Cost Effective Converted Powers Wheelchair with a Baby Carrier Attachment for a Paraplegic Mother to Care and Monitor Her Infant

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Abstract

This paper comprises of a cost-effective solution for a paraplegic mother to interact and take care of her infant. An expected 6.2% of guardians of newborn in the United States have physical abnormality. This investigation depicts how women with physical abnormalities experience taking care of their newborn babies and how they adjust their care duty. The project comprises of a manually converted powered wheelchair attached with an infant carrier. Furthermore, sensors modules are attached for the monitoring of basic body parameters such as temperature and heart rate. A manual wheelchair was converted into motorized one comprising of a differential drive mechanism using h-Bridge system. A total of 35 women subjects and 5 infant subjects were used for test drive the wheelchair. It proved to be most efficiently functional when subjected within the weight range of 65kg. The parameter system gives about 97% measurement accuracy.

Keywords—Paraplegic mothers, infant care, infant heart rate, infant body temperature

1 Introduction

There is a continuous stressful errand for women to deal with any physical disability. Some manage to adjust with lifestyle changes to pact their disability with the environment. However, at whatever point a mother is, the experience of any physical variation from the norm turns out to be troublesome and agonizing, especially when performing various tasks related to taking care of their baby. Our research group aims to design a wheelchair which will make a paraplegic mother's life easy when it comes to attending and taking utmost care of their baby. This wheelchair comprises of sensors modules which are appended for monitoring the most fundamental body boundaries, for example, temperature and heart rate. Infants are sensitive and have frail insusceptible framework which makes them vulnerable by evolving climate, food hypersensitive, and various other conditions. Motivation of the authors has touched the lives of disabled people especially mothers in 120 countries around the globe and we are just as committed to provide disabled people any product and support they need to live a happy, healthy and independent live. We support disabled people, their families and communities to understand their rights and how to tackle stigma and discrimination.

Our project has a great application which proves its significance and motivation for the authors. Some of the cases would account for a paralyzed mother who is able to feed her child with ease, take care of her baby almost without any help and would be able to fully take part in her parenting role, which is the overall goal of the project. Onset of any disease in babies is associated with an increased body temperature and an abnormal heart rate. Moreover, an increased heart rate is a normal physiological response to fever. Heart rate is known to increase by 10 beats per minute (bpm) per degree centigrade increase in body temperature in children [1]. An estimation states that 10% of the population of the world comprising of about 650 million people is suffering from some sort of disability [2]. A child's best friend and the best care giver is his mother who sacrifices many moments to keep the precious mother-child bond which is felt deeply for a disabled mother along with the desire in raising her child rightly.

An estimation concerning United States suggests that a percentage of about 6.2 comprises of parents suffering from disability and have children of dependent

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age [3]. Impairments to the lower extremities due to the malfunction of motor or sensory system is a condition known as paraplegia. Spinal cord injuries, cerebral palsy, etc. can be the main causes of such conditions [4]. A child's mother with such conditions springs out challenges of every kind which comes along with psychological stress causing frustrations and deep helplessness to the physical barriers due to adaptive materials, limited aids and locomotion limiting their involvement in bonding and raising a child with the best possible opportunities [5].

So far, women with physical disabilities are greatly considered unfit to have and raise a child with full potential. Wheelchair is a great tool to assist such women with paraplegia and in the past, attempts were made with motorized wheelchairs in helping out such mothers to gain their full potential in order to raise and interact with their children just as a normal mother would. One such attempt was made in 2004 by Centre of Assistive Technology [6] in which a motorized chair user asked them to modify her chair and add on a baby carrier. The designed included the attachment of a baby bike seat interfaced with mounting attachments to the frame. The final product had a 20°tilting feature, able to spin 360 degrees, lightweight, and could easily be detached from the wheelchair.

In another work [7], engineers attempted to help out women with quadriplegic disease. The device consisted of a car seat attached to the motorized chair facing the mother, welded with aluminum frame giving multiple degree of freedom. These assistive seating were further explored in 2016 [8]. These designs did not only help paraplegic mothers, but also assist in the safety of a disabled neonate [9]. It is very important for a paraplegic mother to be relaxed and be contended mentally so that her physical health may also remain well which is significant in taking care of a child [10].

All of these attempts however were only concerned with the baby carrier attached to already motorized wheelchairs and gaining access to such wheelchairs is not always affordable for people living in the third world countries. To the best of our knowledge, no attempts have been made previously in introducing body parameters to monitor the health of a child in case there is no one around to help a disabled mother.

