Detailed Review of Different Patient Transfer-Assistive Devices

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Abstract: The paper is focused on the study of different patient transfer assistive devices and the effects of manual handling on patients and caregivers. Manual handling has increased musculoskeletal disorders in caregivers and accidents while transferring which results in injuries to patients. In developing countries like India major amount of population lives in small houses. So many people will not be comfortable to accommodate these large devices. The significance of the study is to understand the problems faced by the caregivers and patients transfer-assistive devices while they are transferred from wheelchair to other surface like bed, toilet seat, chair, etc. Handling or transferring of patients with paraplegia or lower limb disorders has been a difficult task for caregivers. Manual transferring techniques used for handling the patients has increased the accidents while transferring and musculoskeletal disorders in the caregiver. Keeping these limitations in mind, there is a need to develop a transfer assistive device which will have an easy operating mechanism. This research will focus on the devices which can be used to reduce the efforts which the caregivers have to put while transferring the patients manually thus reducing the risk of musculoskeletal disorders in the caregiver. Development of such kind of device will reduce the amount of people going for manual handling techniques and thus will reduce the number of accidents and disorders in patients and caregivers.

Keywords —wheelchair, patient transfer, mobility aid, transfer assistive devices, ergonomics, safety, nursing care

I. INTRODUCTION

In today's modern generation, lifestyle of people has changed. People want their life to be easier and more comfortable. For example, people buy more automatic appliances like dish washer, microware, etc. People are tending to live a life without doing extra efforts. Apart from home appliances the automation in the industries have rapidly increased the effortless working. In an advanced industry almost all the jobs like material handling, manufacturing is done with the help of automation. But, as a device gets automated its operating complexity, maintenance and cost increases.

In the similar manner, the paper focuses on such kind of devices which are used to reduce the efforts of nurses and caregivers to transfer patients from wheelchair to bed and vice-versa.

In India out of the 121 Crore population, 2.68 Cr persons are 'disabled' which is 2.21% of the total population. Among the disabled population 56% (1.5 Cr) are males and 44% (1.18 Cr) are females. Majority (69%) of the disabled population resided in rural areas (1.86 Cr disabled persons in rural areas and 0.81 Cr in urban areas). In the case of total population also, 69% are from rural areas while the remaining 31% resided in urban areas. During 2001 – 2011, an increase in the number of disabled persons was observed both in rural and urban areas and also among males and females. The percentage of disabled to the total population increased from 2.13% in 2001 to 2.21% in 2011. In rural areas, the increase was from 2.21% in 2001 to 2.24% in 2011 whereas, in urban areas, it increased from 1.93% to 2.17% during this period. The same trend was observed among males and females during this period. With the increase in the number of wheelchair users, there is need to adapt a proper transferring method. Improper use of transferring techniques has given rise to accidents and injuries of patients. Similarly, manual handling of patients has increased the number of musculoskeletal disorders in caregivers. Apart from the use transfer assistive devices, major reasons behind the risk of accidents during manual transfers is classified into five types: Communications, Cognition, Medical Status, Physical Status and Emotional Status. The caregiver must access the patient's ability or inability to communicate. The risk of injury increases if the patient does not understand or speak the same language as that of caregiver, is unable to speak or has some speaking disorder, has a problem understanding simple commands of caregiver, has a low level of consciousness or has

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a hearing impairment. Often hospitalized patients have an altered level of cognition affecting their ability to participate in lifts/transfers. Short term memory loss, poor judgement, and difficulty making decisions can be manifestations of altered cognition. Questions testing the short-term memory can often give some indication of the level of cognition. Signs and symptoms of various medical conditions can impact on a patient's ability to transfer. Fatigue, pain and stiffness will affect the quality of the transfer. The medical status can change dramatically during a shift and caregivers need to observe these changes and modify the lift/transfer as necessary. Different physical factors of patients affect the risk of accidents like weight, height, strength balance, coordination, sensation, clothing, footwear of patients, etc. Patients behavioral and emotional state may change throughout the day. The caregiver should be aware of the behavioral changes like anxiety, aggression, confusion, depression, low self-esteem, etc. Risk factors related to the equipment are inadequate training in the use of equipment, improper use of equipment or use of faulty equipment. Risk increases when equipment is not adjustable.

There are many assistive devices which are designed and developed to help the caregivers in manual handling of the patients. Some of the examples are gait belts, walking belts, transfer boards, etc. But there has been minimum development in the designing of transfer devices which will help in transferring the patients automatically without having any physical contact between the nurse and patient. In addition, in a country like India, where major part of population is a low-income population, many people prefer manual transfers due to the high cost of automated devices and due to lack of proper education may people are unable to use the automated devices (mainly in rural areas). And this has given rise to accidents and musculoskeletal disorders in patients and caregiver. Many people whose are fit in their upper limbs tend to go for manual lifting and thus the number of accidents during transfers have increased. According to a study, the risk of accident and disorders in reduced by about 95 percent if proper assistive devices are used instead of manual lifting.

This paper focuses on the study of different transfer assistive devices used for transferring of patients from one surface to another surface thus reducing the efforts of the caregivers and preventing the risk of accidents and musculoskeletal disorders in patients and caregivers.

II. Literature Review

A thorough study on the existing transfer assistive devices is conducted by reviewing multiple research papers. These research papers are reviewed by classifying these papers according to the mode of presentation like designing, analysis, etc.

