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Short Communication

Design of an Indigenously Developed Patient Transfer Assistive Device

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ABSTRACT

The patient transfer has always been challenging, usually requiring a number of caregivers to perform this task together, which is time-consuming and can easily cause secondary injuries to the patient. In addition, when the world is in the distressing predicament of a global pandemic covid-19, the issue of patient transfer is even more critical, as caregivers are at a high risk of infection, causing significant damage to healthcare resources. The goal of using assistive devices is to minimize the risk of injury. A lifting device is an assistive device that allows patients in hospitals, nursing homes, and those receiving health care at home to be transferred between a bed and a wheelchair or other similar resting places using different lifting mechanisms. By choosing appropriate equipment and using it effectively, the risk of sustaining an injury is significantly reduced, and the quality of life for all concerned is often noticeably improved. This work aimed to propose a design of a lightweight, durable, and ergonomic assistive patient transfer device named "Patient Lifting Hoist" (PLH); it can assist caregivers in transferring patients, reduce direct contact between them, and avoid secondary musculoskeletal injuries for use in hospitals and homes. The authors concentrated on the partial elimination of manual lifting in order to device could work in two situations: with or without electricity. In the mechanical structure of this assistive device, a chain-drive mechanism and motorized jack lifting mechanism are proposed; they are the key points to the fundamental functional realization of the device and can reduce the cost of the prototype. Furthermore, the device can operate remotely, and a control strategy is applied to ensure the operation's stability and safety. Finally, some preliminary experiments are carried out to verify the device's reliability and lay the foundation for the clinical tests.

Keywords: assistive, caregivers, device, injury, lifting, mechanism, transfer

INTRODUCTION

Healthcare workers experience high rates of work-related injuries. These rates equal or exceed workers' injury rates in traditionally high-risk occupations. Manual handling of patients forms an integral part of caregivers' daily routines. Handling is safe when it does not subject the person to any risk of injury from heavy loads, non-ergonomic postures, movements, or excess repetition.[1] Healthcare providers are prone to sustain injuries while moving or handling patients. The body parts most frequently injured during this process are the lower back, neck, thumb, upper back, and shoulders.[2] Studies show that healthcare workers suffer from high work-related musculoskeletal symptoms. Over 88% of healthcare workers report work-related pain in at least one body part.[3] This could be in position because of faulty techniques and excessive workload among health care workers.

Occupational health Institutions in India, such as National Institute of Occupational

Health (NIOH), National Safety Council of India (NSCI), and the Indian Association of Occupational Health (IAOH) promote safety at construction sites, during road transportation, and carry out research such as evaluation of environmental stresses at the workplace.[4] Improper handling has been shown to cause or exacerbate patient injuries, leading to increased morbidity and longer hospital stays. Person transfers increase the likelihood of injury to both caregiver and person if performed incorrectly.[5] A cross-sectional survey design study for occupational and physical therapists in 2012 displayed that transferring or lifting persons was associated with 26.6% of all injuries during work-related activities.[6] Some research says caregivers should not lift more than 16 kilograms. Numerous studies have shown that training caregivers to use proper body mechanics to lift residents is not an effective prevention measure because lifting the weight of adult patients is unsafe. From a work practice-related control, the risk of injury could be decreased by using education and training on proper lifting techniques and assistive devices. A study that implemented mechanical lifting devices or other "patient lift devices" showed a 43% reduction in patient handling injury claims.[7] Choosing appropriate equipment and using it effectively reduces the risk of sustaining an injury, and the quality of life for all concerned is often noticeably improved. The technological equipment developed to assist the patient in moving should reduce physical pressure and workload.[8] To minimize the risk of injury to caregivers, patients, and care recipients, clinical settings are equipped with assistive technology in lift technologies to assist person transfer.

Many transfer assist devices are available on the market, including transfer boards, slide sheets, roller sheets, transfer belts, and roller boards. While using the first group of devices can lead to many health complications, the reliability of costs enforces resignation from more advanced solutions. Complex solutions like mechanical platforms use electrical motors instead of physical strength. Devices available on the market perform their functions in a hospital setting. However, no available assistive technology uses a transport mechanism that allows the device to work under accessibility conditions and without electricity. In addition, device prices often outweigh the financial capabilities of an individual.

