The recent trends and inspections about powered exoskeletons

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ABSTRACT: The pledge to serve humanity by increasing the quality of human life suffering with paralysed lower half or having paraplegia (i.e. weak lower part of the body) by offering assistance or restoration of the leg mobility along with giving the benefits of well-being throughout numerous physical systems. Schematic study about the exoskeletons, covering the sightings over following topics: (i) Practicality of the powered exoskeletons on the basis of medical safety, (ii) Pros and cons of people using the technology having spinal cord injury (SCI), (iii) Severity of the injuries covered, (iv) The resulting outcomes and, (v) Future aspects about the exoskeleton technology. Researching through the internet and various other sources to understand and identify the medical experimentation and about safety procedures with bottom extremity (lower half of the body), powered exoskeletons for people suffering from SCI. The studies conducted with nine robotic powered exoskeletons, which have been based on specific outline, demographics, tenure of the research, and the initial and final assessment of the exoskeletons. Researches reveal the severity of the injury specifically T10 injuries sums up to a total of 46% of total surveys. A categorical subdivision of the total resulting outcomes shows more than 60% of these measures were related to their style of walking or their type of locomotion, along with their energy consumption (more than 12%), psychic upliftment (13%), and usefulness and ease (less than 10%). Summing up the outcome measures varied through different experiments along with no-one had measures dealing with categorical spreading which made the comparisons little difficult. A brief study reveals that maximum of the recent researches which were made focus on thoracic injuries, also there is a stress on locomotion related preliminary outcome measures. Upcoming studies should stress on the following subjects (i) to develop criteria for skilful knowledge of people to get the utmost benefit from such technology, (ii) design a unique gait detection system which tracks and benefits the user, (iii) adaptation of comprehensive metrics for assessment on the grounds of the safety, profits, and practicality.

1. INTRODUCTION:

In the year 2014, SCI(s) continuously known to affect around 300000 persons in USA, increasing at approximately 12500 neo-spinal cord injury(s) cases every upcoming year [1]. Statements of the University of Alabama-National Spinal Cord Injury Statistical Center, along with Center for Disease Control and Prevention (CDC), shows that expenses for livelihood with a spinal cord injury can be extreme, which often varies with the intensity of the case, along with the age of injury leading to an
loss and unassurity in income. Expenditures till demise of an individual is directly proportional to the risks tetraplegia can reach around $5million [2]. Spinal cord injuries have a cabalistic effect on a persons lifestyle (Quality of life) concluding to the wellbeing of the person [3]. Reduction in locomotive capabilities is often results to a rise in blood pressure, with a decrease in life expectancy, communal strain which also sums to that comes depression [4]. Thus locomotion is generally cited to be a preliminary target in rehabilitation because of psychic and communal status [5,6].

Talking about a rehabilitation method which may be used for the improvement of the capability of the basic wellbeing and locomotion of individuals with lower extremity paralysis the gait therapy acts as a boon. Even in the case of the total spinal cord injuries, subjects or people with loss of voluntary control under the mark of the injury, a human controlled robot or a locomotor results in beneficial cardiac-vascular system and the muscles along with the skeletal systems [7,8]. Assistance of robots in gait allows increased tensing duration, reproducible gait models along with keeping a keen eye on patient’s improvement[9]. Two of the manual methods, in which the locomotory organ(limb) is articulated by the therapist(s) for the maintainance of an appropriate walking posture or style [10], and the method which includes the posture correction with the help of robots shows development in the individuals outcomes, but due to the lack of satisfactory evidence for the definitive demostration of the robot operated training [11]. Currently, every study has condensed for arraying the person and adjustment of the lower locomotory organ activation, on the basis of the command and the requirement of the end user. This concludes that impedance-controlled robotic walking method grants an assist-as required proceedings, and that means the active user engagement in locomotion with hope that exoneration will be having huge effect provided that the patient has focus on the process. Outcomes of the circuit(s) ability on impedance control has been already shown, for the demonstration of any statistical significance it has not been compared yet from different processes [12].