In this paper, we propose a wheelchair prototype designed to limit the expenses of development, to initially test the design concepts, and to test the practical usability of the product which ultimately turned out to be a success. This research proposes an effective and affordable way for a paraplegic mother to care and interact with her infant in conditions where she may or may not have any other assistance. In comparison to the development of this design, our prototype has some differences than the previous works which only had attachments of baby seat in motor-propelled wheelchairs. In order to make our proposed design low-cost, we have assembled a manual wheelchair in such a way that it achieves the task of being a motor propelled wheelchair to add on features of the expensive power wheelchairs available in Pakistan. Furthermore, our wheelchair is also equipped with additional features of temperature and heart rate measurements which may help both a child and the mother in monitoring any health condition. Another feature of the project is its local availability of parts and components which will reduce the time of repair, purchase, etc.

2 Methodology

This section describes our proposed methodology in detail.

2.1 The Wheelchair

About 10% of the absolute world incapacitate populace use wheelchair [11]. With the electric-powered wheelchair being the basic piece of the venture, our task was not simply based over force wheel seat structure, but rather using an approach to change a manual wheel seat into an electric one. A legitimate mechanical coherence was required for the fitting of engine with no error bracket which would later on hinder with the portability and strength tolerance of the seat. After that, the procedure of interfacing and controlling began which would drive the seat with the assistance of traditional joystick.

2.2 Basic Design of the Wheelchair

The augmentation connected to the wheelchair was first planned over "Solid Works" alongside all the estimations and subtleties required for help and dependability as appeared in Figure 2. The model planned was on the rendition of 2013 with a 3D model that demonstrates all the auxiliary highlights of the structure expansion like constant view. At first, separate parts files were created for every joint, support and screw that would be needed for the attachments. Then each file was assembled in an assembly file with proper matching of each part to one another and finally to the wheelchair. The file was saved as a para solid file extension in order to import it and simulate it in Ansys R14.5 software which is used for different structural static analysis of the model designed.

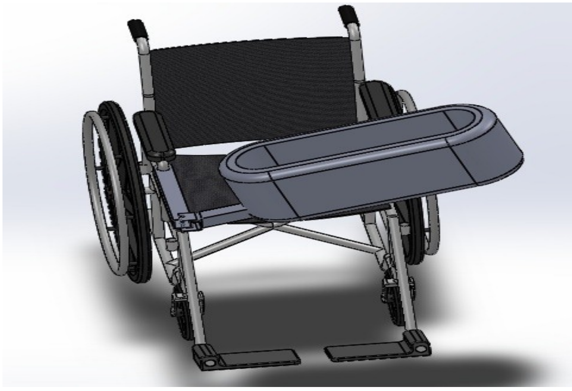

Fig. 1: Solid works model for the carrier attachment

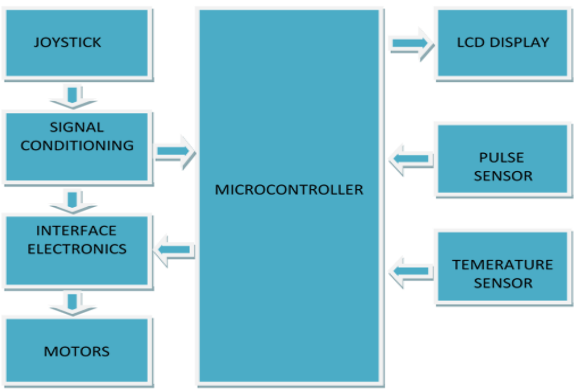

Fig. 2: Block diagram of the implementation

2.3 Structural Integrity of the Wheelchair

Using Ansys R14.5, the model design was tested for carrier attachment extension by applying force load of different values which verified the reliability of support and stability over three structural statics.