This paper aimed to propose a design for a patient lift and transfer apparatus named Patient Lifting Hoist (PLH) for use in hospital and home healthcare settings. The assumption was to design lightweight, durable, and ergonomic device using innovative assistive technology. The authors concentrated on the partial elimination of manual lifting to the device could work in two situations: with or without electricity. This paper describes the specification, mechanical design, material, and analysis.

MATERIALS & METHODS

The requirements for the solution related to functionality, construction, and material selection were determined by the conditions of a particular place of its intended work environment, a hospital, and home health care settings.

Functional Requirements:

The device should fulfil the patient's transport, including lifting and transferring movement between the planes and rooms. However, the field conditions where the device will operate could also face manual lifting during a power shortage. The solution should be mechanized to relieve caregivers.

Construction requirements:

The most critical factors are strength (lifting 200 kg), lightness and ergonomics. Second, the device size should be adapted to the hospital and home conditions (size of rooms, beds). Third, simplicity for minimizing failure rate. The construction should be durable.

Material requirements:

The main criteria include the material's strength and cracking resistance: Young's modulus and fatigue index. Given the working area, the material has to be corrosion-resistant. The economic conditions are also necessary-the availability and low costs of materials concerning their quality and consumption rate. Production properties, such as ease of making, joining individual elements, and finishes, are also critical. When choosing a suitable material, the designer should consider aesthetics, i.e., gloss, roughness, etc.

Transport Mechanism:
According to the requirements, the transportation mechanism involves height adjustment and pattern movement. Three variants of solutions were analyzed during designing the height adjustment mechanism: (lifting/lowering). In the project's initial phase, pneumatic and hydraulic cylinders were considered; however, these variants were rejected due to the inability to operate the device during lack of electricity.

Innovative Design of Patient Lifting Hoist:
The patient's lift uses a motorized pulley mechanism to lift the patient vertically from a bed to a chair or other similar resting places. Different designs were also considered and evaluated before we zeroed down to the pulley mechanism.
Concepts of the lifting mechanism, schemes, and disadvantages of the solutions

First Design:
Increased cost.
The development requires the use of three motors.
The tube casing is in the base frame.
Heavy base framework.
It provides comparatively less vertical displacement.
It is to carry dead weight.
Castor wheels consume extra floor space.
Installing the motor and gearbox on the top of the vertical shaft increases the device's height.

Second Design:
Using Rack and Pinion Mechanism
Drawbacks:
Provide comparatively less vertical displacement
Building rack and pinion mechanisms is an extremely laborious and expensive job.
Higher maintenance costs.

Third Design
Using a winch-controlled pulley mechanism
Drawbacks:
High lifting speed
Lifting movement was jerky (because of the crutch mechanism)
Increased vibratory sound.
The tensile strength of the pulley is less.
Elimination of 360° rotation of horizontal shaft:
To provide 360° rotation, we need to incorporate thrust bearings.
A disadvantage of using thrust bearing is that a slight shift movement by the patient (seated in the sling) will result in a more significant angular displacement, which is unsafe for the patient. Hence, the need to eliminate 360° rotation.

Components of Patient Lift Hoist:
Wheels:
Two types of wheels propel the hoist-
Rear Wheels
Casters
Features:

Rear wheels:
They provide unidirectional motion (forward and reverse motion only)
Their movement is motor controlled (a chain-drive mechanism)
They can bear a load of up to 200 kg.
They are puncture resistant.


Figure 1. Patient Lifting Hoist (PLH)

Figure 2. Parts of PLH

Swivel Casters:
The frame of the caster rotates and is equipped with a wheel called a swivel caster. The swivel caster can turn 360°.
A swivel caster has two "legs." A leg on either side of the wheel is installed in the caster chassis. One leg is on either side of the wheel, which is installed in the frame of the caster. The wheel is held in place by a bolt or axle between the legs of the caster frame. Above the legs of a caster is the pivot bearing, which allows a caster to rotate 360°.