2.1. Design and Models

- R. Bostelman, et al, [1] designed a wheel chair for lifting and transfer of patients from one place to another. Along with designing emphasis has been done on stability of the system while keeping the safety measures of the user in mind. A proper dimensioning of the chair is done so that it can pass through the residential doors. The basic working of wheelchair is shown in the fig.1.

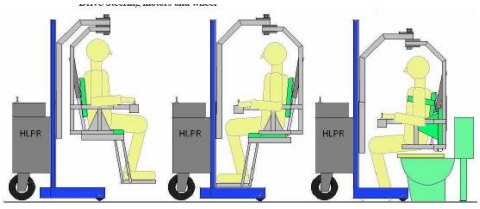

Fig. 1. Working of Wheelchair [1]

During rotation, the problem of center of gravity has been taken care off. For steering of the wheelchair, joysticks are used. Steering of the wheelchair is reverse Ackerman controlled. Wheelchair is powered with the help of batteries. Two wheelchairs have been prototyped for the testing purpose. One for testing the stability and the autonomous controls of the wheelchair. Other for studying the ergonomics and safety of patients on wheelchair.

Considering the safety of the patients on wheelchair, different stability tests are done like the motion of chair on slopes, ramps (tilted), height by which chair can be lifted and braking capability. All these tests are conducted and the chair is designed under standards given by ISO, ANSI, RESNA.

Testing of the autonomous wheelchair is further continued by navigating the chair through a series of obstacles. And this path travelled by the chair is traced and graphical represented. This representation is studied and further changes in the design are made regarding the size, acceleration, braking, etc.

Chair is not designed for steep ramps. Hence there are high chances of failure of wheelchair, which can lead to accidents of patients. The whole design is very large which is difficult to accommodate in country like India where maximum people live in small houses. Large amount of automation is used in the product which will lead to more maintenance and will increase the cost of product. It will become difficult for low-income families to buy the product and eventually they will shift to manual transferring of patients.

- Ma. Janice J, et al, [2] designed a wheelchair that can be converted into a hospital bed. Before designing the bed, analysis was done on nurse posture while handling patients and the overall ergonomics and safety of patients on chair. At the start of the analysis a survey was conducted regarding the problems faced by nurses while handling of patients and then a team of nurses was examined as they took care of the patients. The study came to a conclusion that there was high risk of body problems which might arise if the patients are lifted or transferred manually. Later different assessment and evaluations were done on the subjects (patients and nurses) to study the effect of manual lifting on each body part. And after this research and analysis, design process was started.

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Initially the existing model of wheelchair was studied and the needs of the user were identified. After studying the requirements of patients and nurses, the changes in the design were made. For deciding the dimensions of the chair, a scientific study was done on the body proportions and measurements. Later, the newly designed wheelchair was compared with standard wheelchair to finalize the design. Overall comfort of patients was considered while cushioning the bed and by providing proper handles and footrests. Safety of patients was considered by providing proper levers and locking mechanisms.

- By keeping the current pandemic situation in mind, and to reduce the efforts of nurses to handle the covid infected patients, Michael Kanisuru Adeyeri, et al, [3] have come up with an innovative idea to design a wheelchair which can be used in isolation centres of underdeveloped countries. This is a multi-purpose chair which can be used as a wheelchair and also can be converted into a bed when required.

Initially the dimensions of wheelchair were decided by conducting a scientific study of the body proportions and measurements. Later the chair was designed using a cad software and the materials were selected based on their properties and the researcher's requirements. Such materials were selected which were relatively lower in cost and easily available. To check whether the chair is safe to use, a finite element analysis was done by applying stresses on the chair in a suitable software. The chair was checked under different loading conditions. Once the chair was safe to manufacture, a prototype was built. The designed chair is an automated product which is run on motors and batteries.

Fig. 2. The isometric view of the designed and developed wheelchair on cad Software (left) and prototype of device (right) [3]

In order to check the ergonomic factors and comfortability of the chair, different tests were conducted. Since the chair will be converted into the bed automatically, the time required for conversion was noted by conversing the chair into the bed and vice versa multiple times.

In order to check the ergonomic factors, vibrations in the chair were taken into consideration. Various tests were conducted to calculate the vibrations in the chair and the results were compared with the readings set by the international standards. Once the readings were under the standard limits, and all the tests were successful, the research was concluded and the chair was safe to manufacture.

- Whenever an accident takes place, the major problem arising is the transfer of victim from accident spot to the hospital. Many-times without the help of ambulance, the victim's body is taken to the hospital in a bed sheet. If to be transported by an ambulance a conventional stretcher is used which is usually handled manually by two people. In both the conditions at least two to three people are required to lift the victim from the accident spot. This has given rise to musculoskeletal disorders faced by the workers at the hospitals. In order to reduce the efforts of the workers, Dr. M.S. Rohokale, et al, [4] have come up with an innovative transfer device which can be handled by only one person. Stretcher designed will be height adjustable by a scissoring mechanism which will be operated by a screw jack. Similarly for transferring the patient form stretcher to the bed, a roller mechanism is used which is operated horizontally. When a person is rested on the stretcher and has to be transferred on bed, the patient can just slide on the roller and can be rested on the bed. In this manner the patient can easily be transferred onto the bed without any difficulty to the patient or the nurses.

