INVISIBLE EXOSKELETON FOR PERFECT PERCH

A PRODUCT DEVELOPMENT PROJECT REPORT

Submitted by

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BONAFIDE CERTIFICATE

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INTERNAL EXAMINER **EXTERNAL EXAMINER**

ABSTRACT

When standing occurs continually over prolonged periods, it can result in inflammation of the veins. This inflammation may progress over time to chronic and painful varicose veins. Nowadays, in this busy schedule there are many people having jobs and works by spending most of their time by standing. It is a mechanical ergonomics device that is designed around the shape and function of the human body, with segments and joints correspondingto those of the person it is internally coupled with. So this device will be made in a way that it will be attached on the back of our bending posture of legs. It isattached in the way that the position is comfy while sitting without a chair. It just gives the balanced position for body to sit. Simply bend the knees to a comfortable stance to activate its damper that supports the body weight. Our device is mainly made up of acrylic plastic and fiber glasses. The maximum bearable weight of the device is 100 kg and the overall weight of the device is also less. The design and size adjustment can be customized. The main objective of our idea it to sit whenever you feel tired, helpful for soldiers, teaching staffs and trekkers, also helpful for pregnant ladies, arthritis patients and the elderly people.

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CONTENTS

INTRODUCTION

Standing for some time is good for health, but only if you've not been forced to do it for hours. Excessive sitting is also dangerous as it badly affects the body's metabolic rate, resulting in the risk of disease like high blood pressure, diabetes, cancer, depression, etc. In workstations, main concerned is to enhance the productivity but very less concerned is given to the effect of work fatigue on the worker's body. Even though the workplace is ergonomically designed but, in fact, they are not successful in relieving workerfatigue since most of the time they have to work for hours in a particular posture.

Till now in the present era of fast growing technology, workstations do not have a device which can provide comfort to the worker. It is evident that sloping/kneeling chair preserves lordosis and sacral slope with upright as well as slumped posture than a flat one; it results in less tissue strain which in turns lowers back pain. So why it is preferable to sit on a sloping chair than flat one this means flexible wearable chair provides better comfort than that of flat one for the same working posture.

The ageing population is a global issue, and physical deterioration and frailty in elderly people has become a socioeconomic problem in many countries. Assisting elderly and dependent people by enhancing and strengthening movement of the lower limbs has raised particular attention due to the considerably increasing rate of this population, and exoskeletons are considered as one of the most potential assistive devices for this enhancement. Exoskeletons may be able to treat the patient without the presence of the therapist, enabling more frequent treatment and potentially reducing costs. The application of engineering concepts to human movement control paved the way for rigorous computational and neuro scientific analysis. In order to robotic exoskeleton development, it is critical to identify principles of human motor adaptation and to discover the parameters that affect the rate of motor adaptation to the powered assistance.

Other than that, many improvements are made and Exo-Skeletons are used in many applications like Military, Medical, and Rescue Operations. A bilateral asymmetry in lower limb lengths is called leg length inequality (LLI), or anisomelia. During locomotion the lower extremity joint stresses are further increased by the muscle activity required to control the segments, by inertial forces developed by the moving segments, and by the impulsive force applied to the foot at ground contact.

When the subject stands with the hip vertically above the ankle and when the upper and lower parts of the leg are about equally long, it holds for the ankle angle. The human leg, in the general sense, is the entire lowerextremity or limb of the human body, including the foot, thigh and even the hipor gluteus region; however, the definition in human anatomy refer only to the section of the lower limb extending from the knee to the ankle.

It is like a chair that isn't there, but magically appears whenever you need it. It is well known as the chairless chair and you use it on your legs like an exoskeleton: when it's not activated, you can walk normally or even run. This idea also came over the last several years.

Some researcher found that over the last several years, office workers have begun to see the error of their sedentary ways. Study after study has shown that sitting down all day can contribute to a bunch of health problems, including diabetes and cancer. The aim of this research is to design and develop a lower body exoskeleton or in a simple word is a perching device. This project can also help to improve user posture, allow them to sit anywhere without a visible chair and comfort their leg muscle. This future is like the solution for the worker to keep working with standing posture but can also helpthem to relax their legs.