- Total Deformation
- Equivalent Stress
- Equivalent Strain

A normal baby at birth weighs about 5 to 8 pounds (13 ounces) [12] which is equivalent to test out maximum amount of force before which the extension tends to deform or break. We tested the simulation to the load forces of 10N, 20N, 30N, 40N and 50N. For each force, three parameters were analyzed. From Figure 2, it can clearly be seen that the first step was to accomplish all the aspects of mechanical design and fitting the components to the manual wheelchair. The stage of interfacing and control was divided in two phases. In phase one, the collection of an input signal was required. In our design, this signal was from a conventional joystick with the commands of direction to drive. The second step of the phase one was signal conditioning and error checking with the help of control computer and software. To convert signal-level power to motor-level power, an amplifier was used to implement a motor controller. Furthermore, the other electronic interface with the micro-controller was used to send signals to the motor. The second phase was construction of sensor modules for temperature and heart rate and interfacing them with the baby cot attachment. For the sensors, analogue signals were taken from the infant body and monitored by displaying them over the LCD. At first, separate parts files were created for every joint, every support and every screw that was needed for the attachments. After which, each file was assembled in an assembly file with proper matching of each part to each other and to the wheelchair. The file is saved as a Para solid file extension in order to import and simulate it in the Ansys R14.5 software which is used for the structural static analysis of the designed model.

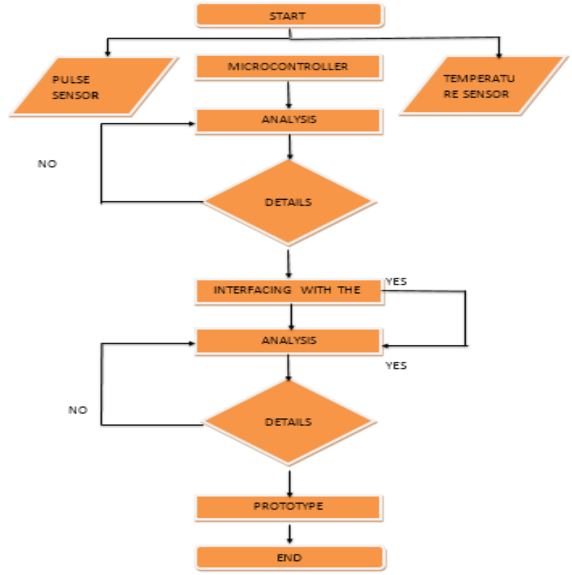

Fig. 3: Flowchart of the modules

2.4 The Design Process

The flowchart in Figure 3 shows the general procedure of advancement, testing and assessment. We started by taking simple signs from the heart rate and temperature sensor from the body. These signals were then given to a miniaturized scale controller to convert them into computerized coherent advanced yields appearing over LCD shown through programming and computational work. After the precision trials, two conditions confirmed that the testing from the outset were not desirable reanalyzing the investigation of the signals and programming. When the desirable outcome were achieved, these modules were then connected with the bunk and investigated with testing again for the

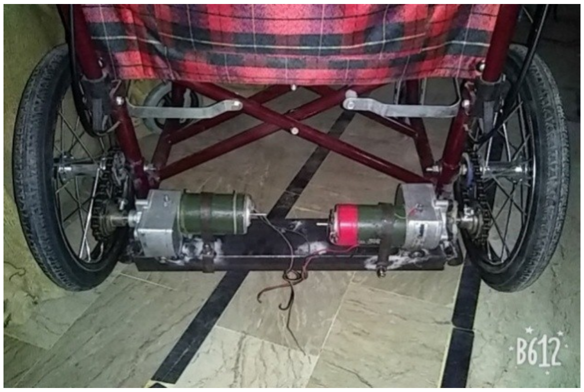

Fig. 4: Manual wheelchair with motor assemble

Fig. 5: Converted wheelchair along with the cot

desirable outcomes. Toward the end, we had achieved a satisfactory level of accuracy from them.

2.5 Arduino UNO Atmega328P

Atmega328P IC has 28 sticks, out of which, 20 pins work as I/O ports. This implies that they can work as a contribution to the circuit or as yield. Regardless of whether they are information or yield, they are set in the product. 14 of the pins are advanced pins, of which 6 has the capacity to give PWM yield. 6 of the pins are for simple input/output. Two of the pins are for the precious stone oscillator. This is to give a clock heartbeat to the Atmega chip. The chip needs control, so 2 of the pins, VCC and GND, provide it the control with the goal that it can work. The Atmega328P is a low-control chip requiring 1.8-5.5V of energy to work. The Atmega328P chip has a built-in simple Analog to Digital Converter (ADC). After the signals are attained from the controller, they are then sent to the electronic circuitry made to send signals for the rotation of motors for driving the chair.

