DE GRUYTER OPEN

TECHNOLOGICAL ENGINEERING
volume XIII, number 1/2016
ISSN 2451 - 3156

DOI: 10.2478/teen-2016-0004

DESIGN AND FABRICATION OF AN ADJUSTABLE SITTING INCLINATIONS SPINAL CORD REHABILITATION CHAIR

[1] Ajao K.R., [1] Yahaya T., [1] Ajimotokan, H.A., [1] Adeleke A. A., [1] Bello M. [1] Ojegbenro O.

[1] Department of Mechanical Engineering
University of Ilorin, Nigeria

Article history:
Received 30.4.2016
Accepted 22.7.2016
Available online 10.10.2016

Abstract
The adjustable sitting inclination rehabilitation chair was fabricated with mild steel and soft upholstered fabric was used for the overlay on the seat, headrest and armrest. The components were coupled with a linear actuator at the upper frame for the reclining of the backrest about it axis. The wheels are located outboard of the seat of the chair to enhance stability while foot rest supports the posterior weight of the users. The narrow seat allows free movement of the leg when the user is seated. Sitting inclinations of 120 and 135° protect the spine disc from compression and proffer more comfort for the users than other angles experimented. The adjustable sitting inclination SCRC is simple and affordable for low-income people with Spinal cord injury, especially for those in developing countries in order to support other therapies for their recovery processes

Keywords: Rehabilitation chair, spinal cord injury, spine disc

1 INTRODUCTION

Design in relation to spinal cord injury (SCI) is the application of engineering knowledge, creativity and technical perception to produce machines or equipment to fast track the rehabilitation process involve in SCI patient [1]. The spinal cord is one of the most important parts of human body [2]. It is a major bundle nerve that carries nerve impulses to and fro of the brains to the other part of the body [3]. The delicate nature of this part of the body makes it recovery difficult when injured.

Recently, the SCI menace is approximately 3 million cases per year as reported by Colin and Jon [2], resulting from natural disaster or accidents. SCI is the damage to the spinal cord that results in a loss of function such as mobility, loss of control of bowel and bladder and loss of sexual function [4]. Motor accidents, fall from heights, violence, sporting injuries or diseases are paramount cause of SCI [5]. As a result of an individual exposure to SCI, rehabilitation of such a person becomes paramount. Rehabilitation programme combines physical therapies with skill building activities and counseling to provide emotional support for the recovery processes [2].

Researchers and medical personnel experiences shows that spinal cord injury is complex as the repairing process has to take into account all the different kinds of changes that occurs during and after the injury [6, 7, 8].

Rehabilitation process is a long-term process that involves series of medications and exercises. A rehabilitation team is usually led by a medical doctor, specializing in physical medicine and rehabilitation (physiatrist) and often includes social workers, physical and occupational therapists, recreational therapist, and rehabilitation psychologists among others. In the initial phase of rehabilitation, therapist emphasis the regaining of legs and arm strength since mobility will only be possible with the assistance of devices such as leg braces, wheel chairs or rehabilitation chair [9].

Apart from efforts of other field of studies, engineers over the time have help in the area of constructing equipment/gadgets that aids the rehabilitation processes. Knabush and Shoemaker [10] designed a wood slat outdoor folding chair from orange crates. They are credited with gaining a patient on a wooden recliner, which was named La-Z-Boy recliner. The recliner, which is a comfortable concept, follows the contour of a person's body both sitting up and leaning back. Another effort by Mary [11] brought Geri-Chair. Elderly and/or disabled person in long-term facilities utilizes the chair. It has deep seat typically on the order of 21 inches, full-upholstered back, footrest and a front tray to secure the person on to the chair. Galen [12] conducted a study between 1999 and 2007 on rehabilitation chair in a bid to improve the performance of the chair. It was observed that spinal cord rehabilitation chair set at 110 – 135° protects the discs of the spine from compression pains and damages. Continuous effort is been made by the engineers in order to ease the pain of rehabilitation from SCI. Thus, this paper presents the highlights of the design concept for an adjustable sitting inclination SCRC and its fabrication, which would help to fast track the recovery process from SCI.

2 METHODOLOGY

This research involves the design analysis of the adjustable sitting inclination spinal cord rehabilitation chair (SCRC), material selection for each component, operating description of the components, operating sequence for the fabrication and estimated production cost.

2.1 Material Selection

The objective of material selection is to minimize cost as well as selecting the appropriate materials to be used for each component considering many engineering factors as well as the environmental factors or service conditions. The tendency to perform properly with high degree of reliability especially for this sensitive injury was a major concern during the selection. Different components and the rationale behind the selection of material(s) for them and components design factors are as given in Tables 1 and 2.