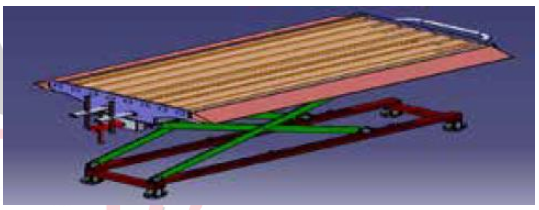

Fig. 3. Mechanism Model. [4]

- Today, many injuries are caused while transferring a patient from bed to the stretcher and vice-versa. Normally, conventional stretchers are used for lifting of patients which causes a lot of effort to the nurses and also can cause spinal cord injuries to the patients. As the patient is transferred form one department to other many times a day, it becomes uncomfortable for patients to be always lifted from the bed. There are times when there is an emergency and the patient is needed to be taken to some department. In such hard and fast situations there are chances that there might be injuries to the patients as well as the nurses. To tackle these problems, Arunkumar K N, et al, [5] have come with such kind of a stretcher which will have the ability to transfer a person to the bed.

Before starting to design the product, researchers did a thorough research in this field. They collected some data regarding the type of patients which came to the hospital, types of injuries or disorders the patients had (all regarding the use of stretcher) and how the hospital handles a patient with a certain disorder or injury. The researchers visited a hospital and acquired the actual data regarding the same. After gaining enough knowledge researches came up with a design of a stretcher which will be multifunctional and can be used by all kinds of patients.

This stretcher will be height adjustable with the help of hydraulics and also will have the ability to tilt sideways to transfer the patients from stretcher to bed. The sliding will be done with the help of rollers and a worm wheel gearbox.

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Different kind of mechanism is being used for transferring of light weight and heavy weight patients.

Proper calculations are done for designing of worm gears and flat belts. The designing is then done on cad software followed by a finite element analysis to check the safety of the product. The stretcher is tested under different loading conditions and verified properly.

The operation of the device is very complex. In hard and fast situations, the caregivers might get confused on how to use the stretcher which can lead to accidents.

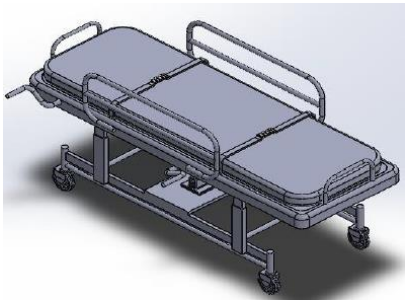

Fig. 4. Isometric view. [5]

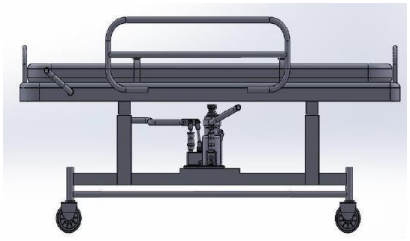

Fig. 5. Side view. [5]

- Sanju Kumar Pujari, et al, [6] have come with an innovative idea to design a patient transferring device where in the patient will be transferred from stretcher to bed with minimum efforts. As a conventional stretcher requires two to three nurses to help the patient transfer to the bed, researchers have confirmed that only single nurse will be required to perform this job. Along with transferring ability, the stretcher can be folded into a wheelchair and vice versa. If a person with minor injury (one who is comfortable to sit) needs to be taken to a different ward, the transfer device (stretcher) can be converted into a chair which will be more ergonomic to handle.

  The product is designed in such manner that it can be used in two different ways:

1. The stretcher can be converted into a wheelchair when required.
   For this application connecting rods and spur gear mechanism is used.
2. A patient lying on the stretcher can be easily transferred onto the hospital bed.
   For this application, the stretcher consists of two beds: one made up of metallic frame which will help in the conversion of stretcher to chair(fixed) and the other will be a normal bed made of cushion(non-fixed) which will slide on the metallic frame while transferring the patient with the help of rollers attached to it. A screw jack is used to lift the upper bed to a required height depending on the height of the adjacent hospital bed.

The calculations of every component like the gears, connecting rods and also the speed, torque and power required to run these components is properly done to ensure overall safety of the product. The design of the product is shown with the help of a proper CAD software.
Many functions have been embedded into a single product which makes it easy for nurses and patients. The researchers have designed the product in such manner to make it ergonomic and safe to use.

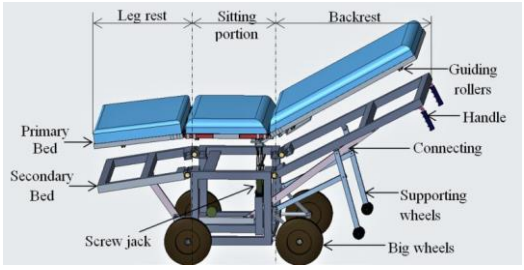

Fig. 6. Assembly of the device. [6]

- YoshikazuMori et al, [7] have come up an innovative idea to develop a wheelchair which will have a lifting function. There are many lifting devices which are used to lift patients from wheelchair or bed. But a limitation of these devices is that they can only be used indoors. Wheelchair developed by these researchers is such of a kind that it can be used both indoors as well as outdoors. Only one caregiver will be required to operate this chair. The wheelchair and the lifting mechanism both are run by the help of electric motors. It also comprises of a folding mechanism such that the patients can even use this chair outdoors. In this way, both ergonomics and safety of patients has been taken into account.

  The design of the wheelchair is shown in the fig.7.