2.6 Mechanical Assembly of the Wheelchair

A manual wheelchair shown in Figure 4 was assembled with additional components like d.c motors (Maxon DC Motor 44.060.000-00.15-073), chains, chain sockets, mechanical pulley, etc. The manual wheelchair was purchased keeping in mind the weight, size and ease in mobility for the mother with limb ailment who is focused to be the rider of the chair. Therefore, an adequate space availability below and in between the tires of the chair is ensured during the assembly of motors, circuitry and battery.

After the assembly, which was to convert manual wheelchair into a powered one, designing of attachment of an extension frame to the wheelchair was the next focus. The frame would hold and support a baby carrier for providing ease to mother who can carry her child in it wherever she desires. The weight limit for the babies' cot is 50 lbs keeping in mind that the newborn's weight may vary from 21.1 lbs to 23.4 lbs. It is also necessary to bear in mind that the attached cot fulfils all the safety requirements for the baby as well as for the mother. The cot must be lightweight and comfortable enough to be attached with the wheelchair easily. Comfort and ease are the core and primary factors which are considered for this design. The final design in Figure 5 shows the structure and the height of the baby carrier according to the person seated in the wheelchair.

2.7 Speed Control System of the Wheelchair

The prototype was constructed by converting manual wheelchair into a motor propelled wheelchair in which DC motors proved to be useful machinery as a means to drive the wheels [10]. For this wheelchair model, Maxon DC Motor 44.060.000-00.15-073 was used. Controlling these motors for the drive was based on differential mechanism. The differential mechanism is basically designed for pair wheel drive allowing variable speed rotations which takes two wheels into account for the drive and hence controls the motion of the application it is being used for [9]. Therefore, for this research, the controls on the motion and speed of the wheelchair was done via micro-controllers.

For the navigation system in the wheelchair model, Arduino UNO module is used along with an H-bridge motor driving circuit which controls the speed. The schematic diagram (Figure 6) shows the driving circuit for the wheelchair which consists of a micro-controller, a joystick and 4-rey module controlled by a joystick conditioning. In this wheelchair, the joy stick used was a bi-axial XY joystick of module KY-023 which has an edge to be easily interfaced with Arduino board. This joystick module produces an output of around 2.5V

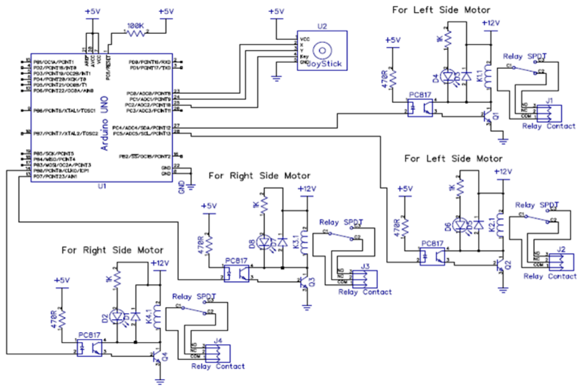

Fig. 6: Schematic diagram of the driving mechanism

from X and Y when it is in resting position. Moving the joystick will cause the output to vary from 0v to 5V depending on its direction. If it is connected to a micro-controller, expected readable value of around 512 in its resting position is seen and when the joystick is moved, the value changes from 0 to 1023 depending on its position [12]. The input from pin number 2 and 3 of the joystick corresponds to X and Y values which are connected to pin number 23 and 24 in Arduino board which serve as analogue inputs. Pin number 27 and 28 of Arduino serve as output for the right side motor, while pin number 14 and 13 serve as output for the left side motor. These outputs are connected for switching of two relays, each for either side of the motor. Before reaching the relays, the output goes to PC817 photo coupler IC which provides isolation between the two circuits to prevent any short circuit.

2.8 Parameter Modules of the Wheelchair

This wheelchair has a unique feature of adjustable baby cot aligned with the basic parameters of infant body temperature and heart rate, so that a mother is aware of the clinical conditions of the baby and does not face any difficulty to search for a thermometer. The pulse sensor SEN-11574 for measuring heart rate and NTC thermistor 103 for the temperature were successfully interfaced with a micro-controller displaying readable outputs on an LCD embedded in the baby carrier.

2.9 Trial and Experimental Setup

In the first experimental setup, we took random women of different weight to test drive the newly designed wheelchair. Total 35 volunteer women participated in the trail who tested the wheelchair inside the premises of their home on flat floor with no bumps. These women were chosen randomly regardless of their

Vital Sign	Infants (0-12 Months)
Heart rate	100-160 beats per mint (bpm)
Temperature	98.6 Fahrenheit (F)

TABLE 1: Standard values of heart rate and temperature of an infant

size or shape. Nonetheless, before the trial, weight of each volunteer was measured and was found to be in the range of 100 kg to keep record of the desirable weight the wheelchair would work efficiently with.