Table 1

Material selected for components before assembly

S/N	SCRC PARTS	MATERIAL S	REASONS FOR SELECTION
1	Headrest (HR)	Mild Steel	Better resistance to shear and bending forces, high strength to weight ratio
2	Backrest (BR)	Mild Steel	
3	Seat (S)	Mild Steel	
4	Stand (SD)	Mild Steel	
5	Arm rest (AR)	Mild Steel	
6	Footrest	Mild Steel	
7	HR, BR and S Overlay	Upholstery Fabrics	Durable, ability to dissipate moisture, easy to clean, cost effective and readily available

Table 2

Components design factors

S/N	COMPONENT PART/ FACTORS	DESIGN FACTORS	MATHEMATICAL MODEL	DESIGN VALUE
1	Rectangular pipe (HR, BR, S, SD,PLUNGER,)	Weight Bending moment (M_b)	$\rho=mv$ Calculation from free body diagram	318.82 N 41973 N.mm
2	Hollow rectangular pipe	Stress, Bending stress	$\sigma_b = \frac{Mb}{Z}$	10.75 MPa
3	Factor of safety	Safety	$\sigma_b = \frac{\sigma y}{n}$	23.5

Table 3 shows the operation sequence adopted during the fabrication of the adjustable sitting inclination SCRC. An electric portable drilling machine was used on the thick flat bar mounted behind the backrest for coupling of the actuator. The joining operation used for this fabrication was carried out using electric arc welding for permanent joints during assembling of the component parts.

Table 3

Operation sequence of construction of SCRC

S/N	COMPONENT	PROCEDURE	TOOLS/EQUIPMENT
1	HEAD REST	600mm flat bar was marked out and bent into Ø320 mm and height of 200mm, and welded to the backrest	Scriber, hacksaw, arc welding machine with electrode
2	BACKREST	50mm by 20 mm rectangu-lar pipe of thickness 2mm was marked out, cut and welded to form a rectangular shape of 450mm and 420mm.	Scriber, hacksaw, arc welding with electrode
3	SEAT	50 by 20mm rectangular pipe of thickness 2mm was marked out, cut and welded to form a rectangular shape of 500mm by 450mm joined to the back rest using a hinge each on both sides	Scriber, hacksaw, arc welding with electrode
4	STAND	50mm by 20mm rectangular pipe of thickness 2mm was marked and cut out in four pieces of dimension 500mm and welded to the seat	Scriber, hacksaw, arc welding with electrode
5	ARM REST	$1\frac{1}{2}$ inch pipe of length 1600mm was marked, cut out and bent to form required shape.	Scriber, hacksaw, arc welding with electrode
6	FOOTREST	50mm by 20mm rectangular pipe of thickness 2mm was marked and cut out and welded to form a rectan-gular shape of 450mm by 200mm. 1mm thick mild steel plate was cut out with dimension 450mm by 200mm, then welded on the rectangular shape.	Scriber, hacksaw, arc welding with electrode, and grinding machine.
7	PLUNGER	A thick flat bar of length 740mm was marked and cut out, which joined the back rest and the foot rest	Scriber, hacksaw, arc welding with electrode

.

Table 4

Cost of spinal cord rehabilitation chair

Item	Naira	USD
Bought-out component cost	*8000*	20.0
Material cost	11000	27.5
Machining cost	10000	25.0
Non- machining cost	3000	7.50
Total Estimated cost	32000	80.0

The cost analysis of the adjustable sitting inclination SCRC is estimated in Table 4. The isometric drawing of the adjustable sitting inclination SCRC is shown in Figure 1. The front view, end elevation and its plan, which combines in an orthographic projection is shown in Figure 2.

