An External Aid for Amyotrophic Lateral Sclerosis (ALS) and Drooping Head Syndrome (DHS) Patients

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Abstract: Every year thousands of people get affected by Amyotrophic Lateral Sclerosis and drooping head conditions that disable the people to have control over their head and neck extensor muscle. Commercially available supports impart four major hazards to the patients: suffocation, skin irritation, difficulty in swallowing, and neck soreness/pain. To reduce these adverse effects, a unique three-way support system that supports the head, neck, and chin is designed to arrest head movements such as flexion, extension, rotation and abduction. The proposed design is built incorporating essential biomechanics and ergonomics principles that provides required thrust in bringing the head upright with minimal stress zones. The system consists of a base panel, head panel and chin cap that are fabricated using polypropylene and the anterior and posterior support frames are fabricated using aluminum flat respectively. The supporting components are integrated using straps, made up of Nylon-Velcro material, facilitating effective head immobilization as well as easy portability. Coverings are provided with liner foam sheets that provide cushion support and protective covering for the users. Total deformation, safety factor and fatigue characteristics of the structural elements of the support are studied in a 3D modeling environment to understand the load distribution on the aid during actual usage through finite element simulations. No human data is collected during the simulation and all force acting on body is based on FEA simulation. The simulation results prove that the net force acting on the body-torso is negligible with minimal stress effects. This ensures all the mentioned hazards are greatly reduced in the proposed design in comparison with prior-arts

Keywords: Head and neck support, Total deformation, Immobilization, Load distribution, FEA simulation

1. INTRODUCTION

Amyotrophic lateral sclerosis (ALS) is a progressive, degenerative, fatal neuromuscular disease characterized by the degeneration of upper neurons in the motor cortex and lowers motor neurons in the brainstem and spinal cord, that causes muscle weakness, fasciculation, and increased reflexes[1,2,3]. The prevalence of Amyotrophic lateral sclerosis is 6 per 100000 of total world population[4,5]. The occurrence is higher in people aged over 50 years. Only 10% of cases are familial (inherited from parents) while the remaining 90% are not. According to the Foundation for Research on Rare Diseases and Disorders (FRRDD), the frequency of ALS cases in India is 5 in 100,000[6]. People suffering from the above condition, lack postural instability, primarily pertaining to spine[7]. They also lack eye contact with their tutors during education and cognitive training.
Hence, there is an immediate need for a support that reduces spinal disorientations, to establish better postural stability and to improve eye contact.

In order to address all these issues, the aid model should satisfy certain preliminary conditions to prove its efficacy with the intended application. The optimal design should administer a multi-directional support for maximal head stabilization, a fine-tune mechanism to improve adjustability, flexibility of the support and a height adjustable vertical assistance for improving adaptability of the aid. Another important aspect is that, the aid itself must not indulge in complicating the condition rather than reducing it. The aid that is intended to satisfy all these functional aspects can enhance postural stability, reduce spinal disorientations and also can improve eye contact of the users without aggregating side effects. The main aim of the work is to develop such an aid for ALS[8] and DHS patients that help in proper positioning their head and upper thorax. The Proposed design has three-way support system that conjointly holds head, neck and chin (i.e.) Sternum Occipital Mandibular immobilization, to control flexion, extension and abduction. The aid includes an adjustable stem that glides over vertical axis to incorporate height-adjustment mechanism. Further Velcro strapping system is utilized to provide fine-adjustments and foam covering to avoid direct skin contact. The proposed design greatly minimizes the major hazards such as suffocation, skin irritation, difficulty in swallowing, and neck soreness/pain faced by the currently available designs.

The paper is organized as follows: Section 2 discusses on literatures and prior arts. Section 3, describes the methodologies relating to the principle, concept, theoretical force calculations and major components in the design. Section 4, discusses the simulation results, analysis, shape justification and discussion. Section 5 and 6, ends with conclusion and future work.