The second experimental trial required both adult and and a child to be seated on the wheelchair. In this trial, 35 women volunteers and 5 infant volunteers from up to 8 months of age participated. For the purpose of the comparative analysis of temperature and heart rate, two very common and reliable instruments were used which are trusted by many for their accuracy: thermometer and a smart health watch. Initial readings obtained from the adult subjects when they were asked to be motionless and then were told to take 5 minutes brisk walk to record their heart-rate after after exercise. Following this, the attached modules of temperature and heart-rate were tested on children under 1 year of age. The readings at rest were recorded for comparison.

The auxiliary respectability of bearer connection was then tried by reenacting the model on Ansys R14.5. Model planned was tried against various forces from 0N to 50N applied for 1 second and 5 minutes of time length. We observed the bearer connection structure against stress, strain and distortion. The wheelchair was additionally recorded through the sensors in the trial stage. At this point, the boundaries were cross confirmed by the thermometer for temperature and for pulse. These gadgets were picked to test the approval of boundaries as they are usually utilized by medical clinics, medicinal services arrangements and the outcomes are considered as reliable. According to the World Health Organization (WHO), the normal values of heart rate and body temperature of infant child are within the range of 100-160 bpm and 98.6°F respectively, as mentioned in Table 1. Figure 7 shows the normal and abnormal values of heart rate and body temperature of infants according to their age (0-12 months).

3 Results

The conversion of a manual wheelchair into electronic one was achieved successfully with proper assembly of motors with the wheels of the wheelchair along with balancing and weight driving design. The wheelchair

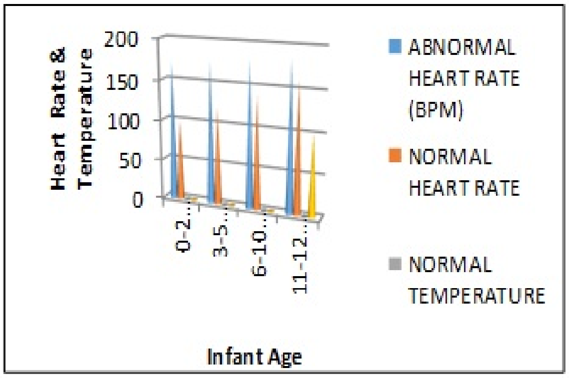

Fig. 7: Comparative chart of normal and abnormal values of heart rate and temperature of infants

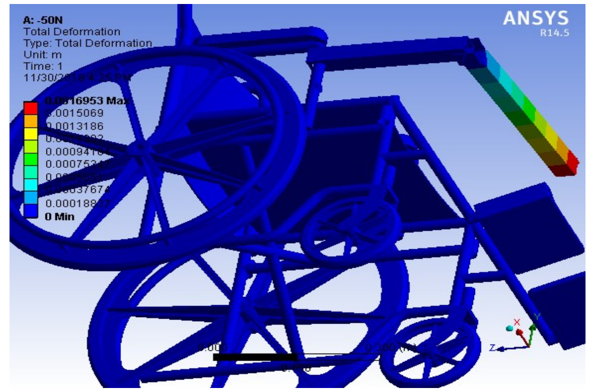

Fig. 8: Simulated results of total deformation over 50N of force

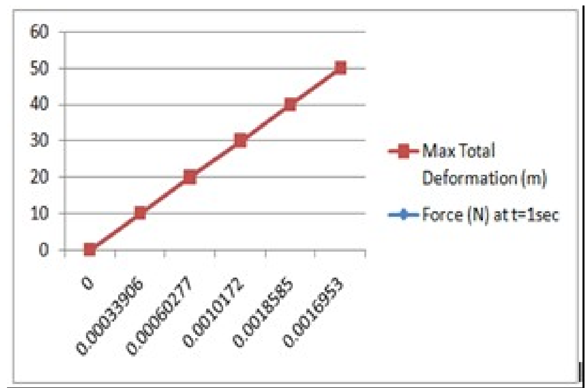

Fig. 9: Relation between force and maximum deformation

was interfaced with electronics components to be controlled by a joystick driving the two gear motors attached to the axial of the wheelchair. In this way, the manual wheelchair was efficiently converted to a low-cost power wheelchair. The results showed smooth drive in all direction, however, when the subject weight (women and child together) exceeded from 70 Kg, the movement of wheelchair in left and backward direction was jerky and slow.