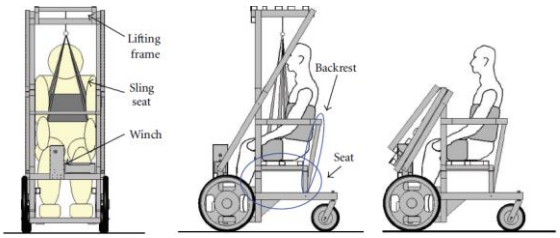

Fig. 7. Wheelchair with a lifting function. [7]

The working mechanism of the wheelchair is shown in the fig.8.

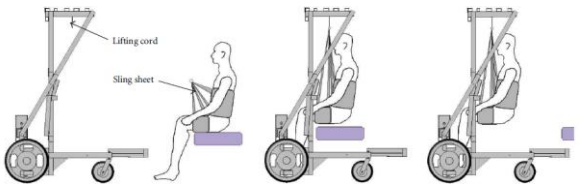

Fig. 8. Procedure when transferring from a bed. [7]

Two different analysis are conducted for ensuring the safety of the product:

1. Strength analysis is conducted with the help of a suitable finite element method software. The chair is

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checked under different loading conditions and the safety of the wheelchair is guaranteed.

2. Stability analysis is conducted as the patient is going to be lifted and placed at certain position. Because of which there are going to be changes in the centre of gravity which through analysis is taken care off. When the patient is lifted and placed, there is going to be some speed and acceleration with which the patient will be transferred. So, a proper acceleration is fixed so as the patient feels safe while being transferred.

Two experiments were performed to confirm the use the chair:

1. Travelling experiment: the wheelchair was ridden on a bumpy road where in the suspension was checked and it was found that the user was comfortable to travel on the road. The operation of the joystick was also checked.

2. Lifting experiment: A lifting mechanism was tested by lifting a subject(patient) from one place to another. The velocities and lifting were recorded for further studies.

The patients are lifted with the help of belts which can be uncomfortable for the patients and can also cause injuries. The belts are connected to the wheelchair with the help of hooks. These hooks must be strong enough and should last for a longer period of time as it can be fatal if there is any kind of malfunction.

- R. Krishnan, et al, [8] have come up with an innovative idea to design a wheelchair which will have self-transfer ability viz. the patient would not need to take help from nurses from transferring from one surface to other (ex. Wheelchair to bed or toilet seat).

Before actually starting to design the chair, the researchers studied the various techniques by which a patient is transferred from wheelchair to other surface (ex. A bed or toilet seat). They divided their research into two categories: Transfer of patient with someone's assist and transfer without assist. In both the cases they found out it was highly risky to carry out the transfers. Before deciding the actual mechanism of the wheelchair, a thorough study is done on different kinds of mechanisms which can be used and proper characterization is done on the basic of various factors. Factors are shown in the fig.9. After studying different mechanisms, a proper transfer method and mechanism is decided. The selection criteria shown in fig. 10. The working of the wheelchair is shown in fig. 11 and fig.12.

The researchers developed have two types of chairs:

1. Manually handled wheelchair transfer device.
2. Powered wheelchair transfer device.

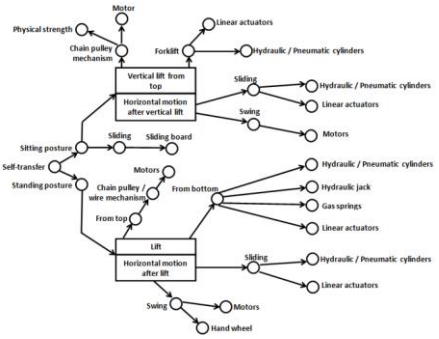

Fig. 9. Concept classification tree with various options available. [8]

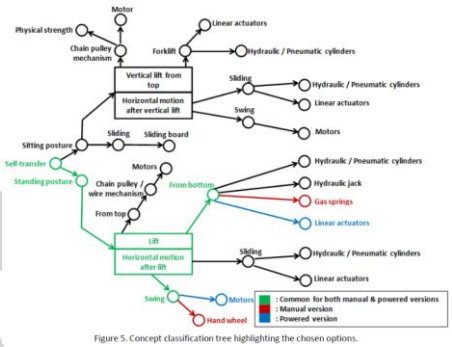

Figure 5. Concept classification tree highlighting the chosen options.

Fig. 10. Concept classification tree highlighting the chosen options. [8]

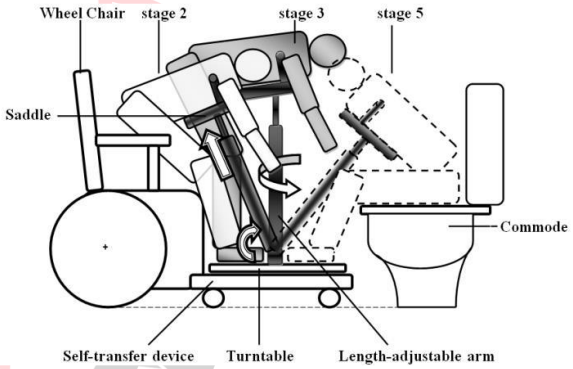

Fig. 11. Conceptual design of self-transfer device showing stages of transfer motion. [8]

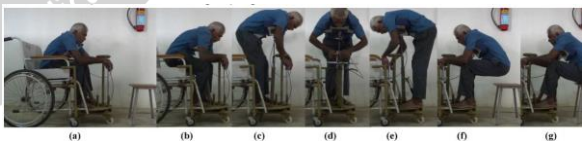

Fig. 12. Process of transfer of a person from wheelchair to a stool using manual self-transfer device [8]

The dimensioning of the wheelchair is properly done by keeping the size of a residential bathroom in mind as this chair is being designed majorly for patient to use the washrooms. Weight of the transfer device is not a major problem as it can be attached or detached from the wheelchair. But researchers have tried to keep the weight as minimum as possible as it will be difficult for a disabled person to handle it as this is a self-transfer device.