Uprising technological improvements in robotic exoskeleton technology, there is an emergence of robotic exoskeleton technology as efficient devices for assisting lower extremity neural cutoff or the weak legs as an instrument for the assistance and facilitate the work of home doctors. A fresh product differential listing has the fresh acceptance of The Food and Drug Administration (FDA) of the United States for robotic exoskeleton technology (commodity key PHL, a Class II instrument with exeptional features)[13]. An exoskeleton technology continues to evolve and mental and physical benefits of lower limb movement that are considerable, the expected benefits from multiple physical systems stays largely indistinct. Summing to the earlier facts more researches and experiments are needed to evaluate the large challenges in not selling this technology out of the clinic, which includes in accidents, increase or decrease in the hyper and hypotension(diastolic blood pressure) and rise in beating of the heart(heart rate), skin attritions, contusing, rise in convulsions, lightheadedness, and injuries in the soft tissues of the body.

The systematic review of the recent trends and inspections abut powered exskeletons clarifies the following points:

1. Recent evidence of medical safety for lower extremity robotic exoskeleton technology
2. Pros and Cons of the patients with SCI
3. The differential segments of severity of the injury considered in this research
4. Their resulting measures, and
5. Future scopes for powered exoskeletons.
2. Constituents of a robotic powered exoskeleton:

By the words of the Food and Drug Administration a robotic assisted gait device (powered exoskeleton) is a prescription instrument which comprises of an outer, computerised, motorized orthoses for clinical studies that is set upon the patient’s dysfunctional or weak legs for the need for the need to provide locomotion [14]. This explanation is different to that of the proposal given by [15], which restricts the term exoskeleton to an instrument enhancing physiological abilities of a normal person, but is coherent with the view of an orthoses as an instrument applied for the assistance of a patient with damaged legs.

For reviewing the purpose, the NIH has redefined the medical trial which was applicable as inclusive requirement to select medical studies of robotic gait devices. The NIH redefines a medical experimentation as ‘an in-depth study within, singular or more human subjects are expectedly are designated to singular or more interventions (which might include an inactive drug or other means of control) to assess the aftermaths of those interferences based on health related biomedical or behavioural outcomes’ (https://grants.nih.gov/grants/guide/notice-files/NOT-OD-15-015.html). Therefore medical research as a form of a probe inquiry for re-definition, has been included where single or multiple patients has been necessarily assigned a singular robotic gait device (powered exoskeleton) to study the locomotive behaviours and assess effects of the interference(s) on practical, physiological, behavioural or mental results. Topping it up the evaluation and for the creation of a better comprehensive study of the recent documents a robotic assisted gait device (powered exoskeleton) study was chosen for accommodation within the study as of the aim of the study was to determine whether the intervention of the effectiveness of the powered exoskeleton, and the target population were the patients suffering from spinal cord injuries. In this study we exempted indirect support systems such as that of the ankle foot support systems unless they were a part of a powered exoskeleton. For the adequate knowledge, the reader is engulfed by several published studies which survey the lower limb powered exoskeletons [16, 17, 18, 19, 20, 21]. Whilst there are numerous researches conducted which review all of the design and control mechanisms of numerous types of robotic aided gait devices (here the powered exoskeletons) from the view of an engineer [22, 23], including the locomotive speed [24], few have gone through the analysis of the restoration safety with these devices [25, 26, 27]. However to the knowledge attained by us none of the studies have scrutinised the preliminary along with the ancillary results of the available documentaries and medical experimentations including robotic gait devices (powered exoskeletons) for the patients with spinal cord injuries.