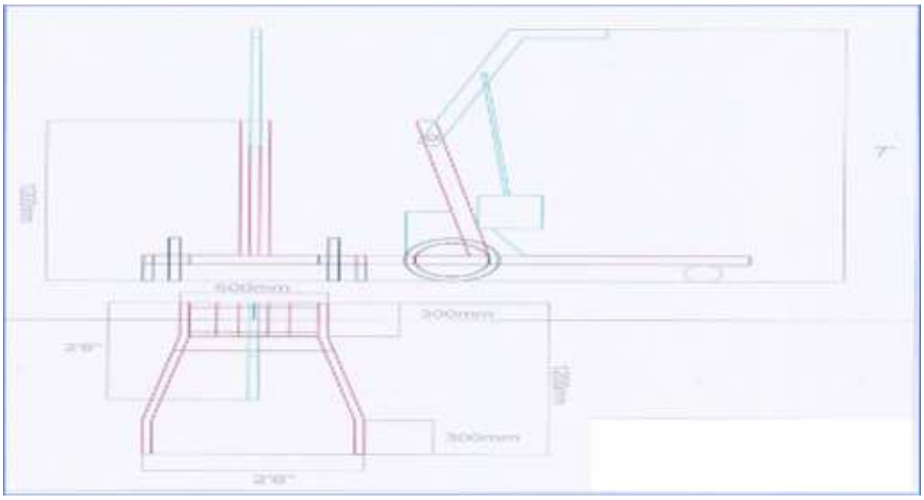
Figure 3. CAD Drawing of Parts of PLH

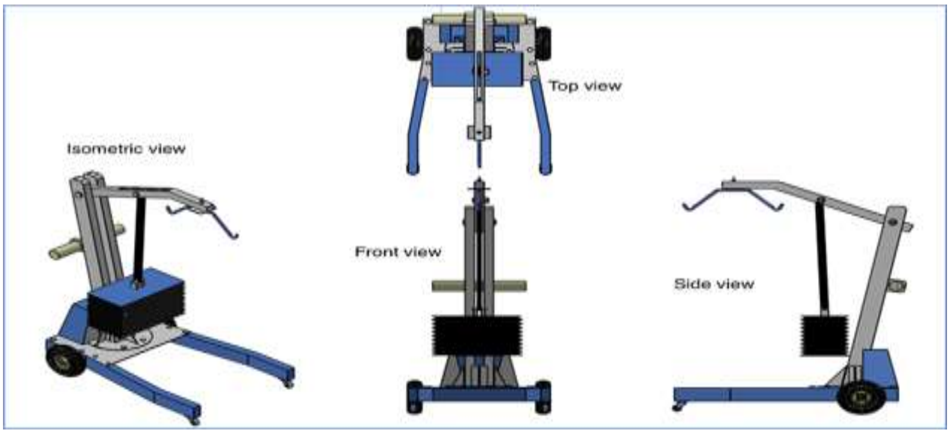

Figure 4. VIEWS OF PLH

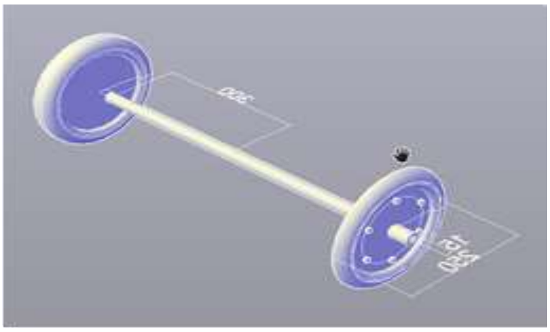

Figure 5. CAD Drawing of Rear Wheels

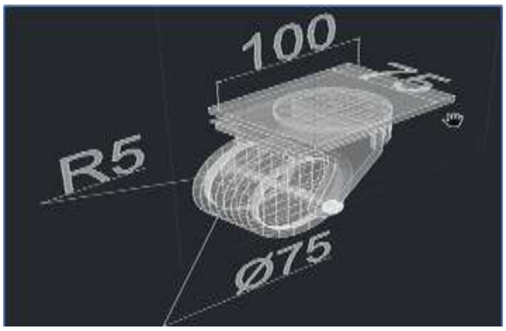

Figure 6. CAD Drawing of Swivel Caster

The top of the caster is used to attach the caster to the equipment.

There are several methods to attach a caster to a piece of equipment. The most common method is a mounting plate, commonly referred to as the top plate.

The mounting plate of a swivel caster is connected to the pivot bearing and the legs under the swivel bearing. Sometimes casters are attached by welding the mounting plate of the caster to the equipment.

The primary purpose of having swivel casters is to move the equipment forward, backward, and sideways. This caster configuration is advantageous when you have to move caster equipment with little space to maneuver.

Locking of casters is possible.

Dimensions of rear wheels-

Outer diameter: 250 mm

Inner diameter: 200 mm

Dimensions of casters:

Height: 100 mm

Width: 100 mm

Thickness: 75 mm

Materials:

Rear wheels: solid rubber wheels

Casters: Hardened plastic

Base-Plate:

Features:

The weight of the lifting mechanism and the patient's weight (seated on the sling) will be transmitted to the base frame through the base plate.