2. LITERATURE REVIEW

DHS is a group of disorders with diverse etiologies involving different anatomical components of the neck, ultimately resulting in a debilitating, flexible, anterior curvature of the cervical spine. Causes of dropped head syndrome include myasthenia gravis, amyotrophic lateral sclerosis, Parkinson disease, radiation therapy, and cumulative age-related changes. Idiopathic cases have also been reported[9]. The two methods of treating the disease progression in progression that includes surgical and non-operative treatment. Surgical treatment of dropped head syndrome consists of cervical spine fusion to correct the deformity. Considering the cost and complications involved in surgical treatment, affected individuals prefer non-operative treatment. Non-operative treatment of dropped head syndrome includes orthotic bracing and physical therapy. Out of the two widely accepted non-operative treatment, physical therapy demands lot of time and patience from the affected individuals to obtain better results. Hence DHS patients prefer orthotic braces to provide the required corrective treatment. In certain cases, health care professionals even prescribe drugs. Riluzole, the only globally licensed drug treatment for amyotrophic lateral sclerosis (ALS)[10].

The most common treatment for DHS is the external support for neck instability. Conventional supports including SOMI brace, Minerva, Elastic head support for persons with ALS, Savant wheelchair headrest system, Tetra volunteer Brain Graham, Cyber spine cervical orthosis and The Baseball Cap Orthosis are available commercially. The above-mentioned conventional supports are capable for controlling movements of head in their unique way. SOMI brace, Minerva, Elastic head support for persons with ALS and The Baseball Cap Orthosis have been restricted to provide support for particular movements. Savant wheelchair headrest system, was suited only for patients in wheelchair and Cyber spine cervical orthosis is not able to restrict rotational movements. Existing supportive braces shows that the systems do lack in arresting a particular type of head movement. A study on the statistics of advancement in the treatment of ALS, revealed that patients got affected indirectly leading to excess discomfort with chin and occipital support[11]. Resulting in increased pressure, potential for interfering with eating and swallowing. Some extreme consequences like...
The presence of pillow like cushion and aeration grid can be ideal for new-babies. However, this design may not be suitable for any minor deformities[18]. The patent(US20150202072), describes a brace with head frame, a strap assembly and a cervical bar, preventing from head drop without any respiratory problems. This literature is not restricted to any type of diseases associated with head drop but adds a clause of the stiffness offered. This stiffness may give rise to soreness and discomforts[19].

The patent (US010327941B2), describes a Cervical neck brace comprises an anterior brace element, and a posterior brace element which is engaged or engageable with the anterior brace element. The device resides over the face and the covers the complete head and may highly hinders the patient’s day-to-day activities[20].

It is evident that the solution for complete restriction of all kinds of head movements with comfortness, has not been found. Hence, there exist a need for system that can overcome the above problem and alleviate the sufferings of all aged DHS patients. Further, there is a need to provide the ultimate solution for all problems in a single unit that also satisfy the condition of better efficiency and more economical to the patients. Thus, the current research work aims in achieving the head support with three-way Sternum Occipital Mandibular Immobilization (SOMI) along with height adjustable and light weight brace frames to achieve the intended clinical benefits.

3. MATERIALS AND METHODS

The following subsections discuss the objective, principle behind the design, the various parts of the support and assembly of these parts to provide an efficient aid that would provide maximum immobilization. The principal objective is to design and develop a simple but efficient, lightweight and height adjustable external aid that supports neck and chin for Amyotrophic lateral sclerosis and Drooping Head Syndrome patients. The proposed design of the external aid has a Sternum, Occipital and Mandibular components that immobilize respective regions to arrest the head- movements such as flexion, extension, rotation, and abduction. It predominantly consists of two height- adjustable supporting stems fixed to the anterior and posterior supporting frames. The stems act as a leverage system that offers an upward thrust for head immobilization.

3.1. Principle
3.1.1 Concept behind
The device is designed with biomechanics principles to generate the upward thrust in bringing the head upright in head drooped patients[21]. The leverage system (shown in figure 1) principle is utilized for producing the sufficient thrust with minimalistic force action over other parts of the body[22]. The force
exerted by the shorter arm levers is larger than longer arm levers due to the shorter relative distance between fulcrum and load. Theoretical calculations also showed that longer levers exert lesser force when compared with the shorter ones. Hence it is preferable to use a longer lever for lesser force action over the spine.

![Leverage System Concept](image)

**Fig 1.** Leverage system Concept

### 3.1.2 Theoretical Force Calculation

The leverage system is introduced to calculate the effort (force) exerted on the vertebral column by the mass of the drooping head 'W'\(^{[23,24]}\). The head acts as load/resistance with the neck positioned to be fulcrum and the resultant force is exerted over the lumbar region. The distance between the neck and the point of force application by the drooping head 'W', is denoted by 'X' and the distance between the neck and the point of force application \(F_{\text{max}}\) are defined as lever arm whose length is denoted by 'L'\(^{[24]}\). For calculating the force exerted on the spine, the following assumptions (proximal to real data) are made.