3. Wearable robotic gait devices or powered exoskeletons:

Whilst numerous products present in the market today of the same topic i.e. wearable exoskeleton and several are under clinical trials with human patients. Studies with nine robotic gait devices had been recognised, that do settle into incorporation standards. The robotic gait devices are reviewed below:

3.1 Bionic Leg (AlterG Inc. Fremont, CA, USA, http://www.alterg.com/products/bionic-leg/professional-physical-therapy/)
The AlterG Bionic Leg (formerly Tibion Bionic Leg) is an independent robotic knee orthoses (RKO) for those types of people who have unsymmetrical lower extremity (limb) movement dysfunctions, as in the context of the Brown-Sequard syndrome [28]. This device helps the patients with their perching and standing changeovers, walking on the ground along with helping in climbing and descending from the stairs. Bionic Leg basically works with the calculations based on the receiving capacity of four sensors which have been mounted on the foot plate which helps in the detection of the amount of the weight that has been bearded by the foot itself. Moreover, additional sensors that measures angles of the extensions of the knee along with extension force that have bwn provided by the commanding device are also included. The patient allows the therapist from the company itself to accustom the amount of the support and resistance that has to be provided by the device, the device’s area of locomotion and also the minimal amount of force which is needed for the device activation. When inactive the device can be back-driven that acts as a feature of safety which grants the medical practitioner to place the device in a function called as the weight-bearing exercise mode. Bionic Leg does not depend on an external power sources that can be connected by the means of cords but carries its own battery pack that can last up to 3hrs. as maximum limit for operation. For the certification purpose of the balancing and the safety of the patient [29].

3.2 Ekso exoskeleton (Eksobionics Ltd., Richmond, CA, USA, http://eksobionics.com/)

Ekso is also a powered exoskeleton that can be worn in the lower limb which contains two supporting legs connected to a frame which further houses the comforter along with the batteries. The frame is adjusted with respect to the patient’s lower back portion by hook and loop with use of buckled straps which further adjusts the lower back of the user and joints to that of the device. Adding to that two supplementary straps are fastened which are brought over the users shoulder to support the frame like structure. Ekso has four different walk modes: first two are the ones in which a physical therapist pushes a button for making the sit-stand move and then to steps with the push of another button. The remaining walk modes consists of the motion detection is for the mandating the robotic gait device which accompanies forward and the oblique movement of the hips (for accomplishment of shifting of weight), or by the users shifting of the bodily weight and thus the start of the straight ward locomotion process. Also like other devices, Ekso needs the help of aids required for walking such as walkers or crutches that provide stability of the body along with the provision of the safety related to that of the patient, the bottom part of the walking aids are fitted with sensors that detect the impact force which detects the sturdy placing of crutches on the ground and the imperfect weight bearings. The controller does not allow triggering a step until both the crutches have been firmly set on the ground and also uses a hierarchical state of machinery for the transition between locomotive positions and by not forcing the patient, which can lead the patient into unsafe positions [30]. Conferring to the manufacturer, latest versions of their technology are utmost capable to provide a varying assist or an assist as needed to their fellow patients and the user would have the power in their hand.

3.3 Hybrid Assisted limb (HAL, Cyberdyne Inc., Tsukuba, Japan, https://cyberdyne.jp/english/)

HAL is a mutually co-ordinating lower extremity robotic gait device which has three degrees of freedom which can act actively for movement to actuate the hip along with the knee and the ankle joints. The total system of the HAL comes in different parts to cater to the specific needs of the patients which allow a single joint or a total body support during the locomotion process along with the standing and sitting operations [31]. HAL basically made up on six main parts excluding the body
that caters to all the necessity of the patient, some of which are the controller, power unit, battery unit, electromyography sensors (EMG) and the force reaction sensors [32]. The control systems receive data from all the sensors working together and formulate it to give the necessary reaction to complement the individual’s actions. Purpose of the electromyography sensors is to analyse the individual’s motive other than a joystick or any other manually controlled device as it is beneficial and solemnly allows the individual to access the device by actuating a movement. Firstly live of the battery was sustained to only 2hr and 30mins. For the safety of the user and their walking stability, HAL is proposed to be used with crutches or similar walking aids [33].