It serves as a means for attachment of the vertical shaft and provides stability to the vertical shaft.

Thus, the base frame should be sturdy, durable, and stable.

Material:

Mild steel

Dimension: 630 mm x 480 mm x 570 mm

Thickness: 6 mm

Main-Frame:

The chain drive mechanism for transferring mechanical power between two places is a standard locomotion method.

Typically, a chain drive works by having a power source, usually, a motor, rotate; a toothed wheel known as a sprocket spins, and its teeth catch slots in the chain drive, causing it to turn around the sprocket.

At the other end is a Driver Sprocket that transforms the mechanical energy delivered by the drive chain into the desired force.

Characteristics:

High axial stiffness

Low bending stiffness

High efficiency

Relatively cheap

Dimensions:

Driver sprocket's outer diameter: 20 mm

Driven sprocket's outer diameter: 75 mm

Base-Frame:

Features:

It is a steel frame over which the entire hoist is built.

It consists of the device's frame, wheels, and machinery on which the body is supported.

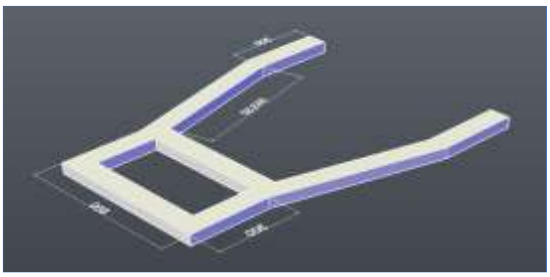

Figure 7. CAD Drawing of Base-Frame

Control Strategy of PLH:
During the operation of this device, the system's stability is of great significance to the safety and comfort of the patient and must be considered.

Motor:
The motor is considered the heart of any mechanical system/tool as it relays the needed power to make it work in the desired manner, connects all the mechanical elements, and makes them perform efficiently.
The following is a summary of the motors used together in tandem to make the hoist perform its primary function, i.e., lift or lower person.
General Specifications:
12 DC Motor with planetary gearbox
Speed: 40 rpm
Number of motors used: 2
Mounting of motors:
The first motor is mounted on the base plate at the back of the vertical shaft, powering the rear wheels.
The second motor is mounted adjacent to the first one to work the lifting mechanism, i.e., screw-jack.

Vertical Shaft
Features:
Space is provided between the two vertical shafts for fitting the horizontal boom. This spacing is 60 mm.

Flanges: a projecting flat collar on an object, strengthening and maintaining the vertical shaft position on the base plate.
It provides stability to the horizontal boom.
It creates an axis of movement for the horizontal boom.
It is attached to the base plate at an inclination of 10° to reduce its apparent length and increase stability.
Its lower end is attached to the base plate, while its upper end is attached to the horizontal boom.
Material:
It is made up of Mild Steel.
Dimension:
Height: 1200 mm
Tube dimension: 40 mm x 80 mm

Horizontal Boom:
Features:
It lifts the patient from their bed or wheelchair or any other seated device.
Similarly, it lowers the patient and sets them down on any desired surface.
It can be lowered to 107 cm (above the ground) and raised to 213 cm.
It is a bent shaft, angled at 45°.
One end is attached to the vertical shaft, while the other free end is used to hook a spreader bar.

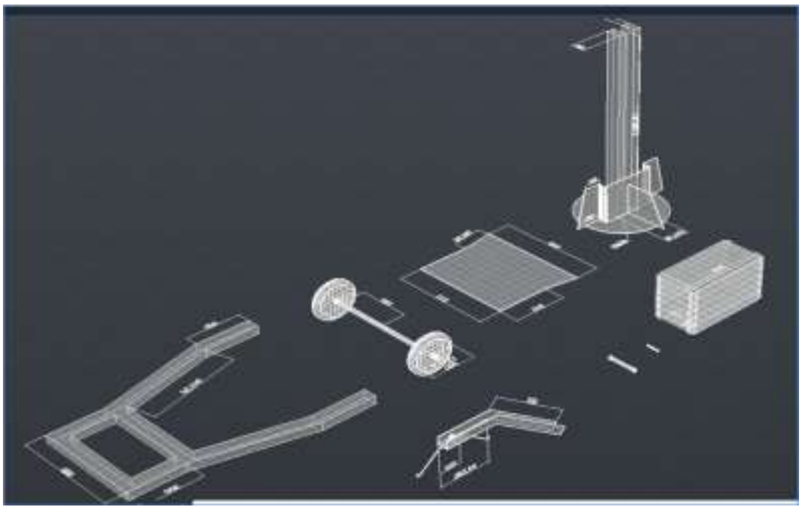

Figure 8. CAD Drawing of different parts of PLH

The spreader bar is used to suspend the slings on which the patient will be lifted.