Pulse rate and temperature of infants exhibited very close readings when monitored from the designed modules and cross validated at other devices with slight difference of 3 units in heart rate measurements and 2 units in temperature measurements as shown in Table 2.

We concluded the design by graphical representations between the increasing force that was applied to the extension and the values of maximum stress, strain and deformation the carrier supported. These results showed the design's performance in terms of 97% accuracy.

3.1 Force vs. Total Deformation

Deformation of the extension was one of the factors that was considered in determining the reliability and stability to carry the weight of the baby placed in the cot attached to the wheelchair. The result of simulation from Figure 8 and graphical representation in Figure 9 shows a linear relation between the increasing force up to 50N and the maximum deformation on X-Axis that occurred with the extension in meters, keeping in mind that the force applied on the extension was for 1 sec of time on Y-axis.

Considering the maximum force of 50N, it was observed that the maximum deformation is of about 0.00169 m (0.169 cm and 1.69 mm). As for the the same amount of force for 5 minutes gave about 0.507 m of deformation with the possibility of bending and breaking from the point of contact.

3.2 Force vs. Equivalent Stress

It can be observed from simulation results in Figure 10 and graphical representation in Figure 11 that when the simulation is done to check strain on wheelchair assembly, the maximum stress was found to be about 6.30×10^{8} Pa for force up to 50N for duration of 1 second. Considering the same amount of force for 5 minutes would give about 1.89×10^{11} Pa of stress that will cause the extension to break from the point of contact.

3.3 Force vs. Equivalent Strain

The simulated result of equivalent elastic strain over 50N of force is shown in Figure 12. The results of simulation from Figure 12 and graphical representation of the strain analysis in Figure 13 on the extension show a linear relation between the force and maximum strain expressed in m/m on X-axis, keeping in mind that the

Infant's age	Pulse rate from smart watch (Bpm)	Pulse rate from our module at rest (Bpm)	Temperature from thermometer (°F)	Temperature from module (°F)
Newborn	100	98	975	89
1 months	120	117	97	90
3 months	130	130	99	92
6 months	155	152	97.5	91
8 months	100	98	97.3	85.6

TABLE 2: Pulse rate and temperature of infants measured from designed modules and from the other device