3.4 Indego (Parker Hannifin Corp., Macedonia, OH, USA, http://indego.com/indego/en/home):

It is a modular robotic gait device which comprises of a powered bilateral hip joint and also the knee joints. Indego also works on the basic technology but also incorporates AFO’s for the stability to the ankle by the transferring the total weight to the ground [34]. The exoskeleton hip, and the upper and the lower extremity supports connect quickly by the feasibility of quick connect to enable quick assembly and reassembly and for the feasibility of the transportation process and as well as the compactness of the exoskeleton. The body makes it adaptable with the basic locomotive supports and can be worn while sitting on chair. This exoskeleton allows the patient to perform the following functions like sitting, and conversion of sitting to standing position and vice versa and make swift transitions in between them. The ability to perform moving and stationary transfers or objectives which are based on the patient’s capacity to influence his or her centre if pressures by the use of their upper part of the body with a walking aid like for example a walker or crutches to provide an edge over the stability. The controller uses the differences between the lengths of the centre of pressure and locates the forward ankle joint for the supply of the input to the device. The requirement of the user is to just tilt the body forward or backward such that the centre of pressure moves in a forward or backward direction that instructs the controlling part to transition to a different movement mode. TO provide an additional safety to this device there are brakes which are fixed in the knee joints for the prevention of buckling in case of power failure [35]. On March 2016, the FDA released its summary of the 510(k) premarket notification for the Indego exoskeleton (https://www.accessdata.fda.gov/cdrh_docs/pdf15/k152416.pdf).

3.5 Kinesis (Technaid, Madrid, Spain, http://www.technaid.com/products/robotic-exoskeleton-exoxoesqueleto/):

Another lower proximity rehab exoskeleton is Kinesis which is specially designed for providing hybrid medical therapy for locomotion to their users comprising of atrial SCI. Their target customers are the ones who consist of patients with an acute diagnosis of functional recovery of locomotion, i.e. users who can work short distances but mainly are dependent on their wheelchair for their locomotion and also with some signs of functioning of their hip flexor muscles. Kinesis is also a knee-ankle-foot robotic gait device furnished with an active locomotive part in the knee and passive locomotive device in the ankle (actuator) for planar and dorsal flexion and is furnished with an active knee actuator, a passive actuator at the ankle for planar and dorsal flexion and is also furnished with embossed strain gauge based Wheatstone bridge for measuring the torques that are developed during the user-robot interaction [36]. A biologically influenced system for the knee allows it to supersede axial translator motion of the physical axis of the knee and thus improving the dynamic unity amongst the exoskeleton
and the end user with respect to a single axis joining. As it is a hybrid therapy system Kinesis can provide functional electrical stimulation to the knee part and the flexor muscle through surface electrodes. Kinesis has numerous inbuilt safety features such as mechanical braking devices in the physical restraints of movements at the automated joints, software limits for the ultimate and the minimal positions for the movement of the lower limb with equivalent amounts of the calculated output torques including a functional electrical simulation pulse width along with amplitude modulation and a mechanical safety button to physically disconnect the power from the entire exoskeleton.

3.6 ReWalk (Argo Medical Technologies Ltd., Yokneam Ilit, Israel, http://rewalk.com/):

ReWalk is an end effector based exoskeleton with the footplates placed on a double crank and a rocker gear system. It basically comprises of a robotic gait device that connects both sides of the hip and the knee joints, adding an external battery pack, a wireless mode selector and sensors that continuously measures the movements if the upper body and the joints along with the ground contact. It is connected to the footplates distally and to the sacral band proximally. The exoskeleton senses the patient’s way of walking using control algorithms that are designed to work in a closed loop pattern [37]. The working can be explained as such like during the ‘walk’ mode, the forward movement of the upper half of the body is detected by the tilt sensor present in the exoskeleton with co-ordinates with the computer present in the same housing backpack to trigger a step. The style of walking is a three point pattern advancing one step at a time. Additional modes include sit-stand, stand-sit, and moving upstairs, coming downstairs, along with an average speed of 2.6kmph [38]. Undesirable rapid knee and hip movement may result in falling of the user which is thus prevented by the combination of the sensors and the software. The device as others requires a walking aid as the others do to ensure the safety of the user along with their stability. The FDA has approved a version of ReWalk for its use in the United States as a Class II prescription device with special controls under 21CFR Part 801.109 regulations.