Transmission Bar:
Features:
It is a vertical pipe.
One end is attached to the apex of the jack, while the other is attached to the horizontal boom.
The upward and downward displacement of the screw-jack is transmitted to the horizontal boom by the device from any medium (bed, wheelchair, bathroom, commode, etc.) to the other.
Material:
It is made up of Mild Steel.
Dimension:
Width: 60 mm
How much vertical displacement is the 'patient lift hoist' providing?
The horizontal movable shaft should traverse a distance (leaving 107 cm) from the ground and up to 213 cm above the ground.
Variation in Displacements for-
A Bed:
The standard height of a hospital bed ranges from 38 cm to 56 cm. The horizontal boom can easily attain this height.
A Wheelchair:
The average height of a wheelchair ranges between 50 cm and 52 cm which the horizontal boom can easily scale with the help of the slings provided.
A Ground:
A patient resting on the surface can also be lifted with slings by the horizontal movable shaft. This is done by positioning the horizontal boom at the sling height.

Spreader Bar:
Features:
A bent pipe distributes weight equally on either side when lifting a patient seated in the sling.
Attached to the horizontal bar, it provides suspension for the sling.
It can swing forward and backward and rotate up to 45° along its axis.
Material:
Mild steel
Dimension:
Length: 750 mm
Height: 150 mm

Lifting Mechanism
Definition:
A horizontal lead screw drives a lifting jack; the linkages of the jack are parallelograms whose horizontal diagonals are lengthened or shortened by the screw.
Features:
In our hoist, the scissor jack mechanism and a vertical rod are used as the lifting mechanism.
Additionally, the scissor jack is fitted with a gear motor with 50 rpm.
Also, the vertical rod is attached to this scissors jack mechanism to help in the upward and downward movement of the horizontal shaft to assist in patient lifting.
Mechanism:
Scissor jacks have simple mechanisms used to drive large loads.
The powered design of a typical scissor jack lessens the force the user requires to drive the mechanism.
A scissor jack is opened by twisting a small handle inserted into one end of the scissor jack.
The handle is generally in the form of "Z".
The end fits into a circular hole mounted on the end of the screw, which forms the force object on the scissor jack.
When its crank is turned, the screw spins, which lifts the actuator.
The screw functions as mechanical gear.
It has teeth (screw threads), which turn and move both arms, producing work.
Just turning this screw in a scissor jack is the foundation of the whole mechanism of a scissor jack.

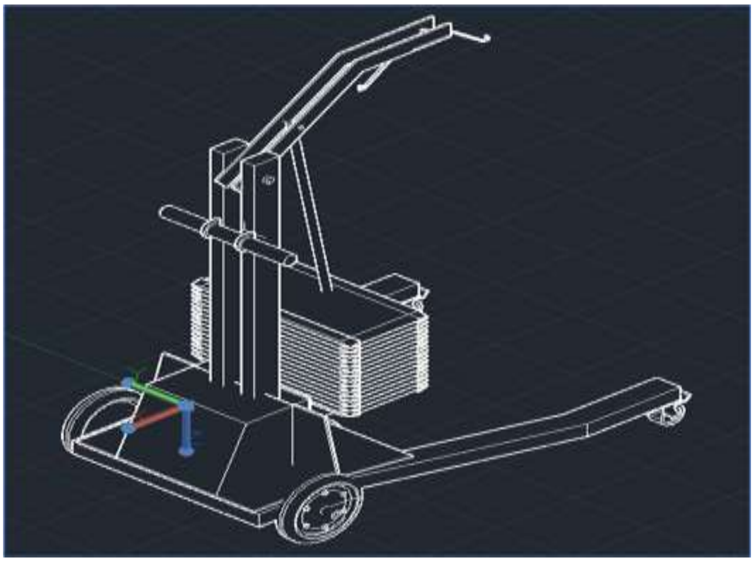

Figure 9. CAD Drawing of Assembly of PLH

Construction:

A scissor jack has four principal metal parts and two base caps.