A control method is proposed for exercising specific muscles of a human's lower body. This is accomplished using an exoskeleton that imposes passive force feedback control. The proposed method involves a combined dynamic model of the musculoskeletal system of the lower-body with the dynamics of hydraulic actuators. The exoskeleton is designed to allow for individual control of bi-particular muscles to be exercised while not inhibiting the subject's range of motion.

The method implemented is designed to resist the motion of the human knee but works in principle similar to that of inverted four bar chain mechanism. The two lower limbs will assist to sit a human being without any chair and back support.

The Velcro strips will be provided so as to clamp the assembly with human limbs. In this project we have focused on making the design simplewith emphasis on reducing the cost so that it will be affordable for all, including workers and patients with leg injuries.

CHAPTER 2

LITERATURE REVIEW

S. T. MCCAW AND B. T. GATES[1] described the effects of mild leg length inequality on posture and gait has been the source of much controversy. Many opinions have been expressed both for and against the need for intervention to reduce the magnitude of the discrepancy. Their paper emphasizes the need for accurate and reliable assessment of leg length differences using a clinically functional radiographic technique and reviewsthe biomechanical implications of leg length inequality as related to the development of stress fractures, low back pain and osteoarthritis.

AYDIN TOZEREN[2] wrote a book on how Human movement obeys basic laws that govern static and dynamic bodies, and this textbook takes a quantitative approach to studying human biomechanics. A quantitativeapproach to studying human biomechanics, presenting principles of classical mechanics using case studies involving human movement.

ROBERT PETER MATTHEW[3] work helped us get an overview of active and passive type of exoskeletons. Assistive devices such as exoskeletons can provide rehabilitative improvement and independence for individuals suffering from musculoskeletal conditions. Typical devices use either active assistance methods such as DC motors or passive methods such as springs or orifice valves or levers. Active methods require continuous power input, while passive methods are limited by user capability. This work introduces an Active/Passive Exoskeleton framework. This device can passively provide continuous assistance, only requiring energy to change the dynamic properties of the passive state. The first prototype (APEX-α) is introduced and tested on six healthy subjects who performed hammer curls. It was found that changes in the passive state of the APEX-α affect the number of curls performed by an individual. By changing the passive state of the exoskeleton, increases in curl count of 65 - 92% were observed. This indicates the potential for such devices to provide assistance to an individual through the use of lightweight, energy efficient active/passive actuators.

PAUL DOMINICK E. BANIQUED1 AND NILO T. BUGTAI [4] presented on how the Robot-assisted rehabilitation systems have been clinically proven to be just as effective in stroke rehabilitation as with the traditional methods. In particular, robotic exoskeletons for the upper limbs are powered by wearable devices designed to be aligned with the user's joints and linkages. Current methods in product design simplify the complex requirements of the human upper limb, thereby compromising the comfort and safety of the injured patient. In rehabilitation robotics, it is important to consider the user needs and requirements of such a device early in its design phase. Their study demonstrated how the assessment of user needs participate in the design of a wearable robot for the rehabilitation of Filipino and Asian patients. The results of the study and discussion later were translated into a list of user requirements for wearable robots in neurorehabilitation. After which, corresponding importance ratings from both the design engineers and their medical collaborators were assigned to arrive with a matrix that determines the final design priorities and specifications of the device. Their study was successful in evaluating at least fifteen of the users' needs in consideration. The results of their study were then used in the design of a 7- degree-of freedom robotic exoskeleton for patients with Filipino and Asian body types. This approach enables medical device developers to have prior knowledge of existing design problems and use it to incorporate user-centricityand compatibility with their current design.