Alternative mechanisms which can be used are for designing the same product is clearly explained.

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On frequent use, it can be painful for the patients as they have to rest on the stomach while being transferred. As the device can be attached and detached from the wheelchair there are high chances of malfunctions if the assistive device and wheelchair is not attached properly.

- Garrett G. Grindle, et al, [9] have come up with a design to develop a wheelchair device for transfer of patients from wheelchair to bed or to toilet seat. This transfer device is completely electric driven robotic device. Before making a final device, a prototype of the device was made and was tested on number of test subjects (patients) and above 80% percent of them found this transfer device to be effective because of the robotic control.

The authors have done a lot of research on the accidents that happened in the past years during patient transfers and have properly presented the data in numerical figures. Authors have also emphasized on the injuries caused to different body parts during transfer for both patients as well as nurses. They have discussed different transfer techniques like ceiling transfer and have pointed out the flaws in them.

Since this device is fully electronically powered, different sensors, actuators, motors are used to run this device. The block diagram of different components used is shown in the fig.13.

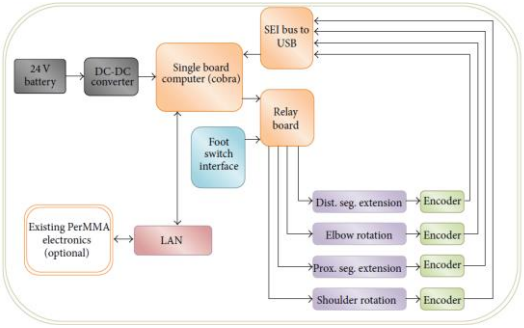

Fig. 13. A block diagram describing device's motors, sensors, and associated electronics [9]

The working of this chair is shown in the fig.14.

Fig. 14. A sequence of photographs of the device being used to transfer a person from an electric powered wheelchair to a table, by a caregiver [9]

On completion of designing, testing of this chair was conducted on 15-18 test subjects(patients). The patients were transferred with this device and their experience was noted and presented in numerical features. Opinion was taken from those patients regarding what changes can be made in the design to make it ergonomic and safe to use. At the end, a survey was taken by asking them a series of questions regarding different topics like the expected cost of product, comfort, safety,etc.

Since high-end technology is used cost will be more. Due to a complex working there are chances that the new user might find it difficult to operate. Frequent maintenance of device is required to keep all the sensors and other components in proper working condition. Since the device is completely robotic-driven there are chances of malfunctions which can cause accidents.

- An innovative wheelchair transfer assistive device has been designed by the Mahammed KS et al, [10] to assist the patients with lower limb problem to be transferred from wheelchair to bed, toilet seat or other surfaces. Along with designing, proper testing of this device is done by transferring 18 test subjects (patients). The results were gained by monitoring the heart rate and rate of exertion of the subjects as it gave the amount of strain that was caused to the subjects while being transferred.

At first a CAD model of the design was made. Before physically designing the device, a survey was conducted by the authors in two steps. In the first step they visited a hospital and had conversation with the authorities regarding the available transfer techniques and the problems faced by the patients and nurses while being transferred. In the next step, the researchers gathered 45 members (physiotherapists, nurses, transfer device users) and were given a survey form which consisted of questions regarding problems faced by them while handling the patients or different transfer devices. The last question consisted of the cad model of the device designed by the researchers. Opinion was taken regarding the design of the device and what changes can be made in the design.

Based on the feedback and comments from the hospital authorities and survey conducted, a final design of the device was confirmed and a prototype of the device was manufactured.

Further the testing of this device is conducted on 18 test subjects (students). Before testing, the heart conditions of the subjects are noted. During transferring the subjects, their heart rate(bpm) and rate of exertion was noted continuously at a specific interval to calculate the amount of strain experienced by the patient while being transferred.

After transferring all the students, a survey to conducted to get know their experience while using the device.

Fig. 15. Working prototype of device, user and wheelchair in a lab-simulate setting. [10]

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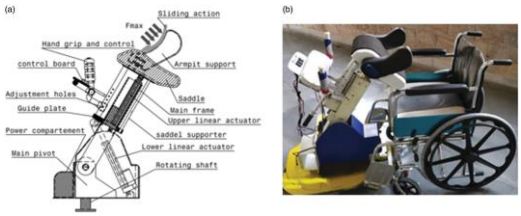

Fig. 16. 2D schema of device with a part name (left), a working prototype of device and a wheelchair in transfer set up mode (right). [10]

- Emi Ozawa et al, [11] have come up with an innovative idea to design a wheelchair transfer assistive device from transferring of patients from wheelchair to bed, toilet seat or other surfaces. The emphasis is done on the problems faced by the elderly people when transferred from wheelchair to toilet seat during the excretion process.

  The authors have explained the problems in different body parts which occur in both nurses and patients when they are transferred. In proper numerical figures, the researchers have claimed the reduction in the problems in different body parts if the device designed by them is used instead of a conventional wheelchair. They have achieved these figures by taking a survey and testing this device on 12 subjects.