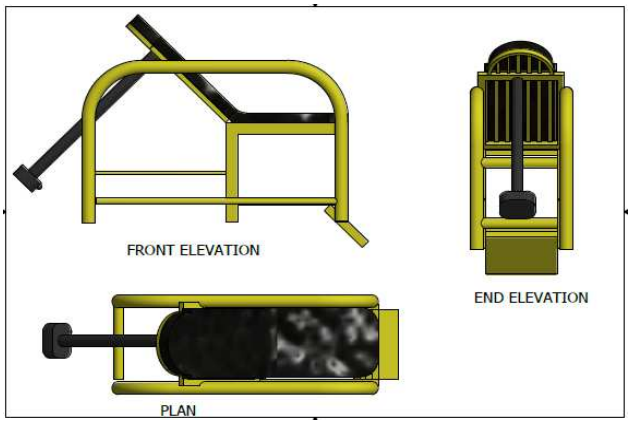

Figure 1 Isometric drawing of the SCRC

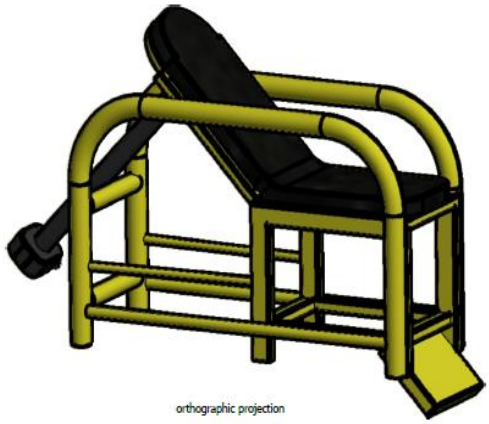

Figure 2 Orthographic projection for the SCRC

2.2 Operational Mode

The adjustable sitting inclination SCRC consists of eight major components; the headrest, backrest, the armrest, footrest, plunger and linear actuator. After fabrication of all the components and the coupling of the remote-controlled, off-the-shelf linear actuator (usually used in old satellite dish), the chair was assembled. The upper frame has the seat, side frame with arm assembles, linear actuator while the lower frame includes the footrest and the wheels. The linear actuator actuates the electric motor coupled with the cylinder and piston lateral projection. The actuator projects to recline the backrest about it axis. The wheels are located outward of the seat to enhance stability while the footrest supports the posterior weight of the user. The seat of the chair is a narrow depth in order to allow freedom of the leg motions when the user is seated. There is a positioner that retracts the reclining angle of the actuator and its mechanical limit. This limit can be set at different angles of 90^o, 105^o, 120^o and $135,^o$ by pressing the "store" key on the remote control for two seconds; a LED light will be displayed signifying that the angle has been successfully set.

3 RESULTS AND DISCUSSION

The adjustable sitting inclination Spinal Cord Rehabilitation Chair (SCRC) has been designed, fabricated and tested. In a random test carried out at a local hospital with the SCRC using people with SCI of different weight (63kg, 74kg and 82kg) and setting the chair at different angles of 90^o, 105^o, 120^o and 135^o. It was observed that sitting at an inclination angle of 120^o and 135^o protected the disc of the spine from compression and the patients were more comfortable at these angles than at 90^o, 105^o. It suggests that people with SCI will find these angles convenient when using SCRC in their rehabilitation process in order to aid their improvement over time.

4 CONCLUSIONS

The design and fabrication of adjustable sitting inclination Spinal Cord Rehabilitation Chair (SCRC) was done for people with Spinal Cord Injury (SCI). In an effort to make life easier for these people in Nigeria that may lack financial means to purchase imported SCI rehabilitation chair, the constructed SCRC will be of great help. It is simple to fabricate, affordable and can be adjusted to suit the needs of a new user with their comfort, posture and pressure management uncompromised. The SCRC will greatly assist in fast tracking the rehabilitation process, which is a major problem faced by SCI patients because of its adaptability and effortless adjustability.

References

[1] Khurmi, R.S. - Gupta, J.K: A Textbook of MachineDesign, 14th Revised Edition, 2005, Eurasia Publishing House Ltd, New Delhi, India

[2] Colin, T. - Jon, G.: Spinal Cord Injury and Compression journal, 2014, document ID 3906(v25) Available at www.spinalcordinjury.com, [9.3.2016]

[3] Dietrich, D. W.: Protection and Rehabilitation After Spinal Cord; Accomplishment and Future Directions. Spring (US National Library of Medicine), 21, 2 (2015), pp 174-187

[4] Prasad, P.-Joe, W.- Rizwan, H.- Micheal, C.- Juhan, S.: Effects of Spinal Cord Injury on Semen Parameters, The Journal of Spinal Cord Medicine, 31, 2 (2008), pp 27-32.

[5] Quadriplegic, Paraplegic & Caregiver Resources by the National Spinal Cord Injury Association Resource Center Fact sheets (NSCIARC), 1995. Available at www.sci-info-pages.com [9. 3. 2016]

[6] Emily, C.: Design and Rehabilitation; a Three- day workshop on design for people with Spinal Cord injuries, Republic of South Africa, 2011.

[7] Yvonne, J.M,- Janssen, .P,- Henk, A.M,- Seelen, J. D.- Jos. P. H.R.: Chair configuration and balance control in person with spinal cord injury, Archives of Physical Medicine and Rehabilitation, 81, 4 (2000), pp 401-408.

[8] Nicholas, E.- Brooks, W.- Elizabeth, S.- Andrey, H., Ashraf, G.S.- Eric, H.: Exercises Recommendations and Consideration for Persons With Spinal Cord Injury, Archives of Physical Medicines and Rehabilitation, 96, 9 (2015) pp 1749-1750.

[9] Michael, R.: Perform Ergonomic, 2013. Available at www.performergonomics.com [9.3. 2016]

[10] Knabush, K - Shoemaker, R: History of La-Z-Boy, 1928. Available at www.lazboyjobs.com [9. 3. 2016]

[11] Mary, H. M.: Patent US622062#forward-citations; wheeled height adjustable rehabilitation chair,1999.

[12] Galen, C.: Theidproject, 2007. Available at www.org/blog/dan-cayer.[9.3.2016]