DAVIDOVITS[5] book deals with Physics in Biology and Medicine, covers topics in physics as they apply to the life sciences, specifically medicine, physiology, nursing and other applied health fields. This is a conciseintroductory paperback that provides practical techniques for applyingknowledge of physics to the study of living systems and presents material in a straightforward manner requiring very little background in physics or biology.

DARCY ROBERT BONNET[6] invented a wearable chair in 1977which allowed users to sit on two legs, which was not obvious. But the design suggested by them has some de-merits viz., it allows only one sitting position, irrespective to the user desire, also there is large stress on lower leg resulting from the reaction force imposed by the lower bar. The basic idea is that introducing internal hinges to the mechanism (structure when sitting)releases joint moment and providing these hinges coherent with human lower body joints helps in releasing severe joint stresses which occur during working.But the approach poses some ergonomic challenges, the biggest problem with such a design is ensuring that workers can move freely and after sitting, it is in stable equilibrium. It is well illustrated that how flexible wearable chair satisfies static equilibrium and stable configuration under loading.

ASHUTOSH BIJALWAN, ANADI MISRA[7] analyzed design of a flexible chair like mechanism. The flexible wearable chair is like a lightweight mobile exoskeleton that allows people to sit anywhere in any working position. The traditional chair is difficult to move to different working locations due to its large size, heavy weight (~5 - 7 kg) and rigid structure and thus, they are inappropriate for workplaces where enough space is not available. Flexible wearable chair has a gross weight of 3 kg as it utilizes light-weight aluminum alloy members. Unlike the traditional chair, it consists of kinematic pairs which enable taking halts between continuous movements at any working position and thus, it is capable of reducing the risk of the physical musculoskeletal disorder substantially among workers. The objective of this paper is to focus on the mechanical design and finite element analysis (FEA) of the mechanism using ANSYS software. In the present work, all the parts of the mechanism are designed under static load condition. The results of the analysis indicate that flexible wearable chair satisfies equilibrium and stability criterion and can reduce fatigue during working in an assembly line/factory.

H. ZURINA ET.AL[8] paper was of interest in wearable devices which help in increasing the efficiency of the human and decrease the rate of fatigue of humans during work. The device discussed here is the passive device. The device is known as virtual Chair which helps the wearer to work effectively at any location in a sitting posture. Zurina and A. Fatinhas worked on the Design and Development of Lower Body Exoskeleton. In their paper an attempt had been made to evaluate the possibility of using the virtual chair that will help in increasing the energy efficiency and offer weight support when the user feels tired rather than continuously taking on the weight. Other than that, in term of ergonomics, and the objectives to give comfort to user has achieved by give choices to user to choose their comfort degree level from 45° to 90°. Apart from the benefit of their experiment it can be concluded that his design still confronts with some problems that need to fix in future so that the objective to give an ergonomic chair to user can be achieved.

ADITYA BHALERAO ET.AL[9] worked on Pneu portable chair for employees to sit while working. By referring to human seating and walking characteristics a leg mechanism has been conceived with as kinematic structure whose mechanical design can be used by employees as a wearable exoskeleton. As per the Specified Design parameters the body can suitably carry around 100 Kg of Human Body weight. In the later part to reduce the cost, Oil was also brought in the weight sustaining mechanism thus providing better results.These types of devices with ergonomic background can be easily upgraded with the use of more advanced technologies and culminating various facilities into one body and be constantly modified. A basic idea of how a exoskeleton using Pneumatic or Hydraulic Cylinder can be used to reduce fatigue by using simple kinematic mechanisms. In this Particular Machine due to certain restrictions not much advancement has been made and it is similar to tailor-made clothing which is just suitable for one single person and may not fit properly to other user.