Length of the vertebral column in Average Indian men\(^{[25]}\): 71.00cm

Length of the vertebral column in Average Indian women\(^{[25]}\): 61.00cm

Average mass of human head in adult\(^{[26]}\): 11 pounds or 4.5-5kg

The average length ('l') of human Vertebral column

\[
l = \frac{71 + 61}{2} = 66.00\text{cm}
\]

Number of vertebral segments in region of force application ('n')= segments in cervical region(8) + segments in thoracic region (12)

\[
n = 8 + 12 = 20\text{ segments}
\]

The force acting on the cervical and thoracic region is calculated using the lever formula \(^{[27]}\),

\[
F_{\text{max}} = \frac{(W \times X) \times g}{L},
\]

\(g\), acceleration due to gravity (9.8 \(\text{m/s}^2\)).

Substituting the known values in equation (1),

\[
F_{\text{max}} = \frac{(5 \times 9.8 \times X)}{L}
\]

The average length (Avg\(_l\)) of each vertebral segment is obtained by dividing the length of entire vertebral column by the number of spinal segments of force application,

\[
\text{Avg}_l = \frac{\text{Total length of vertebral column}}{\text{Spinal segments of force application}}
\]

\[
\text{Avg}_l = \frac{66}{20} = 3.30\text{cm}
\]

Let \(X\) be the length of force action in cervical region.

\[
X = \text{Length of each vertebrae} \times \text{No. of vertebrae in cervical region}
\]
X = (3.30 * 8) = 26.40cm \hspace{1cm} (5)

Let $L$, be the length of force action in thoracic region.

$L = \text{Length of each vertebrae} \times \text{No. of vertebrae in thoracic region} \hspace{1cm} (6)

L = (3.30 \times 12) = 39.60cm \hspace{1cm} (7)

Maximum force exerted by the support in the human body, can be derived by substituting the values from equation (5) and (7) in equation (2).

$$F_{\text{max}} = 5 \times \frac{26.4 \times 9.8}{39.60} \hspace{1cm} (8)$$

$$F_{\text{max}} = \frac{1293.60}{39.60} \hspace{1cm} (9)$$

$$F_{\text{max}} = 32.677 \text{ N}$$

From the obtained result, it is evident that the pressure exerted by the aid is much less compared to that of maximum force sustained by the body without affecting the normal physiological functions of the human.

3.2. Major components of the design

The major components used in the design depicted and labeled in figure 2 can be classified into two sections, anterior section and posterior section respectively, based on the region where they have been utilized.

Posterior Section includes the following components,
- Semi-circular base head panel
- Posterior Cervical-Thoracic (CT) bar
- Posterior thoracic (PT) base panel

Anterior Section includes the following components,
- Anterior-Thoracic (AT) base panel
- Sternum-Mandibular (Chin) bar
- Chin cap

3.2.1 Posterior Section

**Semi-Circular Base Head Panel**, shown in figure 3, is made out of Polypropylene (PP) sheet. PP sheet is heated and shaped to take its characteristic Semi-circular form for supporting Occipital and partial Temporal regions of the head. Polypropylene sheet is used in the process, includes four holes, out of that two holes are made at

![Figure 2. External aid design](image-url)
Figure 3. Unshaped base head panel

Left-Right edges and other two holes are made at central axis from top-bottom edges respectively. The Semi-circular shape is provided in order to cover the circumference of the head. Polypropylene sheets are chosen due to its superior characteristics like low cost, high durability, and ease in shaping. The panel is attached to the cervical-thoracic bar through two-hole pits.

Figure 4. Posterior Cervical-Thoracic (CT) Bar

**Posterior Cervical-Thoracic (CT) Bar**, is made out of an aluminum flat of various length of bars can be used according to the spinal length of the user. The cervical-thoracic bar shown in figure 4 is relatively stiff and connects the headframe to the PT base panel as to support the wearer’s head. The cervical-thoracic bar is provided with a characteristic S-shaped bend to match the cervical and thoracic curve made by the human-spine. A series of holes are drilled in its bottom surface each placed at a distance of 1 inch between them. Holes are made to provide the height adjustments in the posterior bar, through these holes the bar is connected to the Posterior-Thoracic panel frame using a washer. A screw nut is used to lock the bar at the bottom surface. Similarly, two holes are made at the top surface to join with the two axial holes made at the head panel frame through two split pins, serving as a central axis of load bearing and load distribution.