  The working mechanism of the device is shown the fig.17.

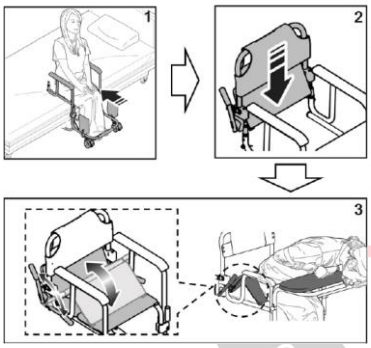

Fig. 17. Assisting with transfer-type wheelchair. [11]

For testing of the device, 11 test subjects were transferred from the wheelchair to the transfer device. While testing, eight different muscles of the body we monitored and the muscle activity was recorded by electromyography. The different body points are shown in fig.18.

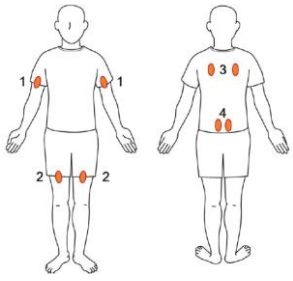

Fig. 18. Electrode points for electromyograph of examinees. [11]

Similarly, the time required for the transfer by using a conventional wheelchair and the transfer device are calculated. Thus, the results from muscle tests and time interval tests shows that:

1. Less time is required to transfer by using the device designed by researchers.
2. The amount of burden on the body muscles is less by using the transfer device.
3. The patients feel much safer and comfortable while being transferred with the help of the transfer device.
   The product designed is easy to use and lower in cost.
   As the patients have to rest on their stomach while the seat is being attached, it can be painful and uncomfortable for the elderly patients to stay in that position.

- Number of accidents happening in India is increasing rapidly due to which there is an increase in the number of disabled patients. The patients have to face problems while they are being transferred from wheelchair to a stretcher. While keeping this problem faced by the patients in mind, V. Mohanavel et al, [12] have designed a wheelchair which has an ability to be converted into a stretcher. The developed stretcher is manufactured by stainless steel. The reason behind selecting this material is to make the device lighter in weight so that it can be used at various public places like schools, vehicles, hospitals, etc.

  For proper dimensioning of the device various calculations are done to design various components of the device. The cad model of the device is shown below:

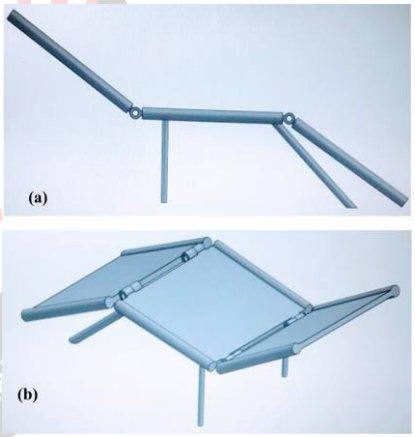

Fig. 19. CAD modelling of stretcher cum wheelchair. [12]

Hydraulic or pneumatic systems or some automation can be used, which can reduce the efforts of nurses to convert wheelchair to bed.

2.2 Analysis of Devices and Patient transferring techniques

- Caregivers are two types: experts and the non-experts. Non-experts are generally the new-comers. While the training of the non-experts is conducted, many experts are unable to explain the techniques to the non-experts in proper manner after being handling patients for more than 10 years. In order to tackle this problem, Mikako Ito, et al, [13] have come up with a new technique by which the experts can educate or train the new comers by the help of a Three- dimensional motion analysis.

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For the experimentation purpose, one expert caregiver and 4 inexperienced caregivers were chosen to volunteer. Each caregiver was given one test subject which was needed to be transferred from wheelchair to bed.

For the analysis purpose the caregiver's body was marked at eight different positions and these marks were viewed with the help of infrared camaras. In order to analyze the motion of caregiver while transferring the person different parameters were considered, like the distance between the wheelchair and the back of the caregiver, angle between the legs of the caregiver, angle of lifting, etc. The marking on caregiver's body were plotted in three dimensional coordinates and the motion was studied separately for every parameter mentioned.

Example: The distance between the wheelchair and the back of the caregiver and the distance between the legs is monitored in three dimensional coordinates while motion of transferring has occurred. The picture during the moment of lifting in three dimensional coordinates is shown in fig.20.

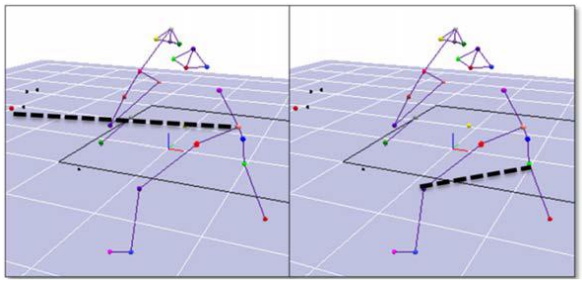

Fig. 20. Stick picture at the moment of lifting. [13]

Thus, the non-experts were able to learn under which parameter they were going wrong. And the non-experts can be trained properly with the help of these analysis. Thus, further preventing the accidents caused during the transfer.

- Tang R, et al, [14] have done an analysis on two transfer assistive devices which are major used for the transferring purposes. Those two devices are gait belt and walking belt. The analysis is done to prove which belt is safer to use and comfortable for the patients as well as caregivers.