CYRIL VARGHESE AND VEDAKSHA JOSHI[10] worked on the Exoskeleton Based Hydraulic Support was successfully fabricated, and it was found to be suitably safe. Under fluctuating load during walking as well as under Dead Load when the user sits/rests on it. (Tested the Extra-Large Size Variant for a user weighting 116 kg for a span of 43 days) The entire cost of making the EBHS is Rs. 8540 ($ 126.84) thereby making is very economical for the public as well as for Industrial use and also for the Military. When in full scale production, the EBHS will be available in three sizes, From small, regular size, From 5"5” to 6ft: Large size and Extra-large size. The exoskeleton based hydraulic support being extremely light in weight causes very little hindrance while walking and the user can easily get used to it.

CHAPTER-3

3.1 PROJECT FLOW CHART

Collected the necessary parts for the fabrication work. For when certain parts weren’t available, design was tweaked to fabricate using available ones. The fabrication was done using methods such as coupling, welding, bending, cutting, screwing etc. Testing was done and flaws were determined, the determined flaws were corrected and strapping, and upholstery work was performed. The final product was prepared and reviewed.

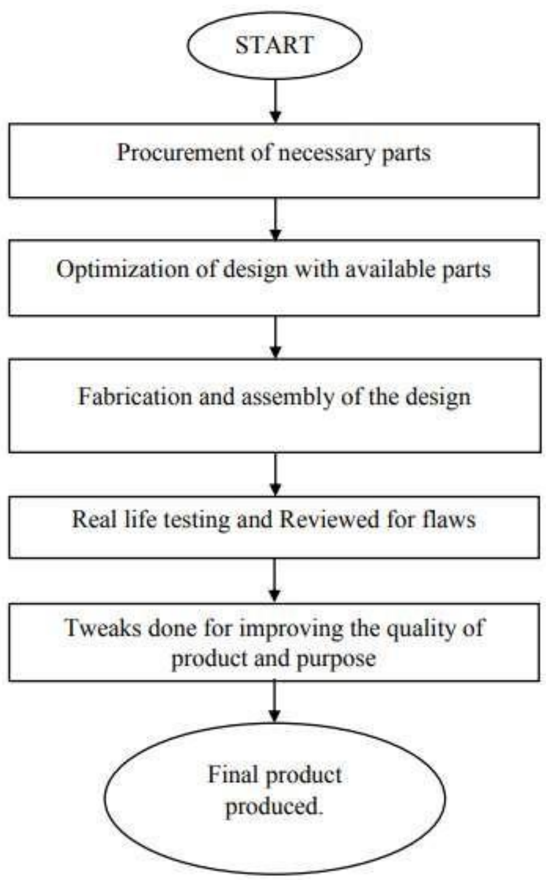

Fig. 3.1 Flow chart

Procurement of necessary parts START Tweaks done for improving the quality of product and purpose Optimization of design with available parts Fabrication and assembly of the design Real life testing and reviewed for flaws Final product produced.

3.2 STABILITY CRITERION AND DESCRIPTION OF THE MECHANISM

There can be as many models as possible for the proposed idea, but the successful model is one which competes with traditional chairs. Since for such structure, stability is of prime importance, to construct the most optimum model it is necessary to analyze all the parameters affecting stability and comfort. For astructure to be in static equilibrium the vectoral sum of all the forces and moment acting on it must be zero. A body satisfying the equilibrium equation, not necessarily to be stable (as stability is defined as a resistance to the disturbance of the body's equilibrium), balance within muscle groups and alignment of the skeletal system affect body equilibrium and balance. Slight changes in the body posture can affect the whole weight distribution. For a structure to be in stable equilibrium, the center of mass of the body must fall within the base of support (BOS) (Figure 3.3). If the center of mass is outside the base, the torque producedby the weight tends to topple the body.

Base of support is the supporting area beneath the body, it includes the points of contact with the supporting surface and the area between them; these points may be body parts (such as the feet), or extensions of body parts (such as crutches or other walking aids).