**Posterior Thoracic (PT) base panel**, is made out of a rectangular sheet of Polypropylene, curves are created at opposite faces producing a Butterfly shape, aiding in uniform stress distribution over the thoracic region. The upper wings are bit large in dimension than the lower wings due to considerable shoulder to waist dimension variations, depicting the typing wing of a butterfly. The panel is provided with a series of holes placed at hole gap of 1-inch aiding in the attachment of posterior cervical thoracic bar’s lower end. PT base panel has four other holes on to each wing for holding the Hook-Loop straps of shoulder and waist using split pins through the holes. Foam padding is pasted to the posterior-thoracic base panel using synthetic rubber glue, as same construction of the posterior-thoracic base panel but over the axial line of foam layer with a depth to provide housing for cervical-thoracic stems lower end. It also has the same number of holes with exact dimension and positioning is given to back polypropylene layer over that another foam sheet to cover the Aluminum stem and lower foam layer, forming a double layer to offer added comfort to the user. The 3D model of the
Posterior thoracic base panel along with the foam padding is shown in figure 5.

![Posterior Thoracic (PT) base panel](image)

**Figure 5.** Posterior Thoracic (PT) base panel

### 3.2.2 Anterior Section

**Anterior-Thoracic Base Panel** shown in figure 6, consists of anterior-thoracic base, chin bar, and chin cup. The anterior-thoracic base panel, having the same shape to that of posterior-thoracic base panel, has variations in the total dimension of length, breadth and the double foam covering for the chin-bar insert. One major difference anterior-thoracic base panel from the posterior-thoracic panel is that the placement of D-rings on each wing of the butterfly panel through the holes made in it. Upper two D-rings are used for looping through of shoulder straps and lower two D-rings are used for waist straps.

![Anterior-Thoracic Base Panel](image)

**Figure 6.** Anterior-Thoracic Base Panel

**Sternum Mandibular (Chin) Bar**, is made out of Aluminum flat in L shape. The figure 7 shows the longer arm being inserted to the rectangular cut out of anterior base foam layer and has a similar hole pattern of that of an anterior-thoracic base. The hole helps for inserting the washer and screw that anchors the bar to the base. While shorter arm helps in holding the chin-cap.

![Sternum Mandibular (Chin) Bar](image)

**Figure 7.** Sternum Mandibular (Chin) Bar
**Chin cap** shown in figure 8, is made from Polypropylene sheet that has reduced width at the center, provided with a characteristic, “U” shaped cup structure to hold the chin in position. It has two D-rings for the chin strap arising from the head base panel.

![Figure 8. Unshaped Chin Cap](image.png)

The anterior panel connected with chin bar and chin up along with mandibular/jaw straps provide a secure foundation for the head frame without interfacing with respiration and thus help to mitigate the head drop in patients.

### 3.3. Assembly of parts

The external aid discloses the Hook and Loop system for connection of the system units. The connection between components is provided with Nylon VELCRO material[28,29]. The loops are D-shaped rings where the straps are passed to establish the connection. The anterior-thoracic base panel has four D-rings on each wing of the panel. While the chin cap has two D rings for chin strap arising from the base head panel. The complete assembly of designed parts (without strap system) shown in figure 9 is carried out in two major steps: Anterior and Posterior part assemblies. The posterior part assembly accounts for fixing the top end of cervical thoracic bar, with the Semi-circular base head panel. The bottom end of CT bar is fastened into the cervical-thoracic bar base using screws. The Anterior part assembly, accounts for fastening the lower end of chin bar with the posterior frame panel using screws.

![Figure 9. Assembly of Design Parts (without straps)](image.png)

The Anterior and posterior setups are joined using four major strapping systems namely jaw, head, shoulder, and waist straps. The jaw straps between the head and the chin cap can be adjusted in accordance with the head dimension. The shoulder straps adjust both the panels forward and backward. The waist strap adjusts anterior and posterior panels around the body. The different views of the complete design are shown in figure 10.
4. RESULTS AND DISCUSSION

The objective of the work is to design an efficient aiding system for the Amyotrophic lateral sclerosis and Drooping Head Syndrome patients, as already discussed in methodology in section 3. Finite element analysis of all parts of the aid are performed using ANSYS R15.0, an FEA based analysis software [30,31,32]. Only the major load-bearing structures such as aluminum bars and polypropylene panels are considered for performing stress load analysis[33].