For the experimentation purpose, 14 students were selected. 7 students had to be the caregivers and the 7 students to be the patients. The experimentation was to transfer the students from the wheelchair to the bed using a gait belt and walking belt respectively. A standard hospital bed and a wheelchair were selected. The examples of gait belt and walking belt is shown in the fig.21.

Fig. 21. Examples of gait belt (left) and walking belt (right) used in this study. [14]

The experimentation was conducted by giving strict instructions to the subjects on how the transfer should be carried out. While the transfer was taking place, the force applied by the caregivers was calculated with the help of sensors. At the end of the experiment, the amount of comfort experienced by the subjects in both the cases (gait and walking belt) was noted on the scale of 5. Similarly, the amount of physical stress on shoulders and back experienced by the subjects was noted.

Results of the analysis showed that:

1. The gait belts required more force that that of walking belts.
2. The walking belts produced less stress on the different body parts than that of gait belts.
3. Lifting carried out by walking belt is safer than that of gait belts.

Further the authors have shared the limitations of the experimentations and how it can be improved:

1. The test subjects which were used were students which were mentally and physically fit unlike the elderly patient who are generally low on their self-confidence.
2. Similarly, the physical stress values were low as compared to the actual values which are observed in the elderly patients

The comparison has been carried out on the basis of the comfort, safety, physical stresses and loads experienced by the test subject while using the gait belt and walking belt. After calculating the results, the researchers claim that walking belt is much safer and ergonomic to use than the gait belt.

- Koontz, et al, [15] put an emphasis on the barriers to the wheelchair users in the community due to improper transferring assistance and places where transfer accessibility should be increased so that there can be active participation of wheelchair users at such places. A survey is conducted among the users to get to know their problems.

A survey was conducted among the wheelchair users regarding the mentioned topics:

1. Effectiveness of the mobility devices and transfer assistance devices, availability of such devices at various locations and the problems faced by users while accessing these devices. Ex. Size of transfer device, availability of room to use the device like in restrooms, availability of grab bars and handles, different between the height of wheelchair and mobility device etc.
2. Transfer accessibility in public places like restaurants, schools, hair salons, dressing rooms, parks, theatres, etc.
3. Transfer accessibility of seats in various places like school chairs, different modes of transportation, public restrooms, etc.

The survey was further classified into different types: Age, Gender, Type of disability, type of mobility device used (manual or powered), time spent on a

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mobility device, number of daily transfers and training to transfer.

After the results of the survey, the authors have listed the limitations in the study and what changes can be implemented. After concluding the survey, the researchers have come up with a conclusion about what changes should be implemented to break this barrier in the life of patients.

- Many wheelchair users are of the age of 25-50 who have to work for a living. Many of these have to sit on the wheelchair for the whole day. It is difficult for them to work for an entire day while sitting in a wheelchair. If the person does not have a desk job and works at places like a grocery shop, then it becomes difficult for the person to work sitting in a wheelchair. Even having a desk job, it is difficult for the physically disabled people to sit in a position for 6-8 hours. It becomes uncomfortable for them to work in such condition and thus they are not able to focus on their work. That is why it is a must to develop a workspace for the disable people which is ergonomic and the people can work comfortably over there. Along with the workspace, the wheelchairs should also be comfortable with features like width and height adjustment, cack support inclination, proper leg rest, etc. Sitting in the same position for a long time also leads to different disorders of back, shoulders and other body parts. T. S. Antonio, et al, [16] have done an ergonomic analysis of the workspace of wheelchair users.

  For the ergonomic analysis, the researchers have conducted surveys and have made use of psychophysiological methods like Rapid Entire Body Assessment, Ovako Working Posture Assessment System etc. In order to access the risks due to load on the person during work, these methods are used. A survey is conducted to get to know the problems faced by the users at workstation. This is analyzed and the users are evaluated by the methods listed above. On studying each case separately, corrective actions are taken by giving feedback to the wheelchair users on what ergonomic chances they should do in the workstation as well as what changes should be implemented in the design of the wheelchair they are using.

  The results of the tests and survey shows that around 40 percent of the patients are at high risk which means that there is an immediate need to change their workstation. Similarly, around same number of people are at a medium risk which implies the same to them. Around 20 percent are at lower risk which implies that if proper ergonomic changes are not made, in a short period they with be at a high risk of disorders. There were no users with negligible risk. The results that the researchers got were irrespective of the age and gender which implies that the risk is only because of improper ergonomic workstations.

- Today, the rate of accidents has increased on a greater extent while transferring the patient from wheelchair to bed. Many people have studied the causes of accidents and remedies to it. The major causes of accidents are: when patients try to transfer themselves without the help of a caregiver, or a caregiver using improper techniques to transfer a patient manually or not making use of transfer assistive devices like handles, belts, etc. A research has shown that many elderly people feel uncomfortable and unsafe when transferred by using belt.

  In this article Okunribido OO [17] has focused on such kind of a causes that results in accidents while the patients are transferred from wheelchair to other surface. For experimentation, a study was done on different variables shown in the table below:

Trunk Position	Seat Cushion	Feet condition
Upright/ Against backrest	Flat polyurethane (PU)	Dangling (unsupported)
Flexed forward	Propad low profile (HOMEPAD)	Supported on footplates

Table. 1. Trunk Position and feet condition on different seat cushions. [17]

Tests were conducted to calculate the stability by using different parameters like the center of gravity. Simulated transfers were conducted and the safety of patients was noted on the scale of 10. For calculating the results, two seat cushions are compared at different seating arrangements of the patients. After the results were gained, the researchers concluded that the seating cushion had an effect on the overall stability of the patients.