The most important factors for achieving balance are the following:

- COG must fall within BOS i.e., one can stand at any posture till the line of gravity lies within the foot base;
- Balancing is directly proportional to the size of the BOS i.e., larger the base of

support, the body is more stable, and, in our mechanism, BOS is user feet area plus the projected area of contact points of mechanism of both legs (cross-section of element E) with the ground;

- Balancing is mass dependent, i.e., the greater the mass body gets more balanced. One can notice that during vertically downward sitting knee bends forward and ensures that the projection of the center of gravity of the body just falls within the BOS. Further, it can be noticed gradually downward sitting has an additional constraint that it has to move vertically downward like guide has to move in a slot.
- Installation of a flexible element between buttocks and ground can mimic the biomechanics of human sitting and transmit the whole-body weight directly to the ground without the muscles pain shows how BOS gets increased by attaching wearable mechanism and kinematic constraint that enforces COG to fall within BOS. CCES consists of three beam elements to support the lower and upper leg, a hydraulic element between buttocks and ground for achieving various seating configurations and a locking mechanism. The flexible or hydraulic link is a rectangle pair consisting of hydraulic pair for any combinations of sitting positions and to lock the mechanism at desired working posture an orifice valve is locked into the cylinder and to be open manually for movement from one place to another.
- To follow the constraint of vertical sitting lower cylindrical link must be fixed at end and co-axial with the upper hollow cylindrical rod. An additional turning pair is installed between bottom support beam and the upper hollow cylindrical rod, finally, the lower hollow cylindrical rod is attached to the bottom most. Slices and base support for various. Both frames of the chair are connected by a wearable cover belt arrangement which must be attached to the thighs. After introducing all these factors, the mechanism becomes completely constrained

and it can be observed that CCES is simply an inversion of four bar chain mechanism. The foam cushion is glued to the beamelement for providing sitting comfort to the users and straps on the beam elements AB and BC are used to attach the CCES to the legs. Data shows a prototype of the flexible wearable chair without wearable cover belt arrangement.

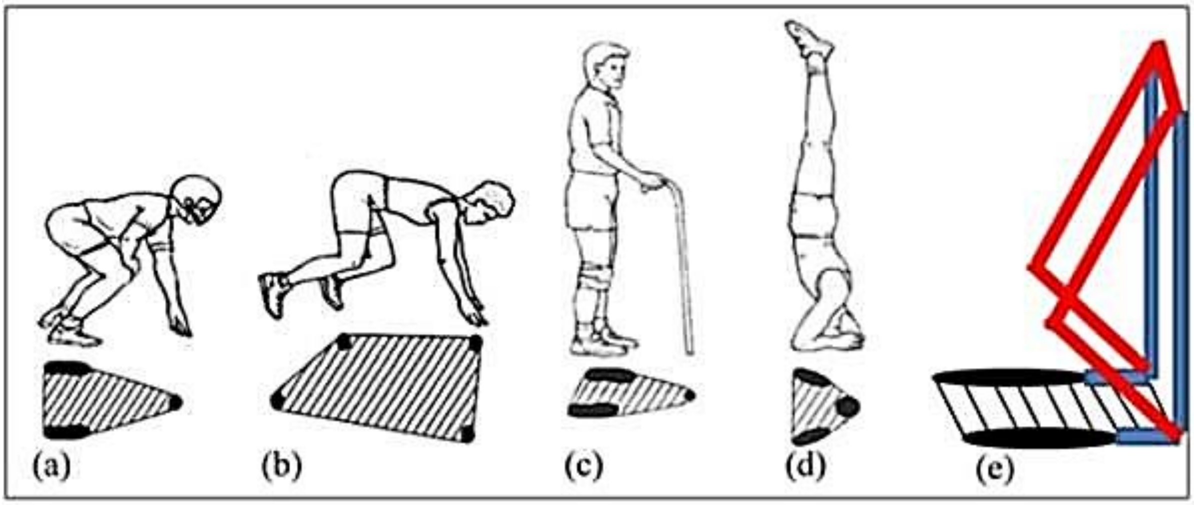

Fig. 3.2 Schematic diagram represents description of the mechanism.