The four metal parts are all connected to the corners with a bolt that permits the corners to pivot.

A screw thread runs through this connection and edges.

When the screw thread is turned, the jack arm crosses it and collapses or congregates into a straight line once close down.

Then, on their way back moving back, they rise and gather.

When opened, the four metal arms contracted together, coming into the middle and lifting the actuator.

Once closed, the arms spread apart, and the jack closes or flattens again.

Figure 10. CAD Drawing of Screw Jack

Lifting:

A scissor jack utilizes a simple theory of gears to obtain power.

As the screw section is rotated, two ends of the jack move closer to each other.

Since the gears of the screw push the arms upward, the applied force is multiplied.

It requires minimal force to turn the crank, yet this action causes the support arms to slide across and together.

As this happens, the arms extend upwards.

The gravitational weight is insufficient to prevent the actuator from opening or stopping the screw from rotating since it does not apply force directly.

If you put pressure directly on the crank or lean your weight against it, the person would not be able to turn it, even though your weight is a small percentage of the device.

Jack Modification:

12-volt gear motor with 50 rpm mounted on the jack with the love jaw coupling.

Jacks function by 12 volts of electricity supplied directly from the battery.

Electrical energy is used to power up the jack to raise and lower it.

Electrical scissor jacks are significantly more efficient than conventional scissor jacks.

Below Box:

It is a flexible bag made of rigid planks.

It is used to cover the screw jack.

As the top bracket of the screw-jack displaces up and down, the bellow box expands and contracts easily.

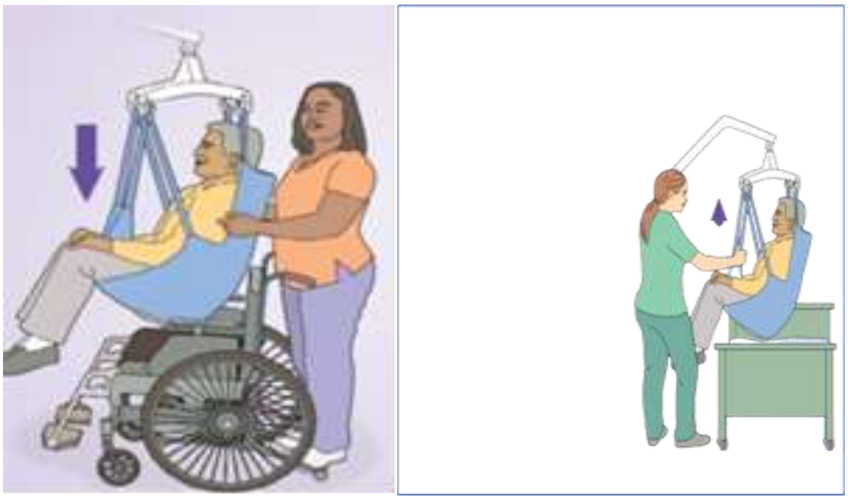

Figure 11. A patient is being transferred to a wheelchair and from a bed with the assistance of PLH

Types of slings used:
Divided sling, Hammock sling, Toileting sling, Amputee sling
Why mild steel is the material of choice for making patient lifts hoist-
Mild steel is ductile and can be machined with ease.
The generation of heat is less than that of steel machining. As a result, the tool can have a better life, and you can do more machining.
The cost factor is paramount since other steels are more expensive than mild steel.
Mild steel is a grade that does not harden when heated and cooled with cold water so that further machining can be easy.
Mild steel is readily available.
There is no need to change the tool multiple times, and no special tools are required for machining.
Cutting speed and feed does not require any particular skills.

DISCUSSION

The designed device fulfils the most crucial criterion, ensuring the safety of patients and medical personnel. The height adjustment mechanism partially eliminates the manual transfer of patients. The device can be used in both the hospital and home care settings. Due to the two usage options of the solution (manual and electrical), the device is valid both when electricity works and during its shortage. In addition, according to previous assumptions, the lift is made of a material that provides the strength (lifting capacity of 200 kg) and makes the device aesthetic. Using a simple lifting mechanism significantly reduces the cost of the designed assistive device. This argument may be essential for customers seeking a reliable, affordable patient transfer solution. To improve the planned device, one may consider reducing the profile size. For this purpose, different combinations of the materials should be analyzed to achieve even better strength properties with reduced thickness