The study gave two main results that is:

1. Risk of falling from wheelchair increased when the patients were seated on thick soft cushion. The researchers therefore recommended a hard cushion seating for a wheelchair.
2. The risk of accidents increased when the patients prone to slouch forward in a wheelchair.

- Gaal RP, [18] has done a study on the accidents and injuries caused to the wheelchair users. The emphasis is made on learning the causes of the accidents and what improvements should be made in the use and design of the wheelchair.

  Large amount of data was collected by taking a survey of over 100 users who had faced incidents while using wheelchair. The participants were classified into different categories like gender, age, disabilities, etc. Classification was further carried on the basis of wheelchair specifications like manual or powered, etc. More than 100 questions were asked in the survey on different domain (ex. Riding conditions like smooth or rough road, plane or slope road, etc.) During analysis, the data acquired from the participants was studied thoroughly and analyzed by using a statistical software. Different tests were also conducted to compare the data and to get potential outcome from it. The incidents which occurred were classified to

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compare the data into different categories like tips and falls, component failures, etc.

After calculating the results, an analysis is conducted on the stability of the wheelchair. For analyzing the stability of the wheelchair, different parameters are considered like the center of gravity and the angle of rotation. Significant changes in these parameters causes the wheelchair to tip and fall. It is shown in fig.22. They have studied the effect the height of cg on different surfaces like during driving it at a slopped road. They have compared manual wheelchair with powered wheelchair under this parameter. The researchers have come to a conclusion that stability of powered wheelchair is better than the manual wheelchair due to its more weight.

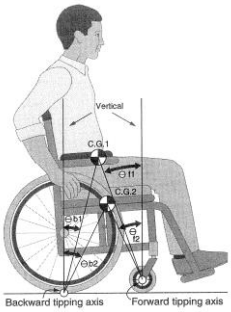

Fig. 22. Effect of C.G. [18]

Similarly, analysis is conducted on different factors influencing accidents like role of riding surface, Effect of wheel size, etc. After analyzing different causes of accidents, the researchers have recommended different actions which should be taken while designing a wheelchair. Some of these changes are lowering the center of gravity of wheelchair to prevent tips and falls, increasing the diameter of the front wheels to overcome obstacles on a rough road, proper footrests and proper suspension system, etc.

The component failure can be prevented by designing the wheelchairs according to the international standards.

- There are many wheelchair users who have to work for a living. They have to travel by personal vehicle or have to make use of public transport. In such cases if proper transferring techniques are not used it might result in high risk of accidents. The barriers faced by the users are both internal and external. Internal barriers include fear, low self- confidence, pain, etc. while being transferred. External barriers include improper transferring techniques, not use of proper transfer assistive devises like grab bars, handles, belts, etc. Because of wheelchair transfers, users are able to participate in many community activities which also boosts their self- confidence.

To get to know more about the challenges faced by the wheelchair users while transfer, Barbareschi G [19] conducted a survey which consisted of 11 wheelchair users and 4 therapists. The users were asked to do independent transfers by their preferred technique: either standing, sitting or by use of transfer boards.

For data collection and analysis, a smart technique was used. The participants were instructed to record a short video on what problems did they face during transfers. The video was then converted to transcripts and with the help of proper software this transcript data was compared to get the desired results. The results were compared among the participants and was further categorized into different categories:

1. Value of wheelchair transfer: If a user is successfully able to transfer himself/herself, the user becomes completely independent that is he/ she will be able to perform almost 90% of work on his/her own. (ex. Using a restroom, getting into a public vehicle, etc.)
2. Four Pillars of transferring from wheelchair: Strength, confidence, techniques and balance are four pillars suggested by the author for successful transfers. In order to get better in these aspects, the user should practice the process of transferring.
3. Internal and external difficulties: Internal difficulties include lack of balance, tiredness spasticity, etc. External difficulties include lack of space, unavailability of wheel locks, etc.
4. Training of transfer: A proper training of transferring should be provided in order to prevent the risks of accidents while being transferred.
5. Negative effects of transfer: Fear is the biggest problem faced by the users. For some users fear is a good thing as due to fear they take excessive care and avoid unnecessary risks. But on the other hand, due to fear many users lack in confidence and there is a chance of mistake which can cause injuries.

III. CONCLUSION

The study was conducted to understand the different problems faced by the caregivers while transferring the patients from wheelchairs to other surfaces like bed, toilet seat, etc. The paper is focused on the study of different patient transfer assistive devices and the effects of manual handling on patients and caregivers. Manual handling has increased musculoskeletal disorders in caregivers and accidents while transferring which results in injuries to patients. Many transfer assistive devices which were designed were large in size. In developing countries like India major amount of population lives in small houses. So many people will not be comfortable to accommodate these large devices. Large amount of automation is used in some devices with the help of robotic assistance which increases the cost of device and working mechanism. In developing countries with majority of low income and illiterate families, it is difficult for people to use these devices. Because of these drawbacks people will tend to use manual handling techniques rather than transfer assistive devices. Keeping these limitations in mind, there is a need to develop a transfer assistive device which will have an easy operating mechanism, will we lower in cost and will be ergonomic to use. Development of such kind of device will reduce the amount of people going for manual handling techniques and thus will reduce the number of accidents and disorders in patients and caregivers.

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