CHAPTER 4

4.1 PROPOSED SYSTEM:

In view of the limitations of the existing solutions and concerns raised by the stakeholders during clinical immersion, the need for a novel device is identified. The proposed novel device is intended to solve the problems and issues associated with the existing model. The proposed system will be made in a way that it will be attached on the back of our bending posture of legs. It is attached in the way that the position is comfy while sitting without a chair. It just gives the balanced position for the body to sit.

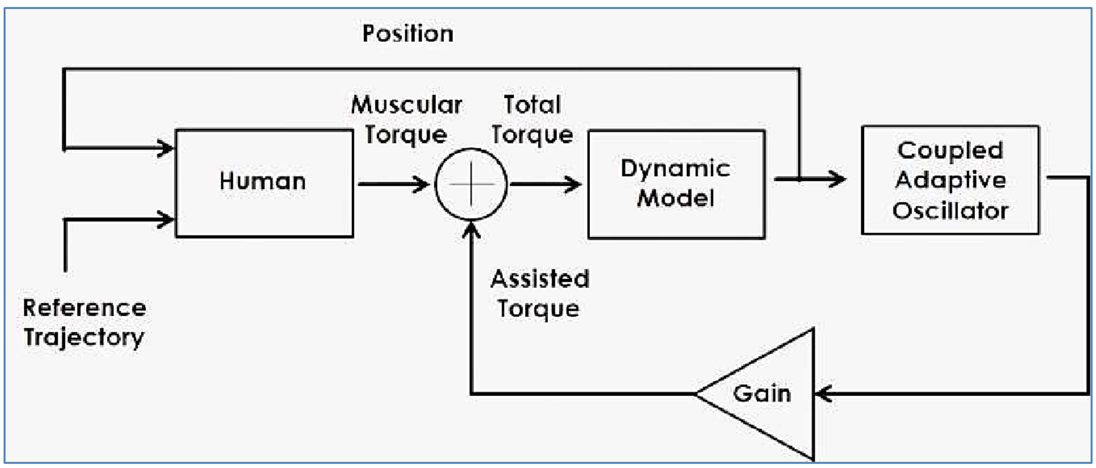

Fig. 4.1 Block diagram for proposed system.

4.2 OBJECTIVE:

In industries, the motivation behind this research involves helping workersto exercise more effectively to mitigate the effects of microgravity on bones and muscles. There is an unavailability of seats when we want to sit anywhereand anytime. It is often difficult to provide seating equipment for all workers in cramped spaces like warehouses and long hours of standing are often detrimental to health. Available robotics locomotion has big issue of energy efficiency. The Portable Chair is like a mobile exoskeleton that allows people to sit anywhere. It uses a dynamic model of the musculoskeletal system of the lower leg combined with the dynamics from a hydraulic damper to provide resistive forces to the muscle forces. The objective of this project is to design the exoskeleton assistive device which allow for normal movement like walking and running when we wear it.

4.3 FACTORS IN CONSIDERATION OF PROJECT:

- Compatibility with objective and plan.
- Availability of needed scientific and engineering skills in R & D.
- Critical technical problems are likely to emerge.
- Market prospects and potential of the proposed new product.
- Availability of production skills needed.
- Financial return expected.

4.4 DESIGN:

Optimum position for use would be about 90^o itself, but bottom beam would be inclined a bit about 20-30 degree from normal to surface. At this position, the CG lies within the bottom/heel link and balance is obtained.

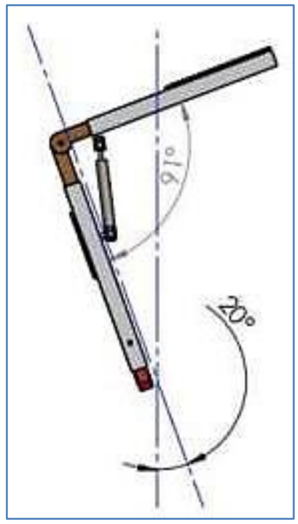

Fig. 4.2 Setup of optimum position.

