1. INTRODUCTION

Spinal injuries have afflicted humanity for millennia with the first documentation appearing in a Egyptian document published approximately 2500 BC, named the *Edwin Smith Surgical Papyrus* after its initial discoverer, Edwin Smith, an early Egyptologist. Within this document, the original author (who is unfortunately not known), describes damage to a person's spine and the resulting 'unconsciousness' of their arms and legs. The author proclaims the described condition as 'an ailment not to be treated' (Hughes, 1988). Fortunately, throughout history, attitudes towards spinal cord injuries were becoming less pessimistic. By the 20th century, doctors such as Sir Ludwig Guttman and Donald Munro had adopted a more optimistic approach (Bodner, 2009) and recognised the need for a comprehensive care of the entire person; rehabilitation with a commitment to the entirety of the patient's needs. (Donovan, 2007). The wheelchair is key item in the rehabilitation of spine injuries.

According to the National Health Service, there are 1.2 million wheelchair users in the UK alone (NHS, n.d). This is approximately 1.8% of the population, a striking proportion. It is approximated that there are 1200 new cases of spinal cord injury, one that may necessitate wheelchair use, every year (McDaid et al., 2019). 35% of these injuries cause tetraplegia, a severe form of paralysis that affects most or the entire body.

Tetraplegia is caused by damage to the spinal cord and or brain, a result of diseases, conditions such as multiple sclerosis and muscular dystrophy and physical trauma such as sporting accidents, the latter cause is the most common (NSCISC, 2020). People with tetraplegia will often rely on the use of wheelchairs, or powerchairs when referring to motorised types rather than self-powered, to aid their mobility and support them throughout the day. Unfortunately, reports show that wheelchairs are lacking in their function, extended use bringing about a number of sitting-related problems (Valent et al., 2019).

2. AIMS

The aim of this project is to examine how the seat of a chair for a wheelchair can be improved to better support a person with tetraplegic.

3. LITERATURE REVIEW

3.1. Background

This section will discuss the background behind this project and why it will focus on tetraplegia.

3.1.1. Tetraplegia

Tetraplegia commonly referred to as quadriplegia, is a paralysis of both the upper and lower body as opposed to paraplegia which effects the lower half only. It results in the loss of movement and sensitivity of all four limbs including the torso. The severity and location of the paralysis is dependent on where on the spinal cord is damaged. There are a number of causes for this damage which are as follows: traumatic injury, neurological conditions such as cerebral palsy, tumours on spine and brain and autoimmune conditions such as multiple sclerosis.

These conditions create lesions, areas of damage or change, on the spine or brain. The location of this damage on the spine correlates to the severity of consequent symptoms, namely paralysis, tetraplegia in the most severe cases. In continuing this project, it is necessary to identify a specific case that the designed solution will address.

The ASIA (American Spinal Injury Association) Impairment Scale (2016) is used internationally to define sensory impairment and extent of any suspected spinal injury. The examination involves grading muscle power and sensation in each designated section of the body as specified in the ASIA Impairment Scale document. Each of these sections are classified according to the segment of the spine they are linked to. Once these results are recorded the level of paralysis completeness can then be determined using a scale from A to E, with A being complete paralysis (no sensory or motor functions preserved at all) and E being no issues with motor and sensory functioning.

This project will focus on C5 category tetraplegia. This means there is a lesion on the C5 vertebrae located in the neck, this entails certain motor and sensory abilities that will be considered throughout the project that are stated as follows: paralysis of the trunk and lower limbs with partial paralysis of the upper limbs. Good functioning of the bicep and deltoid muscles are retained but poor functioning of triceps, shoulder muscles, wrists and hands. Manual wheelchair use may be possible for short distances, but a power wheelchair is most common (Spinal Cord Medicine, 2002).

There are 420 new cases of tetraplegia in the UK every year who require constant care at an average cost of £1.87 million per person’s lifetime (McDaid et al., 2019). Improvements in wheelchair and mobility technology will provide a better quality of life and improvements in independence.

3.1.2. Pressure Ulcers

Immobility can cause incidental health problems. One significant and pervasive health problem is pressure ulcers. Pressure ulcers, often named pressure sores, are defined by the NHS (National Health Service) as injuries to skin and underlying tissue caused by prolonged pressure on skin

(2020). Although any part of the body can be affected, certain areas are more prone than others such as the lower back and buttocks.

Pressure ulcers can be a debilitating and painful condition if left unattended. They start initially as painful sores that can gradually become necrotic if not dealt with sufficiently which can eventually cause severe health problems such as blood poisoning.

3.1.3. Wheelchair

The wheelchair designs most commonly seen today is based on a design from the 1930s known as 'Model 8' (Nias, 2019), a design that has not changed much in its ninety years of existence resulting a design that looks particularly dated in comparison with prosthesis. Prosthesis have seen huge advances over the decades in the same time span. This is especially evident when viewing the history of prosthesis, an artificial hand produced in the 1930s is a world away from the designs of today (Lawrence, 2019). Contemporary prosthesis features a wide variety of technologies, customisation and materials that are far more advanced than those used in currently available wheelchair designs.

4. STATE OF THE ART

Current solutions vary widely in function and price. The highest levels now include *standing* functions. This works by the chair straightening out into a flatter angle which lifts the occupant into a standing position. There are two immediately obvious benefits to this function. Firstly, the ability to reach higher and pressure relief. Standing avoids putting pressure on the same areas for extended periods.

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