3.7 Walk Trainer (SWORTEC, Switzerland, http://swortec.ch/index.php/products/walktrainer):

The WalkTrainer is fitted for bilateral and pelvic gait devices, active bodyweight support, closed loop muscle stimulator and a much larger mobile frame. The leg orthoses comprises of a robotic gait device which can be customised for every single individual and is joined at the back to a robotic leg via bar linkages [39] which contains the devices for the controlling of the hip, knee, and ankle joints with the sagittal plane. The powered limb consists of the total propulsive mechanism cables, battery pack, and etc. making the user’s exoskeleton less bulky, to feel free and stretch themselves whilst walking. The connection to the patient’s feet is made to contact with the powered leg using foot plates embedded to specially modified shoes. The pelvic orthoses has six degrees of freedom which are actuated in co-ordination with leg orthoses using foot switches to detect the strike of the heel and the toe off. Force sensors and the use of potentiometers mounted in each of the axis of the exoskeleton help to monitor the interaction of the patient with the orthoses and are used to adjust it similarly. The active body weight support feature in the system ensures the safety of the user during walking by the precise control of the unloading force applied to the user.

3.8 Wearable power-assist locomotor exoskeleton (WPAL, Fujita Health University, Japan):
WPAL has six degree of freedom for both directional flexion of the hip, knee, and the ankle joint. The level of the robotic hip joint is under the perineum, and has an inside-out curving slide mechanism that helps in moving the virtual rotation centre of the robotic hip joint closer to the centre of the physical joint [40]. Orthotic and robotic components are modular to allow the orthotic components to be personalised whereas the robotic components can be standardised for mass production. WPAL has only one sitting or standing modes and three gait modes. Users can switch from the three different modes as the user can switch from simple gait mode to the other optional modes (basically the curve and the slow mode) while walking and pulling the trigger or by the press of a button. The curve mode allows the user to turn gently. For the safety of the users WPAL is used with a customised walker that provides stability during walking, standing and sitting. The walker also houses the batteries used in the exoskeleton and powers the system controlling it via a wired interface [41].

3.9 PhoeniX (SuitX, Berkley, USA, http://www.suitx.com/phoenix):

The Phoenix exoskeleton is the lightest of its kind present in the world at just 12.8kg, which provide help to individuals having mobility disorders to be upright and mobile. In the clinic, at home, and in the workplace Phoenix has successfully enabled many individuals to stand up, walk about, and speak to peers eye-to-eye. Phoenix has only two actuators at its hip; the knee joints are designed to allow support during stance and ground clearance during swing. It yet has its FDA approval pending and is still under development. As this exoskeleton is one of the cheapest and most affordable along with it features retaining to approximately same as the above mentioned exoskeletons, but the same had one of the drawbacks like it has an external power carrying backpack which also houses the computing system and after all for the safety of the patient’s the company also provides external support crutches which houses the triggering switch for the device which controls the systematics of the exoskeleton.

SUMMARY:

The summary can be drawn as the basic mechanical and controller characteristics of the powered exoskeletons can be drawn from table 1 [42]. Tough there was a lack of information of the PhoeniX exoskeleton developed by SuitX we can still conclude that the working criteria and the purpose solving would be same as that of ReWalk and as that of the other exoskeletons and the level of injuries that they serve to. Each of the exoskeletons cater and each approximately has the same degree of freedom in the sagittal plane to drive the patient’s lower extremity body parts (mainly hip, and knees and sometimes the ankle) to follow the desired gait trajectories during the time of locomotion. In maximum of these exoskeletons the company provides a similar support system like crutches or walker to provide a complete support to the user. Base on the available information that we get all the devices less than 25kg and are operated with an auxiliary weight supporting device such as crutches or walkers or body-weight support. The exoskeleton systems can be adjusted to the compatibility of the user’s anthropometry to accommodate heights between 145-191cm and body weight less than 135kg.
Table 1: Distribution of SCI injury level in participants of studies with powered exoskeletons [43].
4 THE CASE STUDY OF POWERED EXOSKELETONS FOR PEOPLE WITH SCI INJURIES:

4.1 Protocol Designs:

The designs of the exoskeletons differentiated largely over the total duration of the tests. The highest number of sessions across studies was counted to be 120, and yet a fraction of it was used in teaching the patient the proper usage of the robotic gait devices [44]. The study of a single session was also included amongst the other twenty-two studies [45]. Mostly the studies that were conducted varied from two to three, which included the conduction of one experiment through a span of five days in a week [46]. The duration of a single patients study ranged in between of two to three hours and no reports have been found of studies exceeding that limit.

4.2 Distribution of SCI subjects by level of injury:

Several subjects were tried from different age groups, injury level and the time since injury. One of the greatest sources of debates were the number of participants involved and the average number of subjects were near about to six with a standard deviation of four subjects which ranged in between one to sixteen studies per participant. Amongst the 22 studies that we came through four reported findings were based on a singular single subject data, among which one was based on singular subject data, with one of those being a single session experiment. Majority of the studies concluded that majority of patients like these have injuries concluding to T10 category (45.4% of the total). Most of the studies reported chronic with a minimum duration of the day of accident being (>= 6months) SCI subjects with the exception of [47, 48] which also recruited acute SCI subjects.

4.3 Outcome measures focused on assessing mobility:

Seven primary measures are associated with functional mobility in SCI patients which were recognised by a survey [49]: 10 meter walk test (10 mWT), 6 minute walk test (6mWT), timed up and go (TUG), spinal cord injury functional ambulation inventory (SCI-FAI), functional independence measure, Spinal cord independence measure and walking index for spinal cord injury (WISCI-II). The first of the three are timed measures and the rest three are the categorical assessments of locomotion with the SCI-FAI having components of both.

4.4 Overall comparison between studies:

Whilst the comparison of the experimental design there was a general consistency across all the studies in the number of sessions per week (1-3sessions per week) during which the exoskeleton-based intervention was provided. The treatment frequency is also consistent with the traditional locomotor training (e.g. robot assisted gait training) frequency of 2-5 sessions per week [50, 51]. The comparison between the studies that were made during the assessment of the exoskeletons is given below in table 2 [52].
| ID | REFERENCE | DEVICE | NUMBER OF SESSIONS | DURATION IN HOURS | FREQUENCY PER WEEK | NUMBER IN WEEKS | AGE | INJURY LEVEL | TIME SINCE INJURY IN YEARS | 10mW | 6mWn | TUG |
|----|-----------|--------|--------------------|-------------------|-------------------|---------------|-----|--------------|----------------------------|-------|------|-----|
| 1  | [53]      | Bio  | 7                  | 1                 | _                 | 2             | 1   | 22           | C5/C6                       | +     | +    | +   |
| 2  | [54]      | Leg  | 8-24               | 2                 | 1.2               | _             | 7   | 21-49        | T8,C8,C4,L1                 | 0.4   | _    | _   |
|    |           | Eks  |                    |                   |                   |               |     |              | T9,T9,T10                   | 7.4   |      |     |
| 3  | [55]      | Eks  | 6                  | 0.33-1.0          | 1                 | 6             | 7   | 19-40        | T11,T10,T1               | 0.2   | _    | _   |
|    |           |      |                    |                   |                   |               |     |              | T7,T12,T4,T8,T1/T2,T7     | 1.5   |      |     |
| 4  | [56]      | Eks  | 18                 | 1                 | 3                 | 6             | 3   | 26-38        | T1/T2,T7                  | >1    | _    | _   |
| 5  | [57]      | HAl  | 24-36              | 0.5-0.75          | 2-3               | 12            | 1   | 34           | T9/T10,T10               | _     | _    | _   |
| 6  | [58]      | HAl  | 16                 | 1.5               | 2                 | 8             | 8   | 31-69        | T7/T8,T10                 | -     | 1.1- | 6.3 |
| 7  | [59]      | HAl  | 6                  | _                 | _                 | 3             | 1   | 39           | T8,L1,T12,L1,T11,T1      | _     | +    | _   |
| 8  | [60]      | HAl  | 51.7               | _                 | 5                 | 3             | 8   | 36-63        | _                          | _     | +    | +   |
| 9  | [61]      | Ind  | 1                  | _                 | _                 | _             | 1   | 42           | T10,T10                    | 10    | _    | _   |
| 10 | [62]      | Ind  | 2                  | _                 | _                 | _             | 28-51 | T7,T8,T10   | _                          | _     | X    | X   |