4.5 MATERIALS:

The mechanism can be portable if it is light weight, for this one must choosehigh specific strength material. Additional to this, considering hollow section further reduces weight and making beam/column stiffer. As most of the load is carried by column and it increases with width which in turn increases the possibility of penetration of column via locking pin if an appropriate material is not selected. Considering all these aspects and the material availability, the proposed material for this product is acrylic. It is obvious that increasing the beam depth has more effect on the reduction of flexural stress than anincrease in beam width, for ergonomic consideration minimum beam width should be fair. As the thickness of rectangular cross section increases flexural stress diminishes, but the major concern is given to a weight reduction of the mechanism, so it is not feasible to adopt a much thicker section.

S. NO.	MATERIALS	PRICE (Rs.)
1.	Acrylic, fiberglass	600/- (6*4 feet)
2.	Hydraulic gas strut	445/- (pair)
3.	Hinges	50/-
4.	Screws and nuts	55/- (kg)
5.	Cuffs and foams	180/-
6.	Straps and buckles	200/-
7.	Foot bush	50/-

Table 1: Cost analysis

4.6 DEVELOPMENT:

STAGE 1: A knuckle joint was created using door hinge. A knuckle joint enables free motion in a single axis. The acrylic channels were coupled with the knuckle joint by push fit.

STAGE 2: A Gas strut 50n, material: steel, weight of 249g, approx.11.42" / 28 CM Shaft Diameter: Approx. 0.59" / 1.5cm was used as the damper.

STAGE 3: For the seating, foam sheets are used. Over which upholstery is done for a seat like feel. The Velcro aligned on a sheet is made and screwed onto the acrylic channels at strategic locations for strapping.

STAGE 4: All parts were collected, and final assembly is done with all necessary fixings by screws. All the parts are removable and replaceable, in case of any art failing, that defective part can be removed easily and replaced.

STAGE 5: Final product weights 1.02 kg per leg, provides comfortable seating and Velcro based straps which provide quick and proper strapping of exoskeleton to body. Whole of the product can be folded and put in abackpack for portability.

CHAPTER 5

5.1 PLAN FOR EXECUTION:

1. **Research**: By conducting research to understand how the chair-less chair works, its benefits, and limitations. Research the market to identify potential users and competitors.
2. **Identifying a target market:** Determine the specific market segment youwant to target with your product. It includes people who work in jobs thatrequire standing for long periods or people with physical limitations that make traditional chairs uncomfortable. Our target people are pregnant women, school and college faculties, hill climbers, textile shop workers.
3. **Developing a prototype:** Designing and developing a prototype to create a product that is functional, ergonomic, and aesthetically pleasing.
4. **Testing the prototype:** It determines how our idea meets the needs of your target market. Here uses feedback from testers to improve the design and functionality of the product.
5. **Manufacturing the product:** In this stage we concentrate on how to manufacture our idea in large and small scale.
6. **Distribution:** This could include selling directly to consumers online, partnering with retailers, or working with distributors.
7. **Marketing and sales:** Developing a marketing plan to promote our idea to potential customers. This could include social media campaigns, targeted ads, and trade shows. Developing a sales strategy to sell our ideas to businesses and individuals.
8. **Customer support:** This could include offering training and support toensure that users are using the product correctly and effectively.

9. **Iterate and improve:** This could include adding new features, improvingthe design, or addressing any issues that users may be experiencing.

5.2 PLAN FOR MARKETING:

1. **Highlighting the health benefits**: One of the primary benefits of using our idea is the reduction of strain on the lower back and legs. This can be particularly beneficial for people who work in jobs that require prolonged standing, such as manufacturing or retail.
2. **Focusing on productivity:** By allowing users to stand comfortably for longer periods, our idea could help boost productivity in certain jobs. Highlighting this benefit could help appeal to businesses or organizationsthat prioritize efficiency.
3. **Demonstrating versatility:** our ideas can be used in a variety of settings, including in the workplace, during travel, and while participating in sports or other physical activities. Marketing our idea can be used in multiple contexts could help broaden its appeal.
4. **Emphasizing portability:** Unlike traditional chairs or stools, our idea is portable and can be worn like a backpack.
5. **Leveraging social media:** Creating engaging social media content, such as instructional videos or user-generated content, could help generate interest in our idea and spread the word to potential customers.