4.1. Loading
4.1.1 Static structural analysis

The model of the chin bar and cervical-thoracic bar is created in ANSYS modeling environment as depicted in section 3. Hexahedral mesh is chosen as mesh-element type, because of the uniform structure of the components under simulation. The entire structure is divided into finite hexahedral elements through proper mesh setting[34]. Many parameters like displacement, stress, strain, and forces acting in the structural components can be analyzed using static structural analysis[35]. Steady loading and response conditions are assumed (i.e.) the loads and structural response are assumed to vary slowly with time. A static load is set using the ANSYS solver. The load applied for analysis is a surface load that is applied only in the region of base head panel, whereas the lower stem surface remains fixed. The applied direction of the load is perpendicular to the CT bar. Similarly, a surface load is applied perpendicular to the region of chin cap, Whereas the lower stem surface of chin bar is fixed. In static analysis, parameters of load action such as total deformation, fatigue characteristics, and safety factor is studied.

4.1.2 Loads

Material properties of aluminum alloy is depicted in table 1 [36,37]. Some useful assumptions are made to attain accurate simulation results to match practical applications.

| Properties                      | Value   |
|---------------------------------|---------|
| Young’s modulus (GPa)           | 192.99  |
| Poisson ratio                   | 0.33    |
| Density (g/cm$^3$)              | 2.7     |
| Tensile yield strength (N/m$^2$)| 60.88   |
| Ultimate tensile strength (N/m$^2$) | 67.41 |

These assumptions with justifications are as follows,

1. The load acting on the structural element is only due to the head and will not be influenced by other portions of the human body.
   **Justification:** To reduce the analysis complexity and the influence due to other organs. Head is taken as the major load for the leverage system.

2. The inward facing surface of the Chin bar longer arm, that is screwed up with an anterior-thoracic panel remains rigid during the application of load.
**Justification:** Since the surface is attached and made tight to withstand the load bearing. To replicate the scenario fixed constraint was considered for analysis.

3. Similarly, the lower portion of 'S' shaped cervical thoracic bar remains rigid during the application of load.
   **Justification:** Same as the previous justification

4. The total load acting on the aid is assumed to be 49N.
   **Justification:** The total weight of the human head is about 5 Kg and due to the action of gravitational force(9.8N), the total force of 49N is acting on the system [26].

5. The analysis of both the bars is carried out separately. Therefore, 49N load would be acting on them individually and rather mutually.
   **Justification:** In order to provide maximum loading condition, forces acting on the bars are assumed to be independent of each other.

4.2. Outcomes

4.2.1 Total Deformation

Deformational studies on bars are performed with an aim of determining any type of changes occurring at the maximum load point[38,39,40]. Figure 11, depicts the total deformation condition on the chin bar. The red region indicates the maximum force-deformation of 0.64cm acting downwards on chin bar and the blue region representing the least impact region having apparently nil deformation.

**Figure 11. Deformation on the Chin bar**

Figure 12 indicates the deformation condition on cervical-thoracic bar. The red region indicates the maximum force-deformation of 5.29cm acting downwards on cervical-thoracic bar and the blue region at the lower end has least deformation. During traversal from the peak deformation region to the mid-region of S-bend, the deformation magnitude decreases and finally attains nil deformation at the bottom. The load used in the simulation is equal to the maximum force exerted by the human adult but in practical human application, the force exerted will be far lesser than the assumed load, as the load would be shared mutually between the cervical-thoracic bar and chin bars. On account of this, the total deformation well be greatly reduced.

**Figure 12. Deformation on the CT bar**

4.2.2 Safety factor

The calculation of safety factor is critical for the system of bars. The type of loading is fully reversed type, in that the scale factor switches between the range +1 and -1 and thus a sinusoidal type of
loading is implemented. In order to carry out the simulation, there is a need to define the number of load cycles to be acted upon the particular structure. The total number of load cycles is chosen as 1.e+009 or 109 to test the reliability of the system. These loading cycles represent the total lifetime stress-cycles. The safety factor is calculated after the application of total load cycles. The safety factor is the ratio of the yield strength of the material to the allowable working. For chin bar shown in figure 11, the maximum safety region is indicated, with blue having a magnitude of 15 and the least indicated with red, but in this case, the least safe-magnitude is 1.6704, indicated with orange. The safety factor study indicates that the chin bar is safer on usage in a real-world scenario, similarly, the cervical-thoracic bar figure 12, has the least safe region magnitude of 0.2237, representing the maximal stress concentration over the complete cycle of loading.