**EXPERIMENTAL PROTOCOL**

**SUBJECTS**

**OUTCOME VARIABLES**
|   | NCT     | Study Design | Follow-Up | Ind/ego | Movement | Follow-Up | Ind/ego | Movement | Follow-Up |
|---|---------|--------------|-----------|---------|----------|-----------|---------|----------|-----------|
| 11 | [63]    | Indego       | 5         | 1.5     | _        | _         | 16      | 18-51    | X X X     |
|   |         |              |           |         |          |           |         |          |           |
| 12 | [64]    | Kin/esis     | 3         | _       | _        | 3         | 35-43   | L1,L2,   | + + +     |
|   |         |              |           |         |          |           |         | L5       |           |
| 13 | [65]    | Kin/esis     | 3         | _       | _        | 3         | 35-43   | L1,L2,   | X X X     |
|   |         |              |           |         |          |           |         | L5       |           |
| 14 | [66]    | Re/Walk      | 13-26     | 1-1.5   | 3        | 8         | 12      | 18-55    | X X X     |
|   |         |              |           |         |          |           |         |          |           |
| 15 | [67]    | Re/Walk      | 11-45     | 1-2.0   | 3        | 5-6       | 6       | 24-62    | 1-5-14    |
|   |         |              |           |         |          |           |         |          |           |
| 16 | [68]    | Re/Walk      | 12-54     | 1-1.5   | _        | _         | 8       | 24-61    | 1-5-14    |
|   |         |              |           |         |          |           |         |          |           |
| 17 | [69]    | Re/Walk      | 7-24      | 0.83    | _        | 3         | 6       | 21-48    | 3-7 X X X |
|   |         |              |           |         |          |           |         |          |           |
| 18 | [70]    | Re/Walk      | 20        | 2       | 2        | 10        | 5       | 23-41    | 1-4-7.2+  |
|   |         |              |           |         |          |           |         |          |           |
| 19 | [71]    | Re/Walk      | 12-120    | 1-2.0   | 1        | 12        | 12      | 24-64    | X X X     |
|   |         |              |           |         |          |           |         |          |           |
Table 2: Selected studies of powered exoskeletons for SCI with outcomes measures.

(Since much data of PhoeniX, by SuitX could not be gathered. So, it is not being included in the table)

5 FUTURE DEVELOPMENTS:

5.1 There are several powered exoskeletons that cater to the different needs of the different kind of patients but there are not powered exoskeletons that are yet present to serve to all the categories or to the major part of the injuries involved with a SCI patient.

5.2 The high costs of the exoskeletons that are involved in the making and the testing which makes it further costlier when introduced into the market and then making it economically out of reach of the economically middle class and the lower segment of the society. Thus cost cuttings can be done so as to make the product economically viable and so that each segment of the society gets to enjoy the benefits of the same.

5.3 The technology outreach of the products should be made so as to make the products friendlier and each company can make the product for the global outreach for every part of the world and when the technology is there for the sake of humanity so one should not keep it up to themselves.

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