PVC is the most suitable material for carrying the load of passenger's hand. Different types of simulation processes, such as strength, buckling, factor of safety (FOS), resilience, and durability, were performed, and the outcomes are shown in the methodology section. As the targeted section of this study is Bangladeshi people, we have conducted the simulation on that basis and found that PVC can give the best holding strength. Until now, we have found that the grip's dimensions should be 18.626 inches in width, 10.704 inches in height and 1.256 inches in diameter. To get the most comfort while holding the grip, one should use one palm for the push and thumb to carry the stresses.

Different factors were considered when conducting the study. Although we did not consider factors like passenger height, age, and strong hand, understanding the outcomes of such factors could provide additional insights for implementing the model designed in this study.

This study will be conducted further to get an improved version of the handgrip. After the final working procedure and the user's feedback, we will include all the outcomes and an analysis of the final stage of this project. As there are very narrow scopes and sources in this study field, the findings can be used to invent more suitable and comfortable grips for mass transportation.

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