CONCLUSION AND FUTURE WORK

This paper proposes a novel patient transfer assist system called "Patient Lifting Hoist," which can be used for non-contact transfer in emergency medical situations such as COVID-19, reducing the risk of infections and physical stress on caregivers. This device can function in both cases: with or without power. In addition, the motion sequence of the PLH was elaborated, and further preliminary tests of system performance, especially load tests, were conducted, confirming the rationality and effectiveness of the device. It is worth mentioning that the prototype still has some shortcomings in the current version. For example, to ensure the stability of the mechanical structure, all materials are made of mild steel, which leads to the heavy weight of the device. Operating the device may be difficult for caregivers, especially women, in emergencies and at home. Another example, the transfer is very time consuming, which may be one of the reasons for patient discomfort. Further optimizations will be made in future work, including the mechanical structure and control mechanism.

First, lightweight 3D printing materials (such as nylon, resin, etc.) can be used for non-critical load-bearing components to reduce the device's overall weight. Second, some advanced control strategies, such as adaptive, need to be explored, which may affect the application of this device. Third, some sensors, such as distance and pressure, can be added to the system. The preliminary idea is that a distance sensor on the side of the device can detect whether the device conflicts with the bed/stretcher. A pressure sensor on the device can be used as a switch to start the device to ensure the safety of movement. A digital weighing scale may also be integrated into PLH. For the application of PLH in natural clinical environments, the stability of the device under extreme conditions needs to be further tested, e.g., the ultimate carrying capacity and control strategies, etc. This work generally provides and tests a prototype, and much work remains to be done before commercialization.

Declaration by Authors

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REFERENCES

1. Warren G. Moving and handling: Reducing risk through assessment. Nurse Stand 2016; 30:49-58.
2. Vieira ER, Schneidner P, Guidera C, Gadotti IC, Brunt D. Work related musculoskeletal disorders among physical therapists: A systematic review. J Back Musculoskelet Rehabil 2016; 29:417-28.
3. Cheung, Szeto G, Lai G, Ching S. Prevalence of and factors associated with work-related musculoskeletal symptoms in nursing assitants working in nursing homes. Int J Environ ResPublic Health 2018; 15: 265.
4. Saha RK. Occupational health in India. Ann Glob Health 2018; 84:330-3
5. Sivaprakasam A, Wang H, Cooper RA, et al. Innovation in transfer assist technologies for persons with severe disabilities and their caregivers. IEEE Potentials. 2017;36(1):34-41.
6. Mastsumoto H, Ueki M, Uehara K, et al. Comparison of healthcare workers transferring patients using either convectional or robotic wheelchairs: kinematic, electromyographic analyses. J Healthc Eng.2016; 2016:16:1
7. Occupational Safety Health and Administration. Hospital safety: safe patient handling programs. Effectiveness and cost savings. Washington (DC): U.S. Department of labor (OSHO publication 3729-09/2013); 2013
8. Riccoboni, J.-B., et al., Biomechanical comparison between manual and motorless device assisted patient handling: sitting to and from standing position. Applied Ergonomics, 2001. 90: p. 103284.
9. Collins J, Nelson A, Sublet V. Safe Lifting and Movements of Nursing Home Residents. Dhss (Niohsh) 2006; 2006-117
10. Mary M. VHA Patient Care Ergonomics, Patient Handling Equipment Coverage & Space Recommendation, 2016.
11. B. Qi, H. Peng, K.Shou et al., "Protecting healthcare professionals during the COVID-19 pandemic," BioMed Research International, vol. 2020, Article ID8469560, 2020.
12. S. Sivakanthan, E. Blaauw, M. Greenhalgh et al., "Person transfer assist systems: A literature review," Disability and Rehabilitation, vol. 16, no. 3, pp. 1-10, 2019.
13. Y. Tian, H.Wang, and Y. Zhang, " Design and evaluation of a novel person transfer assist system," IEEE Access, vol. 9, Article ID 14306, 2021.
14. Krishnan, R.H. and S. Pugazhenthi, Mobility assistive devices and self-transfer robotic systems for elderly, a review. Intelligent Service Robotics, 2014. 7(1): p. 37-49.
15. Childs, P.R., Mechanical design engineering handbook. 2013: Butterworth-Heinemann.

16. Patient Lifts Safety Guide. Available from https://www.fda.gov/files/medical%20devices/published/Patient-Lifts-Safety-Guide.pdf

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