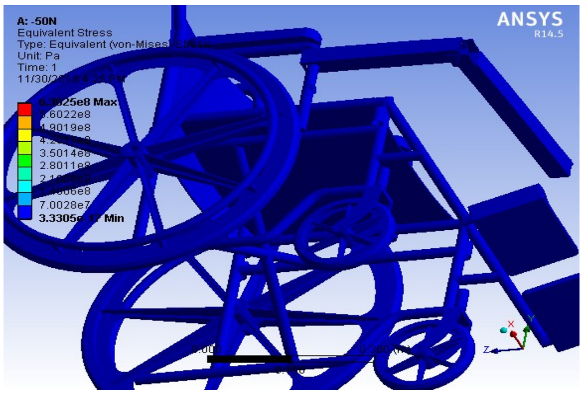

Fig. 10: Simulated results of equivalent stress over 50N of force

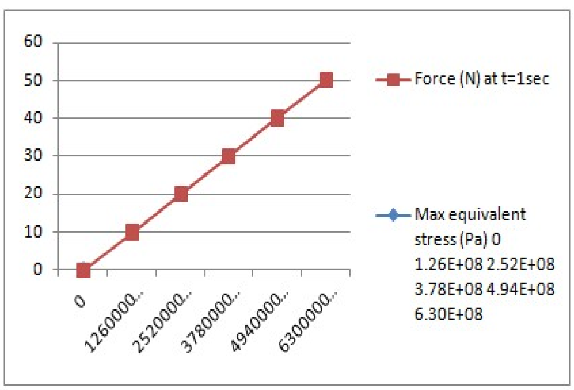

Fig. 11: Relation between force and maximum equivalent stress

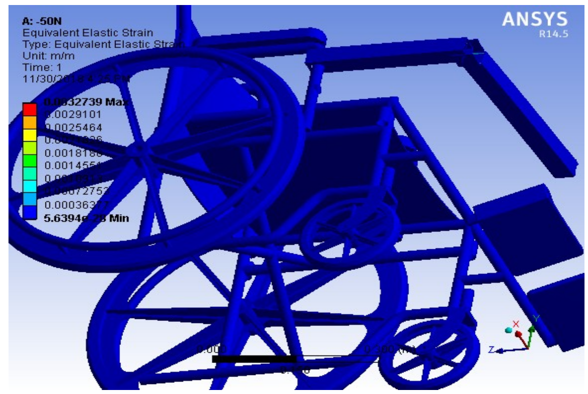

Fig. 12: Simulated results of equivalent elastic strain over 50N of force

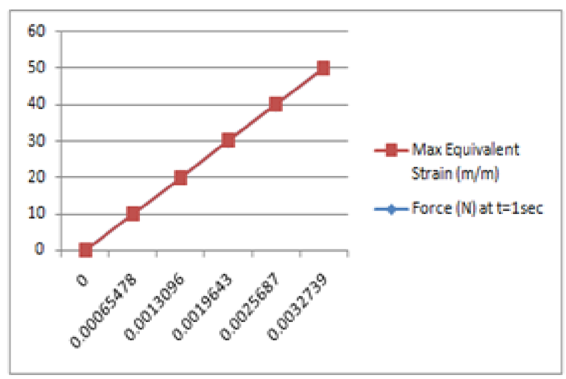

Fig. 13: Relation between force and maximum equivalent strain

force applied was for about 1 sec on Y-Axis. Considering the maximum force of 50N, it was observed that the maximum strain is of about 0.0032739 m/m (0.32739 cm). The same amount of force for 5 min will give about 0.98217 m/m of strain which would not have much effect on the extension.

3.4 Persons with Disabilities (Percentage of Total Population)

According to the provisional summary results of the census, which were presented recently in the Council of Common Interests, 132,189,531 people were categorized as rural and 75,584,989 as urban populations, which showed 2.23 percent and 2.7 percent growth rate over a period of 1998-2017. This research is not only focused on married women since some women faces disability of limb after marriage through any sort of accident. They are likely to suffer from the spinal and sciatic nerve injury during the delivery making the proposed design of the wheelchair to be extremely useful to provide care for their infants of especially for paraplegic mothers. The disabilities are grouped and classified with related terminology in Table 3 as per their census report.

Administrative units in Pakistan	Rural	Urban	Total disabled population	Crippled
Khyber Pakhtunkhwa	327,638	48,114	375,752	31.73
Punjab	1,338,410	488,213	1,826,623	20.83
Sindh	385,984	543,416	929,400	10.56
Baluchistan	117,971	28450	146,421	14.81

TABLE 3: The disability group classification and terminology

4 Discussion

The model proposed in this paper is an intelligent solution by utilizing the least expensive components and minimal effort. It also proposes an essential aid for a paraplegic mother with the advancement of a compelling route framework introduced in a manual wheelchair for indoor use, alongside a newborn child transporter attached to the structure of the seat for the possibility of providing care to a baby nearly without any help. A module framework was introduced to quantify body boundaries of heartbeat and temperature at convenience without the trouble to proceed to scan for a thermometer. Training shall be provided to technicians and clinicians so that the right equipment for specific needs and environments can be prescribed by them along with leverage of peer training for someone who is newly disabled through a spinal cord injury or illness can learn about their independence and mobility.

Our fundamental aim was to design a product which would be useful as well as easy to be used for mothers with paraplegic disability. The preliminaries directed more than 35 women who ended up being successful on the weight territory up to 100 kg. However, the model was not adequately practical to be driven in left and right directions when absolute load surpassed 75 Kg. The boundary modules showed about 97% precision in the qualities to the looked with the items effectively accessible in the market.

The seats that were recently made for this were a bearer connected to be effectively fueled. However, a great number of individuals in developing and underdeveloped nations are not capable of buying costly wheelchairs. Hence, the drive usefulness is diverse for our model to those profoundly propelled seats.

5 Conclusion

Our prototype proposed in this paper is weight limited up to 65 kg and able to function well only within the confinements of a smooth surface boundaries. This prototype, along with few more improvements, can prove to be a highly useful product for not only paraplegic mother, but also other paraplegic handicaps. Mothers who are handicapped and do not have assistance can have great benefits in interacting and taking care of their kids on their own. Paraplegic condition in the life of a mother brings about many challenges. Our prototype will greatly help in overcoming these challenges since it is easy to use and have great structural stability to ensure safety with easiness to navigate wherever a rider desires.

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