5.3 RESULTS:

The safe load that can be applied to this chair less chair is 100 kilograms (Tested with person of 96kg). If the load is slightly greater than this value, the damper hinge at the top part of device can start to bend thus failure may occur. To prevent this from happening in the future, we can replace the damper with high quality of material example Titanium, so that the chair less chair can support more load. The weight of the chair less chair is less 4 kilograms with each leg weight being 1.84kg. It is not too heavy for us but if in the future we want to reduce weight, we can replace the aluminum structure with fiber glass or carbon fiber as well as use thinner yet stronger links. Fiber glass is a good strength to weight ratio component, but it is quite expensive.

Others alternative is to use high grade plastic, but the selection of plastic must be analyzed wisely. Sharp edge at the chair less chair must be removed to prevent injuries to the users. Ourobjective is to solve ergonomic problems that occur during work for long term of period.So, any extra ergonomic problem should not occur while using this chair less chair. The position of a person sitting on is important. If the person is not sitting inposition 130-degree angle in between humour bone and lumbar curve, the person might have to put a bit balance themselves for achieve balanced setting. It’s upon personal comfort level they can adjust to a suitable position.

5.4 ADVANTAGES

- Adjustable position as per desire.
- Reduces human efforts and fatigue free work.
- Easy to wear and operate.
- No frequent maintenance and service.
- High efficiency and increase in production rate.
- Can be used for seating and lifting support.

5.5 DISADVANTAGES

- Possibility of cramps due to long use.
- In case, failure if weight is high than designed value.
- Requires getting used to, due to the extra weight in legs.

5.6 APPLICATIONS

- This portable chair would be helpful to workers and anyone who needs to stand for long hours at stretches.
- Once into mass production, a company can completely alternate the usage of portable chairs to exoskeleton and maximize efficiency.
- In the food and manufacturing industries, laborers work standing hours and hours.
- Can be used by commuters standing in crowded trains or metro to relax themselves without occupying much space.
- With assist from a wall, it can be total reliver as it gives feel of a completechair.
- Upon a high jump, the damper absorbs the impact reducing strain.

5.7 FUTURE SCOPE:

The choice of material was limited due to its availability. In the future, carbon-fiber reinforced polymer (CFRP) can be used to further minimize the weight and increase the strength of the structure. In present work, no full attention is given to locking mechanisms so different locking mechanisms can be used to involve providing better and smoother functioning of the chair. The sensor can beattached to the body for locking of the mechanism by itself as per user needs. This chair is capable of relieving fatigue of lower body parts and needed further modification so that upper body parts are also free from MSD. The portability of the chair can be improved by converting it into a foldable flexible wearable chair.

More of kinematic links can be added and the chair can be made a multi utility tool with CCES being a skeleton where over different products are created:

- With additional links between the legs, we can convert it into a totally self-balancing chair.
- With addons like audio jack, water bottle holder, charging ports, it’s acomplete exoskeleton with features.
- With a focus on damper, electronic control, it could be a walking assistdevice.
- For military applications, it could be converted into a weaponry support, load distribution device and so on.

CHAPTER 6

6.1 CONCLUSION:

The Invisible Exoskeleton system was successfully designed and analyzed. The aim of this project is to develop a lower body external skeletal structure to support sitting and partial standing posture. The finite element analysis is performed on the chairless chair, using Solid works Simulation add-on to find total deformation. Maximum displacement, maximum stresses and deformations are analyzed, andsafe load is determined. Future work will focus on making the design lighter and using high grade materials for greater strength at smaller dimensions and weights. Implementation of the design and testing in real world environment is to be done and effectiveness in daily scenarios is to be determined.

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