4.2.3 Fatigue characteristics
One of the major reasons for choosing aluminum as the structural element is its lightweight property, about one-third of the density of steel, copper, and brass. From the deformation studies, the maximum deformation is 0.64cm and 5.29cm on the chin and cervical-thoracic bar respectively. These values are not as significant as they are within the safer deformation limits.

4.2.4 Shape justification
The S-shaped bend provided on the cervical-thoracic bar imparts a greater safety factor on the frame. 'S' shape doesn't offer a particular focal spot for stress concentration because of its non-contact curved shape that ensures the material and structural components hold good for long-term usage [41]. Any other shapes like 'T' or 'P' supports would have multiple points of Stress concentration zones, while 'S-bend' offers the following advantages namely single stress accumulation zone and maximum force absorption and stress. The benefits of 'L' shape in chin bar, is its resistance against deformation. The chin bar resistance was indicated with a magnitude of only 0.64cm deformation having only one force focal-spot. Further the L shape offers a larger surface to be fixed and exposes only a minor area of shorter L arm to experience the force.

4.3. Analysis
Aluminum has a high young modulus and malleability. Because of which Aluminum is used to fabricate the chin and cervical-thoracic bar. Although a lot of other metals have a high Young’s modulus when compared to aluminum, aluminum is cheap and readily available to any other metals. Akin to the cervical-thoracic bar, the same relation of force with time is obtained for Chin bar. The effect of the force is studied on the bar frames for the course of usage and safety factor. A load, whose weight equivalent to the mass of the head, acting on one end of the bar causing an internal stress on the bar. The force is applied at the rate of 10N per 0.2 sec on the bar and its behavior is analyzed. The stress varies linearly with load. The analysis is performed to determine total deformation, safety factor and fatigue characteristics on the bars and the simulation results were already discussed in the outcomes section.

4.4. Discussion
A simple efficient, lightweight, three-way vertical and height adjustable external aid that supports the head, neck, and chin of Amyotrophic lateral sclerosis as well as Drooping Head Syndrome patients was developed[15]. The aid is designed to arrest head movements such as flexion, extension, rotation and abduction[14]. The components involved in the external aid are covered in detail along with their assembly in Section 3. The various computed analysis such as stress, strain, total deformation, safety factor, and fatigue characteristics are deeply described in section 4 for the structural materials. The simulation results of deformational studies being in millimeters ensure safer application of the material in supporting system. The simulation results indicate that there is a notable stress reduction in the sternum and mandibular regions of the brace. Additionally, to provide a comfortable patient interface, padding is made from non-abrasive, non-allergenic material to prevent skin breakdown and is designed to be readily replaceable. Further, the weight of the aid is 800 grams and the cost of production is also low. Non-collapsible materials and adjustability, incorporated in the design to prevent suffocation and additional neck soreness[16,19]. Design feature with height adjustment proficiency make it
comfortable for users and a good deal for manufacturing and marketing needs[11]. The customized design may allow patients with Amyotrophic lateral sclerosis as well as with other neuromuscular degenerative diseases to participate in normal daily activities and might increase their quality of life[20]. The future work may extend in bringing modifications to the aid to make it suitable for other diseased conditions like cerebral palsy patients with dropping head condition, spinal disorientations, and fracture immobilization.

5. CONCLUSION

The work proposes a novel external support for Amyotrophic lateral sclerosis and Drooping Head Syndrome patients for controlling their head flexion, extension and abduction. The device can be a perfect solution for learning and therapy sessions of the affected individuals that demands concentration and control for needed time. The aid has a height adjustment mechanism to help in suiting various individual torsos and the Velcro straps enabling fine adjustments. Theoretical calculations are derived to elicit the force that would be acting on the aid during actual usage. The same environment has been simulated using finite element analysis software. The obtained results show that the force exerted by the aid is negligible compared to maximum force sustained by the human body without affecting the normal physiological.

6. FUTURE SCOPE

From the simulation results, the design can be implemented on patients under controlled environment. Still the design can be improved with patient specific needs and customizations to suit every user. Current work is carried out on a prototype set up; further the prototype can be converted to actual product.

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